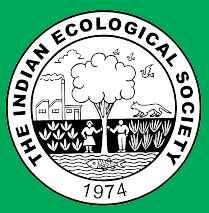
INDIAN JOURNAL OF ECOLOGY

ISSN 0304-5250

Volume 47 Issue-3 September 2020



THE INDIAN ECOLOGICAL SOCIETY

INDIAN ECOLOGICAL SOCIETY

(www.indianecologicalsociety.com)
Past President: A.S. Atwal and G.S.Dhaliwal
(Founded 1974, Registration No.: 30588-74)

Registered Office
College of Agriculture, Punjab Agricultural University, Ludhiana – 141 004, Punjab, India
(e-mail : indianecologicalsociety@gmail.com)

Advisory Board

Kamal Vatta	S.K. Singh	S.K. Gupta	Chanda Siddo Atwal	B. Pateriya
K.S. Verma	Asha Dhawan	A.S. Panwar	S. Dam Roy	V.P. Singh

Executive Council

President
A.K. Dhawan

Vice-Presidents

R. Peshin	S.K. Bal	Murli Dhar	G.S. Bhullar

General Secretary
S.K. Chauhan

Joint Secretary-cum-Treasurer
Vaneet Inder Kaur

Councillors

A.K. Sharma	A. Shukla	S. Chakraborti	N.K. Thakur

Members

Jagdish Chander	R.S. Chandel	R. Banyal	Manjula K. Saxexa

Editorial Board

Chief-Editor
Anil Sood

Associate Editor

S.S. Walia	K. Selvaraj

Editors

M.A. Bhat	K.C. Sharma	B.A. Gudae	Mukesh K. Meena
S. Sarkar	Neeraj Gupta	Mushtaq A. Wani	G.M. Narasimha Rao
Sumedha Bhandari	Maninder K. Walia	Rajinder Kumar	Subhra Mishra
A.M. Tripathi	Harsimran Gill		

The Indian Journal of Ecology is an official organ of the Indian Ecological Society and is published bimonthly in February, April, June, August, October and December six-monthly in June and December. Research papers in all fields of ecology are accepted for publication from the members. The annual and life membership fee is Rs (INR) 800 and Rs 8000, respectively within India and US $ 100 and 350 for overseas. The annual subscription for institutions is Rs 6000 and US $ 300 within India and overseas, respectively. All payments should be in favour of the Indian Ecological Society payable at Ludhiana. See details at web site.

KEY LINKS WEB
site:http://indianecologicalsociety.com
Membership:http://indianecologicalsociety.com/society/memebership/
Manuscript submission:http://indianecologicalsociety.com/society/submit-manuscript/
Status of research paper:http://indianecologicalsociety.com/society/paper-status-in-journal-2/
Abstracts of research papers:http://indianecologicalsociety.com/society/indian-ecology-journals/

Indian Journal of Ecology (2020) 47(3): 607-613

Manuscript Number: 3052
NAAS Rating: 4.96

Effect of Chemical Characteristics of Soil on Orange Productivity: A Case Study of Nghe An Province, Vietnam

Nguyen Thi Hoai, Takahashi Kazuya[1], Hoang Thi Thuy[1], Nguyen Thi Thuy Ha[1], Nguyen Thi Trang Thanh, Hoang Phan Hai Yen, Nguyen Thi Viet Ha, Nguyen Nam Thanh[2], Vo Thi Thu Ha[2], Phan Thi Quynh Nga[1], Hoang Anh The[1], Binh Thai Pham[3*], Indra Prakash[4], Tran Thi Tuyen[1]

Department of Geography, School of Social Education, Vinh University, Vinh City- 460000, Vietnam
[1]Department of Resource and Environment Management, School of Agriculture and Natural Resource, Vinh University, Vinh City- 460000, Vietnam
[2]Department of Land Management, School of Agriculture and Natural Resource, Vinh University Vinh City- 460 000, Vietnam
[3] University of Transport Technology, Hanoi- 100000, Vietnam
[4]DDG (R) Geological Survey of India , Gandhinagar 382 015, India
**E-mail: binhpt@utt.edu.vn*

Abstract: This study was conducted in orange farming area of the central Nghe An province, Vietnam to understand effect of chemical characteristics of soil conditions on orange productivity. Soil samples were collected from 102 sites in three high orange yielding districts (Quy Hop, Nghia Dan and Con Cuong) to analyze 16 chemical factors including pH, macronutrients, some micronutrients and beneficial nutrients. Dataset with 16 factors obtained by chemical analysis was examined with Principal Component Analysis (PCA) to extract combination of chemical factors characterizing soils in the study area. In addition, orange productivity data of five communes of Con Cuong district for the period 2015 to 2018 was analyzed to elucidate the relationship between soil characteristics and orange productivity. The study reveals chemical characteristics of soil and its relationship in the production of oranges in the central Nghe An province. Results of this study show that: (1) Soils in the area is characterized mostly by acidity, where one third area is extremely acidic (pH<4). This can be mainly attributed to sulphate and lower contents of Ca^{2+} and Mg^{2+} in the soil and (2) Low orange productivity in Con Cuong area is caused by extremely acidic soils with excess concentration of Al^{3+} and less concentration of P_2O_5. Occurrence of extremely acidic soils in the study area can also be attributed to washing out of exchangeable cations from steep slopes due to the soil erosion.

***Keywords*:** Soil characteristics, North Central Vietnam, Orange productivity

Nghe an province in North Central Vietnam is one of the main provinces yielding oranges, providing high benefits to farmers as orange farming is the important agri-industry in this hilly to mountainous regions. The Quy Hop and Nghia Dan are the high orange yielding districts and Con Cuong is the relatively lower orange yielding district. Yen Khe commune in Con Cuong district was selected as a model region for heritage tourism project for developing rural economy with natural resources including improving orange products by the central government in cooperation with foreign donor (JICA 2016). Soil for orange trees should ideally be loose, rich in organic matter and well-drained preferably sandy loam. Sustainable orange farming on the mountain slopes is important not only for regional economy but also for land conservation due to contribution to prevention of soil erosion, especially in humid tropical regions (Doanh and Ha 2004). Therefore, development of good practice for orange farming could indirectly contribute land conservation. Dinh et al (2004) proposed orange farming model for land conservation on the steep slope (15-20 degrees) based on the study on several slope types in Nghia Dan district.

Nature and soil characteristics are closely related with crop yields (Zhang and Zhang 2005, Martín et al 2005, Rees et al 2007). Regional soil chemical characteristics determined by Geography Institute Vietnam (GFNCV) indicate different, soil type of Con Cuong in comparison to other two orange farmlands of Quy Hop and Nghia Dan. Sandstone bed rocks are forming light yellow soils which are widely distributed in the western part and central part of province; whereas yellowish red soils on metamorphotic igneous rocks and clay beds are locally distributed in Con Cuong area. Ferralitic soils degrade quickly to acidic soil causing change in chemical composition of the soils influencing strongly on the growth of crops (Shahana et al 2016, Abidoye et al 2016). Soils in the Quy Hop and Nghia

Dan areas were analyzed acidic ranging from 3.8 to 4.7 pH where concentrations of calcium and magnesium cations (Ca2+, Mg2+) were lower than the requirement of orange trees (Nguyen 2012). With background mentioned above, 16 chemical factors were selected and analyzed, to understand chemical characteristics of soils distributing in the central Nghe An province in this study and to elucidate factors affecting low orange yields in Con Cuong district.

MATERIAL AND METHODS

Study area: The study area is hilly to mountainous central Nghe An province covering 14 communes of three districts; Quy Hop, Nghia Dan, and Con Cuong district (Fig. 1). This province is located in the tropical monsoon climate region. The average annual temperature, rainfall, quantity of solar radiation and surface evaporation in this area are 22^{0}C, 1,591.7 mm/year (400 mm/month in rainy season from August to October, and (5-40 mm/month in dry season from January to April), 1,580 hours/year and 835.2 mm/year, respectively (M&HNCV 2018).

Soil sampling Soil samples were collected from topsoil of 0 - 20 cm in depth which include 60 sites from orange farms and 42 sites from other agriculture lands and forests nearby the orange farms (Table 1). These samples were collected from April 12 to 17, 2019 in Con Cuong district and August 15 to 22, 2019 in Nghia Dan and Quy Hop districts (Fig. 2).

Chemical analysis: Soil samples were air-dried and screened to remove particles >2 mm for analysis. Organic carbon (OM) is determined by Walkley-Black (Martín 1999) chromic acid wet oxidation method. T-P and available P_2O_5 are determined by the colorimetric method and by the Oniani Method, respectively. In addition, following analytical methods were applied for other elements: flame photometry for available K_2O (Hesse 1971), atomic absorption spectrum for T-Mn, T-Zn, steamed distillation for T-N (Kjeldhal method), Baricromate method for determination of $SO4^{2-}$, Cl- Al^{3+} and Fe^{2+} with a mixture of oxalate pH = 3 (ratio 1:40), ammonium Swedish ethyl acetate method for Ca^{2+}, Mg^{2+}, K^+, Na+ (ICARDA 2013).

Orange productivity: In order to elucidate impacts related to the soil quality, Con Cuong district was selected to obtain the data on orange productivity from 2015 to 2018 as a test plot. The data was collected from Union of Farmers in Yen Khe, Bong Khe, Chi Khe, Mau Duc, Don Phuc of Con Cuong district through the local branches of the District People's Committee. In addition, interview surveys from 84 farmers, who have worked on oranges for at least four years, were conducted to obtain the information on status of orange growth and agricultural practice such as fertilizing.

Principal component analysis for characterizing soils: Principal Component Analysis (PCA) with 16 factors, which is one of the tools to interpret multivariable dataset (Alkarkhi et al 2008, Bhat et al 2014) was carried out to understand characteristics of soils distributing in three districts in central



Fig. 1. Map of Nghe An province showing soil sample locations (102 sites) of Quy Hop, Nghia Dan, and Con Cuong districts

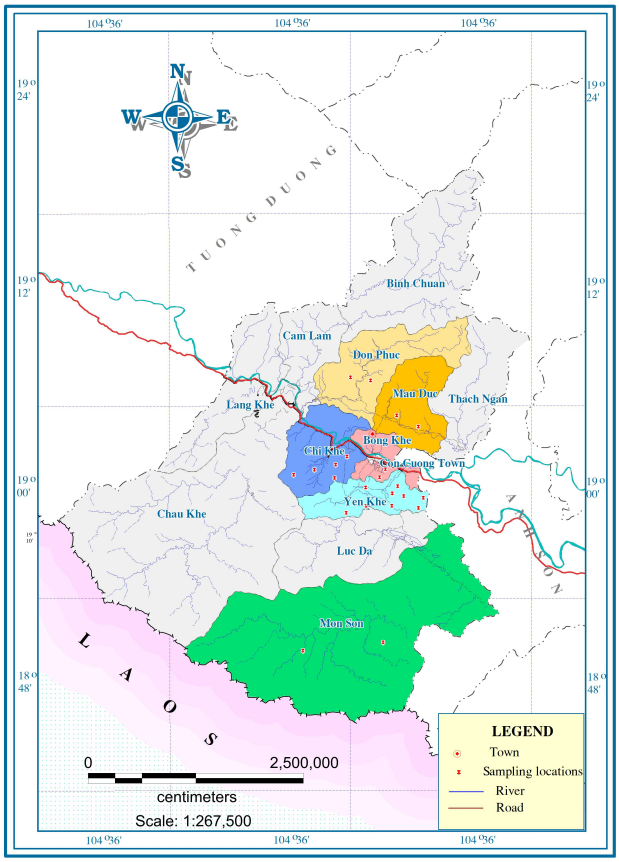


Fig. 2. Map of Con Cuong district. Soil sampling sites of six communes: Chi Khe (CK), Mau Duc (MD), Don Phuc (DP), Mon Son (MS), Yen Khe (YK) and Bong Khe (BK)

Nghe An province. PCA was carried out by EXCEL Statistics (Social Survey Research Information Co., Ltd.). The main idea of PCA is to reduce the dimensionality of a data set consisting of many variables correlated with each other.

Relation between slope gradient and pH: Slope gradient is one of the indicators for soil erosion and also soil pH. On higher slope (angle) erosion will be more likely and pH value would be less due to leaching of soluble catoins. On the contrary, significant higher pH can be observed at the foot hills of the slope where the area is flat due to accumulation of these cations. In the present study, correlation between slope gradient of sampling sites and pH was done for five communes in Con Cuong, from where orange productivity data was obtained. The slope gradient for each commune is represented in degree (Table 1).

RESULTS AND DISCUSSION

Productivity of oranges and fertilizing in Con Cuong area: Productivity is lowest of Mau Duc commune (14.8±0.2 ton/ha) and highest of Bong Khe commune (24.4±2.9 ton/ha) (Fig. 3). There is not much difference in the productivity of Bong Khe and Chi Khe communes, whereas it is almost same in case of Mau Duc and Don Phuc communes.

Fertilizing depends on climate, tree condition such as tree vigor, but standard fertilizing to orange trees aged over 10 years in Con Cuong district is not much different in all the five communes (Fig. 3 and Table 2). Some households provide super phosphate lime together with organic fertilizers after harvesting.

Principal components derived from PCA: PC1 accounting for 23.7% of total variance represents the soil acidity due to strong positive correlation of pH with PC1 and indicates increase and decrease of aluminum cation (Al^{3+}) concentration and exchangeable cation concentration; calcium and magnesium cations (Ca^{2+} and Mg^{2+}), respectively (Fig. 4). Al^{3+} concentration is negatively

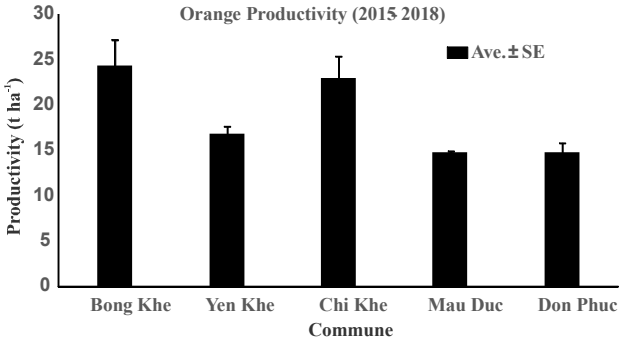


Fig. 3. Productivity of oranges from 2015 to 2018 (Mean +- SE)

Table 1. Soil sampling sites

District	Commune	Number of samples			Topography
		Total	Orange farm	Others	Slope gradient (degree)
Nghia Dan (19°13'N and 19°33'N, 105°18'E and 105°35'E)	NgH (Nghia Hong)	2	2	0	8 - 15
	NgLg (Nghia Long)	10	6	4	10 - 15
	NgLc (Nghĩa Loc)	6	2	4	12 – 15
	NgH (Nghia Hieu)	12	12	0	5 – 10
Sub-total		30	22	8	
Con Cuong (8°46'N and 19°24'N, 104°32'E and 105°03'E)	CK (Chi Khe)	7	5	2	10 – 15
	MD (Mau Duc)	2	1	1	15 – 20
	DP (Don Phuc)	3	2	1	20 – 25
	MS (Mon Son)	2	0	2	20
	YK (Yen Khe)	8	4	4	12 – 20
	BK (Bong Khe)	6	2	4	10 – 15
Sub-total		28	14	14	
Quy Hop (19°10'N and 19°29'N, 104°56'E and 105°21'E)	VL (Van Loi)	10	8	2	15 – 20
	MH (Minh Hoc)	16	14	2	8 – 15
	Xth (Xuan Thanh)	10	0	10	5 – 10
	HS (Ha Son)	8	2	6	15 – 20
Sub-total		44	24	20	
Total		102	60	42	

correlated with PC1, but Ca^{2+} and Mg^{2+} concentrations are positively correlated with it. PC2 accounting for 16.1% of total variance is positively correlated with sulphate (SO_4^{2-}) concentration which affects acidity and negatively correlated with total phosphorous (T-P) concentration. Sodium cation (Na^+) and Fe II cation (Fe^{2+}) concentrations observed increased with increase of SO_4^{2-} concentration. PC3 accounting for 14.0% of total variance represents availability of essential nutrients to plants; both total phosphorous and available phosphoric acid (T-P and available P_2O_5) concentrations and total nitrogen (T-N) concentration mainly originated from organic matter (OM) as both T-N and OM concentrations negatively correlated with PC3. PC4 accounting for 10.3% of total variance also represents availability of essential nutrients to plants; available potassium (available K_2O) concentration due to positive correlation of available K_2O with PC4. PC4 is also correlated with micro-nutrients to plants; positively correlated with chloride ion (Cl^-) concentration and negatively correlated with zinc cation (T-Zn) concentration. PC1 to PC4 contributes 67.1 percent of total variance.

Characteristics of the orange farm soils in Nghe An province: The sample scores plotted in PC1-PC2 coordinate, indicating the soil of orange farms in Nghe An province which is firstly characterised by acidity, varying from 3.51 to 6.58 with wide range of Al^{3+}, Ca^{2+} and Mg^{2+} concentrations. Extremely acidic soils contain more Al^{3+} concetration but less Ca^{2+} and Mg^{2+} concetnrations. Soil samples on PC1 axis are distributed equally both for positive and negative directions (-3.63≤PC1≤4.09), but on PC2 axis they are distributed more widely in the positive direction (-3.24≤PC2≤6.16), implying that acidity mainly is attributed to SO_4^{2-} concentration. Soil samples affected by SO_4^{2-} contain more Na^+ and Fe^{2+} concentration, but less T-P and T-Zn concetrations (Figure 5a). The sample scores plotted in PC3 – PC4 coordinate, indicating soil samples can be grouped by concentration of essential nutrients of phosphorus (T-P and available P_2O_5), nitrogen (T-N) and potassium (available K_2O). Soil samples on PC3 axis are distributed equally both for negative and positive directions (-3.83≤PC1≤3.47), but those on PC4 axis are distributed more widely in negative direction (-3.41≤PC4≤2.87, execpt for 6.85 of PC4 score), implying that the soil in the orange farms containing relatively less concetration of available K_2O is dominant in Con Cuong area (Figure 5b).

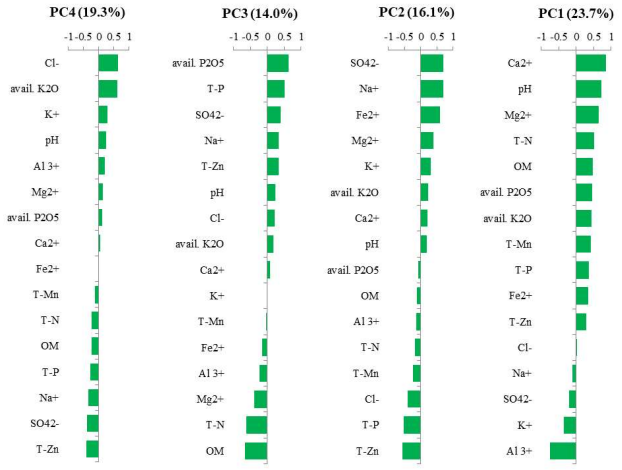


Fig. 4. Eigenvectors of PCs (PC1 - PC4)

Soils in Con Cuong district: Soil samples from Con Cuong district in the PC1-PC2 coordinate distribute from the second quadrant involving soils collected from Don Phuc and Chi Khe communes to the fourth quadrant involving soils collected from Bong Khe commune (Fig. 5a.) It implies that soils in Con Cuong range from extremely acidic to acidic (3.79±0.05 and 4.72±0.08 for Dong Phuc and Bong Khe, respectively) mainly according to the concentration of SO42-

Table 2. Standard fertilizing in orange farms, Con Cuong district

Fertilizer	Quantity (kg/ha)
Organic	
Animal mature	50 - 70
Inorganic	
Phosphorous powder	2 - 3
Synthetic NPK	2 - 3
Lime powder	1 - 1.5

Trees aged over 10 years

Table 3. Soil characteristics in Con Cuong district

Districts	pH	T-N (g/100g)	Available P_2O_5 (mg/100g)	Al^{3+} (meq/100g)	Ca^{2+} (meq/100g)	Mg^{2+} (meq/100g)	SO_4^{2-} (mg/kg)
Mau Duc	4,01	0,06	7,93	1,20	2,53	1,23	39,05
Dong Phuc	3.79±0.05^a	0.09±0.01^{ab}	3.17±0.63^a	1.00±0.06^c	2.86±0.50^a	1.15±0.06^{ab}	170.42±56.95^b
Yen Khe	4.34±0.15^a	0.08±0.01^b	5.87±0.95^a	0.33±0.13^b	3.12±0.25^a	1.04±0.01^b	37.91±1.93^a
Chi Khe	4.72±0.28^b	0.06±0.01^a	22.48±5.14^b	0.10±0.05^{ab}	4.60±0.50^b	1.28±0.09^a	225.69±50.63^b
Bong Khe	4.78±0.08^b	0.13±0.01^c	20.81±1.47^b	0.00±0.00^a	8.90±0.42^c	1.19±0.02^{ab}	46.03±2.85^a

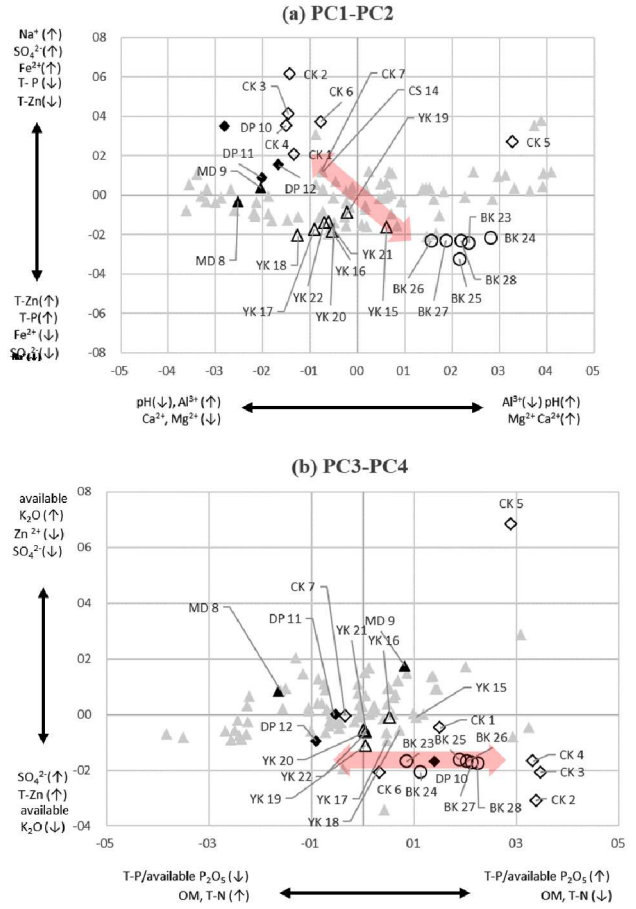


Fig. 5. Sample score plots in (a) PC1-PC2 and (b) PC3-PC4 (Red arrows indicate space distributions of soil samples from Con Cuong in PC1-PC2 and PC3-PC4 coordinates. Light gray shaded triangles indicate samples from Quy Hop district, Nghia Dan district, and Mon Son commune in Con Cuong)

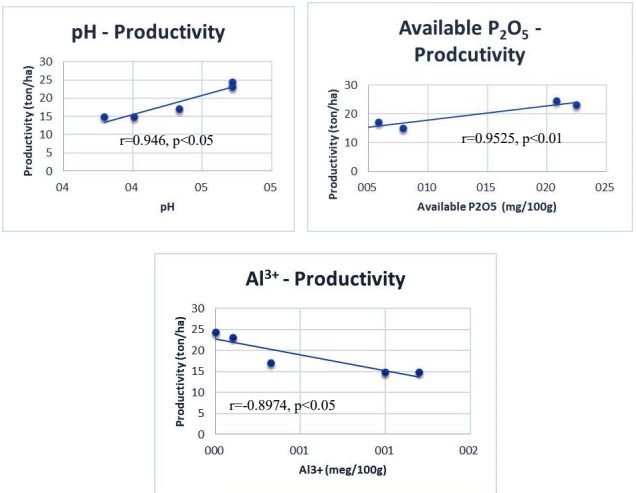


Fig. 6. Factors correlated with productivity

(170.42, 46.03 mg/kg for Don Phuc and Bong Khe, respectively). Extremely acidic soils such as those in Don Phuc contain more Al3+ concentration (1.0meq/100g) and less Ca2+. Mg2+ concentration (2.86and 1.15meq/100g, respectively) comparing to soils such as those in Bong Khe (Al3+: 0.00, Ca2+: 8.90meq/100g, Mg2+: 1.19±0.02 meq/100g). In the PC3 – PC4 coordinate soil samples in Con Cuong tend to distribute from the third quadrant to the fourth quadrant (Figure 5b). It implies that soils in Con Cuong are characterized by difference in concentration of phosphorous (T-P and available P2O5) and nitrogen (T-N), but not much difference in that of potassium (available K2O). Soils in Chi Khe is relatively rich in phosphorous (22.48mg available P2O5/100g) and poor in nitrogen (0.06g T-N/100g), but that in Don Phuc is inverse (3.17mg available P2O5/100g, 0.09g T-N/100g). The main chemical characteristics of soils of five communes: Mau Duc (MD), Don Phuc (DP), Yen Khe (YK), Chi Khe (CK) and Ben Khe (BK) (Table 3).

Orange productivity and soils in Con Cuong area: The productivity in Con Cuong district is correlated with three factors; pH, available P_2O_5 and Al^{3+}. There was positive correlation with pH and available P_2O_5 (r=0.946,), whereas negative correlation with Al^{3+} (r=-0.8974) (Figure 6). Al^{3+} is negatively correlated with pH (r=-0.932) and available P_2O_5 is positively correlated with pH (r=0.953) (Fig. 7).

Relationship between slope gradient and pH: Generally, rain water cause soil erosion which leads to removal of some exchangeable cations with flow, making soil acidic. There is a relationship between soil erosion and slope. Soil on the steeper slopes erode more rapidly with increase of flow. To verify this phenomenon happens in farmlands in Con Cuong, correlation between slope gradient as an indicator of soil erosion and pH was calculated (Fig. 8). The pH is negatively correlated with slope gradients (r=-0.968, p<0.01), which confirms that pH value decreases with increasing slope gradient.

Characteristics of orange farm soils distributing in central Nghe An province

The most distinguished characteristic of the orange farm soils in Quy Hop, Nghia Dan and Con Cuong district of central Nghe An province is low acidity. Focusing on Con Cuong district, approximately one third of the land surveyed is

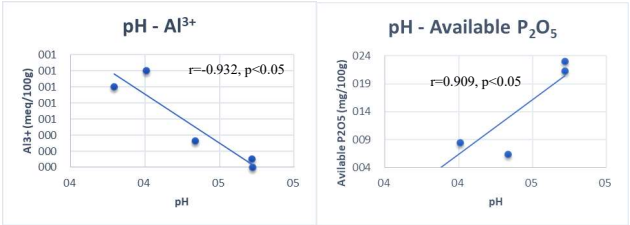


Fig. 7. Relationship pH to $Al^{3+}$and available P_2O_5

extremely acidic; less than 4 in pH (Fig. 8). PCA reveals that extremely acidic soils distribute in Mau Duc and Don Phuc commune, which are plotted in the second quadrant of PC1 – PC2 coordinate. In contrast, acidic but not extremely low pH of soils distribute in Bong Khe commune, which are plotted in the fourth quadrant of PC1 – PC2 coordinate. Samples plotted in the second quadrant contain more SO_4^{2-}, but less Ca^{2+} and Mg^{2+}, whereas ones plotted in the fourth quadrant contain less SO_4^{2-}, but more Ca^{2+} and Mg^{2+} (Figure 5a). It indicates that excess amount of SO_4^{2-} and runoff of exchangeable cations are the main cause of extremely low pH (Pagani et al 2013). pH is an important indicator for soil nutrient availability for crops. Shahana et al (2016) reported that soil of pH 5.5 to 7.0 is the most suitable for general crop cultivation and for orange cultivation appropriate value of pH is 5.8 to 6.5 (Uchida et al 2000). In Con Cuong district even though pH of soils in Bong Khe is relatively higher, mean pH is 4.78 (Table 3), the ratio of pH of 5.8 or more accounts for 12.0%. Thus, approximately 90% of the orange farm is recommended to be neutralized. The soils in Con Quong district are also characterized by nitrogen and phosphorus concentrations. Plot pattern in the P3 – P4 coordinate indicates that the soils in Con Quong vary in T-P, available P_2O_5 and OM, T-N concentrations, those factors increase and decrease inversely (Figure 5b). The soils in Chi Khe tend to contain relatively higher phosphorus but lower nitrogen, whereas ones in Don Phuc contain relatively lower phosphorus but higher nitrogen. The soils in Bong Khe are balanced in nitrogen and phosphorus concentrations. Based on this, more nitrogen and phosphorus supply than current fertilization could be required to some orange farms.

Soils in orange farms and orange productivity in Con Cuong district: Soil characteristics, slope gradients and productivities in five communes in Con Cuong district are summarized in Table 4, grouped into three soil types. The productivity (p) in Bong Khe is significantly higher than that in Yen Khe ($p<0.05$), in Mau Duc and in Don Phuc (both for $p<0.01$). Soil pH in orange farms in Con Cuong is low to extremely low even though lime powder is provided to the farms after harvesting. Soil pH in Bong Khe is significantly higher than that in Don Phuc ($p<0.05$), but not in Yen Khe, however, Al^{3+} concentration of the soils in Bong Khe is significantly lower than both the soils of Don Phuc and Yen Khe ($p<0.01$, $p<0.05$, respectively) (samples from Mau Duc

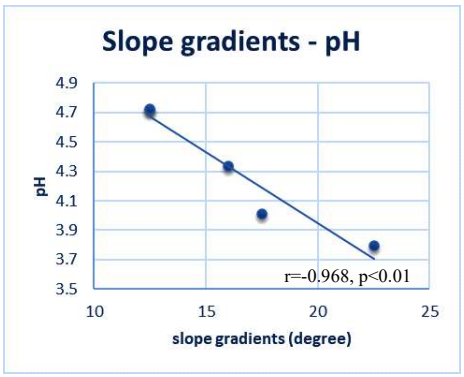


Fig. 8. Relationship between slope gradients and pH

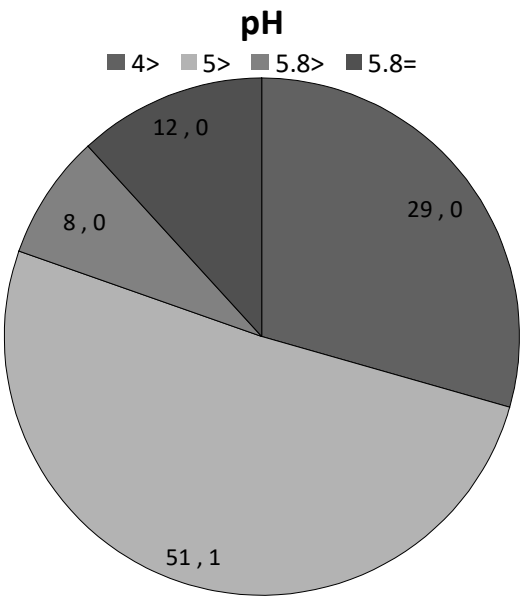


Fig. 9. Soil pH distribution in the study area (Number in the pie graph indicates percentage)

Table 4. Evaluation of orange productivity and soils in Con Cuong area

	Commune	Soil characteristics	Slope gradients (degree)	Productivity
Type I	Bong Khe	Acidic without Al^{3+}, relatively rich in Ca^{2+}, Mg^{2+}, P and N.	10 - 15	Relatively high
Type II	Chi Khe	Acidic to extremely acidic with Al^{3+}, relatively poor in Ca^{2+} and P, medium in Mg^{2+} and N	10 -15	Medium
	Yen Khe	Extremely acidic with Al^{3+}, relatively poor in Ca^{2+} and P, medium in Mg^{2+} and N	12 - 20	Medium
Type III	Mau Duc	Extremely acidic with excess amout Al^{3+}, relatively poor in Ca^{2+}, Mg^{2+} and P, poor to medium in N	15 - 20	
	Don Phuc		20 - 25	Relatively low

have not been examined by ANOVA, due to limitation of samples: two samples).pH is negatively correlated with slope gradients (r=-0.968, p<0.01), implying that soil erosion occurred more frequently on steep slopes in Don Phuc and Mau Duc (gradients: 15 -20, 20 – 25 degrees, respectively), resulting in washing out of more exchangeable cations such as $Ca^{2+}$and Mg^{2+} which makes the soil more acidic and thus promotes elution of Al^{3+}(Rout et al 2001, Kopittke et al 2016). Higher acidity in soil is not desirable as it acts poison to orange growth .Therefore, Al^{3+} elution caused by decrease of pH mostly affects orange productivity in Con Cuong area. Other factors affecting the productivity are available phosphoric acid (P_2O_5) and Ca^{2+} concentration. Concentrations of available P_2O_5 and Ca^{2+} in Bong Khe are significantly greater than those in Yen Khe and Don Phuc (p<0.01, p<0.001both to Yen Khe and Don Phuc for available $P_2O_5$and Ca^{2+}). Available P_2O_5concentration is affected by soil pH, (r=0.953, p<0.05), it was known that P_2O_5 tends to be adsorbed to soil particles under low pH condition (Cheng et al 2014).

CONCLUSION

In short, the acidity and richness of Al3 + is a prominent feature of soil in the mountainous areas of Nghe An, Vietnam. This is due to washing out of exchangeable cations from steep slopes during the process of soil erosion. The soil in orange farms in Con Cuong can be characterized by lower pH (acid) soils with concentrations of cations of Al^{3+} and Ca^{2+}, and P_2O_5, affecting the orange productivity. It can be concluded that proper pH balance is required to be maintained in soil of the farm for best production of oranges by taking suitable remedial measures to check soil erosion and also to have proper balance of cations like Al^{3+} and Ca^{2+}, and P_2O_5.

ACKNOWLEDGEMENT

This study was financially supported by the research fund of Vinh University in financial and technical.

REFERENCES

Alkarkhi AFM, Ahmad A and Easa AM 2009. Assessment of surface water quality of selected estuaries of Malaysia: Multivariate statistical techniques. *Environmentalist* **29**: 255-262.

Abidoye B, Mendelsohn R, Kurukulasuriya P and Tomova M 2016. Economics of climate change adaptation: Agriculture sector analysis for Vietnam. *Technical report printed by USAID & UNDP*.

Received 22 May, 2020; Accepted 12 August, 2020

Bhat SA, Meraj G, Yaseen S and Pandit AK 2014. Statistical assessment of water quality parameters for pollution source identification in Sukhnag stream: an inflow stream of lake Wular (Ramsar site), Kashmir Himalaya. *Journal of Ecosystems* 1–18.

Cheng HY, Ahmed OH and Majid NMA 2014. Improving phosphorous availability in an acid soil using organic amendments produced from agroindustrial waste. *The Scientific World Journal* 1-6**.**

Delhaize E and Ryan PR 1995. Aluminum toxicity and tolerance in plants. *Plant Physiology* **107**(31): 5-321.

Dinh VD, Dinh TKH and Hoang HT 2004. Evaluate efficiency of slope - farming at Nghia Dan district, Nghean province, Vietnam. *Asia -Pacific Journal of Science and Technology*: **22**(1).

Hesse P R 1971. *A Textbook of Soil Chemical Analysis*. *John Murray,* London.

International Center for Agricultural Research in Dry Areas (ICARDA) 2013. *Methods of Soil, Plant and Water Analysis: A Manual for the West Asia and North Africa Region* (3rd ed). *ICARDA,* Beirut, Lebanon.

JICA 2016. *The Project for Livelihood Diversification through Heritage Tourism in Remote Agricultural and Fishery Villages*, https://www.jica.go.jp/vietnam/english/ activities/ c8h0vm00004cfemz-att/ GC_95.pdf Accessed on Jan. 14, 2020.

Kopittke PM, Menzies NW, Wang P, Blamey F and Pax C 2016. Kinetics and nature of aluminium rhizotoxic effects: A review. *Journal of Experimental Botany* **67**(15): 4451–4467.

Martín DZ 1999. Soil organic carbon recovery by the Walkley-Black method in a typic hapludoll, *Communications in Soil Science and Plant Analysis* **30:** 5-6.

Martín NF, Bollero GA and Bullock DG 2005. Associations between field characteristics and soybean plant performance using canonical correlation analysis. *Plant and Soil* **55:** 273-39.

Meteorological and hydrological station in North Central Vietnam (M&HNCV) 2018. Average climate value in Nghe An.

Nguyen 2012. *Research on physical and chemical properties of soil and some methods of intensive farming of oranges on red soil Basalt Phu Quy - Nghe An.* Ph.D. thesis, Hanoi University of Agriculture.

Pagani A, Sawyer JE and Mallarino AP 2013. Chapter 6 : Calcium and magnesium management. *Site specific Nutrients Management,* USDA-NRCS.

Doanh Q and Ha DT 2004. Improving indigenous technologies for sustainable land use in northern mountainous areas of Vietnam. *Journal of Mountain Science* **1**(3): 270-275.

Rees HW, Chow TL and Gregorich EG 2007. Spatial and temporal trends in soil properties and crop yield at a site under intensive up- and down-slope potato production in northwestern New. *Canadian Journal of Soil Science* **87**: 383–398

Rout GR, Samantaray S, and Das P 2001. Aluminium toxicity in plants: a review. *Agronomie* **21**(1): 4–5.

Shahana F, Shaheen B and Azra Y 2016. Assessment of soil quality parameters using multivariate analysis in the Rawal Lake watershed. *Environmental Monitoring and Assessment* **188** (9): 533.

Uchida R and Hue NV 2000. *Soil acidity and liming In Plant Nutrient Management in Hawaii's Soils,* Approaches for Tropical and Subtropical Agriculture.

Zhang H and Zhang GL 2005. Landscape-scale soil quality change under different farming systems of a tropical farm in Hainan, China. *Soil Use and Management* **21**: 58–64.

Indian Journal of Ecology (2020) 47(3): 614-618

Manuscript Number: 3053
NAAS Rating: 4.96

Comparative Study of Sugarcane Agro-Industrial Waste Raw Pressmud and Composted Pressmud: A Case Study

Amol Chougule, P.R. Bhosale and P.D. Raut

Department of Environmental Science, Shivaji University, Kolhapur-416 004, India
E-mail: drpdraut@yahoo.co.in

Abstract: Sugarcane raw pressmud (SRP) and sugarcane composted pressmud (SCP) were collected from Chhatrapati Shahu Sahakri Sakhar Karkhana, Kagal, dist. Kolhapur, Maharashtra, India. Physico-chemical macro, micro-nutrients and heavy metals analysis of SRP and SCP for two consecutive crushing seasons i.e. 2015-16 and 2016-17. The pH was 6.21, percent total nitrogen 2.33, phosphorous 1.25, potassium was 2.33, 1.25 and 0.44. The moisture level recorded was 60.29%. The organic matter 29.17%, total organic carbon17.16%, C:N ratio 9.22%, Calcium 1.53% and 1.07%. Changed characters of SCP as pH 6.6, E.C. 58.7 mhos/cm, total Nitrogen 2.57%, Phosphorous 1.24%, Potassium 0.62%, moisture level 58.7%, organic matter 30.23% and total organic carbon 17.54%. The results suggest that the pH and Nitrogen are the two characters of the improved composted pressmud may increases in the yield of the crop plants.

Keywords: Agro-industry, Pressmud, Composted press mud, Sugar industry, Shahu sugar

Ago-industries are the industries dependent on agriculture produce for their raw material (Parmasivan and Pasupathi 2016). Previously, the agro-industry has given more importance to policy and development programs. Sugarcane is the most important industrial resource of the entire Kolhapur district. Huge amount of sugarcane is harvested in the district which lead to the development of agro-based industry i.e. sugar industry (Sugar industry in Kolhapur district. Present study is associated with utilization of waste of the agro-based industry in Kolhapur, Maharashtra, India. Agro industrial waste: Agro waste is the left residues or after growing and processing of raw agri products like crops, fruits, meat, vegetables, poultry and dairy products etc. (Obi et al 2016). During the present study it was found that, there are exercises and practices of agriculture which contribute considerably to different industrial sectors, such as textiles, food, feed etc. that lead to the generation of vast quantities of waste residues (Kapoor et al 2016). The top ten sugarcane producing countries in the world are Brazil, India, China, Thailand, Pakistan, Mexico, Colombia, Indonesia, Philippines, and USA for the year 2013 (Zhao and Rui Li 2015). Production of sugar and ethanol from sugarcane, a exploited grass is utilized (Goldemberg 2008). Energy crops are extensively grown worldwide and sugarcane is one of them. This sugarcane is having high biomass energy yield in stalks where, sugar is stored. After production of the sugarcane lingo-cellulosic residue remains, that remaining is utilized for the production of bio-products or biofuels (Awe et al 2019). Ethanol production is worldwide highlighted by the sugarcane (*Saccharum* spp.) which is the majority sustainable crop. World's leading sugarcane producer is Brazil which has produced about 620 million tons in the harvesting year 2018-19 (Barbosa et al 2019).

By-products such as bagasse and molasses were evaluated for their ability as fertilizers, with positive results (Keshavanathet al 2007). Pressmud is produced in the filtration process of sugarcane juice and it is compressed sugar industry waste (Gupta et al 2011). Pressmud is generated from sugar industries and it is constructive source of fertilizer and some chemicals (Partha and Sivasubramanian 2006). Sugarcane left biomass has many components like lignin, fiber, pith and pentosans which can be adapted as a useful product by using suitable microbial, biochemical and chemical technologies (Yadav and Solomon 2006). Sugar industries in and around Kolhapur, Maharashtraare co-operative and some are private which are located in various parts of the Kolhapur district (Sugar industry in Kolhapur district 2001).

The high amount of NPK contents in the pressmud has made it a precious nutrient resource along with the luxurious amount of organic matter. Important micronutrients like Zn, Cu, Fe, and Mn are also rich in pressmud, being deficient in calcareous soil (Rakkiyappan et al 2001). Pressmud is a good supply of organic matter, NPK, and vital micronutrients and has its significance in improving productivity, fertility and other physical properties of agricultural soil (Muhammad et al 2008). Pressmud is having high amount of organic matter which may lead to alternate source of nutrients and acting as

soil conditioner (Sharma 2019). The pressmud compost is produced by spraying spent wash on loads of pressmud known as windrows. Time necessary to manufacture utilizable fertilizer varies through the process used. Normally 45-50 days batches were taken to compost production (Rasappan et al 2015). Many farmers are using pressmud as manure. The sugar industries provide pressmud without composting to the farmers and which it may lead to change in pH and hardening of soil leading to reduced crop yield. Therefore, there is a need to study characteristics of raw pressmudas well as composted pressmud as a representative of these sugar industries.

MATERIAL AND METHODS

Collection of pressmud and composted pressmud sample: Sugarcane pressmud as well as composted pressmud was collected from Chhatrapati Shahu S.S.K., Kagal, samples were collected during the sugarcane crushing season 2016-17. The raw pressmud collected as it is but composted pressmud was taken from the composting yard of the industry.

Physico-chemical characteristics: Physico-chemical characteristics of Sugarcane pressmud (SPM), Sugarcane composted pressmud (SCPM) were analyzed for pH, moisture content, total available nitrogen, phosphorus, potassium, organic carbon, organic matter and C:N ratio. All these parameters were analyzed by standard protocols (APHA 1999, Maithi 2002). Macro, micro and heavy metals were measured by Flame photometry and Atomic Absorption Spectrometry (AAS) using individual hollow cathode lamps and by applying background corrections whenever required with deuterium lamp. The method of standard additions was used to compensate for matrix effects.

RESULTS AND DISCUSSION

Physico-chemical characters: The characters were recorded for the two different seasons as 2015-16 and 2016-17. The maximum pH was during the season 2015-16 as compared to season 2016-17. The pH were in the range of 6.57and 5.85 for these seasons. Pressmud shows the average pH of 6.21. Ambigar and Baked (2018) recorded press mud pH of 6.25. In this range microbial activity can sustain however, below pH 6 activity cannot be sustained. This suggests that present sugar industry pressmud is having suitable pH to sustain microbial activity. Phosphorous is one of macro element, necessary for plant growth. Sugarcane residue after harvesting has been recorded with 0.04% Phosphorous amount by Dotaniya et al 2016. Total Phosphorous has been analyzed from pressmud shows 1.17% during 2015-16 season and 1.33% in 2016-17. Maximum percentage of Phosphorous was reported for the season 2016-17 during study period. Rasappan et al (2015) reported Phosphorus level in pressmud about 0.60% to 3.50% of Shakti Sugar Mill, Tamilnadu.

Potassium percentage reported for the 2015-16 season is 0.49% and for 2016-17 is 0.39%. Average concentration of Potassium in pressmud has been recorded0.44 %.Potassium is one of the plant growth nutrient. Rasappan et al (2015) observed Potassium concentration around 0.30 - 1.80 % in Shakti Sugar, Tamilnadu. Ranveer et al 2015 has reported K is 0.9% in raw pressmud from Bidvi Sugar Mill, Saharanpur, U.P, India whereas, present sugar industry reported minimum concentration of Potassium for the study period.

Phosphorous is one of macro element, necessary for plant growth. Sugarcane residue after harvesting has been recorded with 0.04 % Phosphorous amount by Dotaniya et al 2016. Total Phosphorous has been analyzed from pressmud shows 1.17 % during 2015-16 season and 1.33 % in 2016-17. Maximum percentage of Phosphorous was reported for the season 2016-17 during study period. Rasappan et al 2015, reported Phosphorus level in pressmud about 0.60 % to 3.50 % of Shakti Sugar Mill, Tamilnadu. Calcium and Magnesium are the major macro nutrients for the plant nutrition. Calcium was reported for the year 2015-16 season is 1.62% and for the season 2016-17 is 1.43%. Average calciumreported was 1.53%. Gupta et al (2011) reported 4.3% in a typical press mud sample, whereChh. Shahu S. S. K., Kagal showed minimum percentage. Average Magnesium concentration has been reported for the pressmud is about 1.07% during study. Chh. Shahu S.S.K., Kagal has reported maximum Mg concentration as compared to 0.7% reported by Gupta et al (2011). Average organic matter was 29.17 percent. There is no variation observed for the organic matter for both seasons. Average total organic carbon is17.16%, whereas, Bhosale et al (2012), reported maximum of around 40%. The study of pressmud of two sugarcane crushing season showed good characteristics to develop good compost. It showed favourable concentration of various components such as pH, N, P, K, Organic carbon, Moisture level, Calcium and Magnesium during the present study.

Physico-chemical analysis of SRP and SCP: Preliminary analysis of collected raw pressmud was done before composting. Comparative analysis was carried out for raw as well as composted pressmud. pH is observed around 5.9 for pressmud and 6.6 for composted pressmud.SRP shows acidic pH as compared to SCP. Bhosale et al (2012), showed that pH of raw pressmud doesn't show any changes in the process of press mud dewaxing. It has the ability to slightly reduce the pH of soil.

Moisture content for both SRP and SCP observed in the range between 50% to 65%. SRP shows 62.12% and SCP 58.7%. Generally, Pressmud have 60–85% (w/w) moisture content. Chandra et al (2018) recorded more moisture percent of pressmud i.e. 78.48%. Total organic carbon recorded 16.37% and 17.54%, respectively for the SRP and SCP. Practices such as mulching with application of composted pressmud in fields is helpful to achieve the objective of soil carbon sequestration into agriculture soils (Padalkar and Raut 2015). Ram et al (2017) reported 35.5% of organic carbon in pressmud. Total organic carbon percentage of SRP as well as SCP is sufficient to the improvement in agricultural soil carbon level. Essential crop nutrients are NPK to be applied to the crops in agriculture for better yield. There is a need to make sure of their availability in fertilizers before the application. Pressmud and composted pressmud has been analyzed for the NPK status of their composition. Nitrogen concentration has been observed 2.41% and 2.57% for the SRP and SCP respectively. Typical pressmud from sugar industry reported 1% to 1.5% of Nitrogen (Sarangi et al 2008). Phosphorous is reported 1.14% and 1.24% correspondingly in SCP and SRP. Phosphorus was reported by Joshi and Sharma (2010) from Bidvi Sugar Mill, Sharanpur, U.P, India is 1.80 % and for composted pressmud is 1.90 %. Comparatively Chh. Shahu S.S.K., Kagal (Mahrashtra) is recorded minimum percent of phosphorous during the study. Potassium recorded at 0.54% and 0.62% in SRP and SCP. Bhosale et al(2012) reported potassium concentration around 0.6% which doesn't show any variation. Comparative study for SRP as well as SCP shows various characters in favor to support effective pressmud composting.

Macro and micro-nutrients: In the sugarcane raw pressmud the Zn, Mn, Cu, Fewas 0.445, 3.202, 0.418 and 34.44 mg kg^{-1}, respectively. Macro nutrients likeCa, Mg, recorded 22.00and 10.44mg kg^{-1}respectively. The sugarcane composted pressmud showed micro-nutrients like Zn, Mn, Cu, Fe in order of 0.516, 4.024, 0.459 and 37.62mg kg^{-1}. Macro nutrients such as Ca, Mg, was 26.00 and 10.64 mg kg^{-1}. For the sugarcane composted pressmud shows Zn, Mn, Cu, Fei.e. of 0.394 mg kg^{-1}, 0.623mg kg^{-1}, 0.329 mg kg^{-1} and 5.204 mg kg^{-1}, respectively. Macro nutrients such as Ca, Mg, were recorded 32.00 mg $kg^{-1}$and 10.72mg kg^{-1}, respectively. Pressmud compost contains key plant nutrients like N, P, K, Ca, Mg, S and minor elements like Fe, Zn, Mn, Cu, B, Mo. Pressmud compost saves the cost on inorganic fertilizers by 15-20%, it improves structure, texture and value of soil, as well improves water holding capacity of soil as this compost contains fibrous material like decomposed coir waste and other agriculture biomass (Kumar et al 2017). The concentrations of micronutrients in SRP and SCP reported order of abundance as Fe >Mn> Zn> Cu, which follows a natural progressive concentration (Kumar et al 2011). Comparatively, SCP reported maximum

Table 1. Physico-chemical characters of pressmud from Chhatrapati Shahu Sahakari Sakhar Karkhana, Kagal, Dist. Kolhapur (Mean±S.D)

Characters	2015-2016 season	2016-2017 season	Average
pH	6.57±0.04	5.85±0.35	6.21±0.07
Total nitrogen	2.21±0.16	2.45±0.10	2.33±0.04
Potassium	0.49±0.23	0.39±0.16	0.44±0.13
Phosphorous	1.17±0.08	1.33±0.11	1.25±0.05
Moisture content	60.21±1.22	60.38±0.21	60.29±0.71
Organic matter	29.10±0.22	29.24±0.49	29.17±0.20
Total organic carbon	17.18±0.15	17.15±0.25	17.16±0.07
C:N Ratio	9.18±0.38	9.26±0.16	9.22±0.15
Calcium	1.62±0.16	1.43±0.28	1.53±0.09
Magnesium	1.04±0.06	1.11±0.12	1.07±0.04

Except pH all values are in %.

Table 2. Physico-chemical characters of sugarcane raw pressmud, composted pressmud of Chhatrapati Shahu Sahakri Sakhar Karkhana, Kagal

Characters	Sugarcane raw pressmud (SRP)	Sugarcane composted pressmud (SCP)
Physico-chemical characters*		
pH	5.9	6.6
Moisture content (%)	62.12	58.7
E.C. (mhos/cm)	152	241
Total organic carbon (%)	16.37	17.54
Organic matter (%)	28.22	30.23
Total Nitrogen (%)	2.41	2.57
Available phosphorus %)	1.14	1.24
Potassium (mg/l)	0.54	0.62
Macro and micro-nutrients and heavy metals (mg kg^{-1})		
Zinc	0.445	0.516
Magnesium	10.44	10.64
Calcium	22.00	26.00
Manganese	3.202	4.024
Iron	34.44	37.62
Copper	0.418	0.459
Cobalt	0.112	0.125
Cadmium	0.025	0.024
Lead	BDL	BDL

*All parameters are in % except pH and EC (mhos/cm)

concentration of macro as well as micronutrients such as calcium, magnesium, iron, zinc, manganese, copper and cobalt. Heavy metalcadmium is 0.025 mg kg^{-1} and 0.024 mg kg^{-1} for SRP and SCP respectively whereas, lead was reported below detectable level in both SRP and SCP.SRP and SCP are reported with excellent amount of macro and micronutrients such as Ca, Mg, Zn, Mn, Cu, Fe, and Co during the study. This effective amount of macro and micronutrients can be useful to maintain nutrient balance when applied to soil.

CONCLUSION

The SRP and SCP showed improvement in N, P, K, total organic carbon and organic matter as well as sufficient amount of macro and micro nutrients also increased suggesting better conversion agro industrial waste pressmud for increasing crop yield.

ACKNOWLEDGEMENT

The authors are thankful to DBT-IPLS and GJRF for providing financial assistance.

REFERENCES

Allison LE 1965. Organic carbon in methods of soil analysis. *Agronomy* **9**: 1367-1378.

Ambigar S and Byakodi A 2018. Comprehensive study on characterization of sugar pressmud along with suitable microbial consortium for pressmud composting. *International Research Journal of Engineering and Technology* **5**: 2561-2566.

Awe GO, Reichert JM and Fontanela E 2019. Sugarcane production in the subtropics: Seasonal changes in soil properties and crop yield in no-tillage, inverting and minimum tillage. *Soil & Tillage Research* **196**: 104-447.

Barbosa LC, Magalhães PSG, Bordonal RO, Cherubin MR, Castioni AFG, Sarah Tenelli, Franco HCJ, Nunes JL and Bordonaletal C 2019. Soil physical quality associated with tillage practices during sugarcane planting in south-central Brazil. *Soil & Tillage Research* **195**: 104383.

Bhosale PR, Chonde SG, Nakade DB and Raut PD 2012. Studies on physic-chemical characteristics of waxed and dewaxed pressmud and its effect on water holding capacity of soil. *ISCA Journal of Biological Sciences* **1**(1): 35-41.

Bhosale PR, ChondeSonal G and Raut PD 2012. Studies on extraction of sugarcane wax from press mud of sugar factories from Kolhapur district, Maharashtra. *Journal of Environmental Research and Development* **6**(3A): 35-41.

Chandra VV, Hemstock SL, N' Yeurt AR, Woods J and Mani F 2018. Energy Potential of Press-Mud: A Sugarcane Waste. *University of the South Pacific, Suva, Fiji,* 1-19.

Dotaniya ML, Datta SC, Biswas DR, Dotaniya CK, Meena BL, Rajendiran BL, Regar KL and Lata Manju 2016. Use of sugarcane industrial by-products for improving sugarcane productivity and soil health. *International Journal of Recycling Organic Waste Agricul*ture **5**: 185-194.

Paramasivan C and Pasupathi R 2016. Performance of agro based industries in India. *National Journal of Advanced Research* **2**(6): 25-28.

Gandhi Vasant, Kumar Gauri and Marsh Robin 2001. Agroindustry for rural and small farmer development: Issues and lessons from India. *International Food and Agribusiness Management Review* **2**(3/4): 331-344.

Goldemberg J 2008. The Brazilian biofuels industry Biotechnol. *Biofuels* **1**(6): 1-7.

Goldemberg J, Coelho ST and Guardabassi P 2008. The sustainability of ethanol production from sugarcane. *Energy Policy* **36**: 2086-2097.

Gupta N,Tripathi S and Balomajumder C 2011. Characterization of pressmud: A sugar industry waste. *Fuel* **90**: 389-394.

Joshi Namita and Sharma Sonal 2010. Physico-chemical characterization of sulphidation pressmud composted pressmud and vermicomposted pressmud. *Report and Opinion* **2**(3): 79-82.

Kapoor M, Panwar D and Kaira GS 2016. Bioprocesses for enzyme production using agro-industrial wastes: Technical challenges and commercialization potential, pp. 61-93. In: Gurpreet Singh Dhillon and Surinder Kaur (eds). *Agro-Industrial Wastes as Feedstock for Enzyme Production.* Elsevier Inc. Edineburg London.

Keshavanath P, Shivanna and Gangadhara B 2006. Evaluation of sugarcane by-product pressmud as a manurein carp culture. *Bioresource Technology* **97**: 628-634.

Kjeldahl J 1883. A new method for the determination of nitrogen in organic matter, *Journal of Analytical Chemistry* **22**: 366-382.

Kumar B, Kumar S, Prakash D, Singh SK, Mishra M, Jain PK, Lal RB, Sharma CS and Mukherjee DP 2011. A study on sugar mill pressmud compost for some heavy metal content and their bio-availability. *Asian Journal of Plant Science and Research* **1**(3): 115-122.

Kumar Sunil, Meena R S, Jinger Dinesh, Singh Jatav Hanuman and Banjara Tejram 2017. Use of pressmud compost for improving crop productivity and soil health. *International Journal of Chemical Studies* **5**(2): 384-389.

Maiti SK 2003. *Handbook of Methods in Environmental studies*, ABD Publishers, Jaipur, p. 250-252.

McConnell DB, Shiralipour A and Smith WH 1993. Compost application improves soil properties. *Biocycle* **34**: 61-63.

Ranveer Anil C 2015. Vermicomposting of pressmud from sugar industry. *International Journal of Innovations in Engineering Research and Technology* **2**(4): 1-10.

Obi FO, Ugwuishiwu BO and Nwakaire JN 2016. Agricultural waste concept, generation, utilization and management. *Nigerian Journal of Technology (NIJOTECH)* **35**(4): 957-964.

Padalkar RC and Raut PD 2016. Assessment of soil carbon level after application of pressmud and mulching regarding soil carbon sequestration. *Nature Environment and Pollution Technology* **15**(2): 601-604.

Partha N and Sivasubramanian V 2006. Recovery of chemicals from pressmud a sugar industry waste. *Indian Chemical Engineering Section A* **48**(3): 160-163.

Rakkiyappan P, Thangavelu S, Mulathi R and Radhamani R 2001. Effect of biocompost and enriched pressmud on sugarcane yield and quality. *Sugar Technology* **3**: 92-96.

Ram RL, Chatterjee S, Maji C, Kar R and Singh YV 2017. Integrated effect of treated pressmud and fym on mulberry leaves and bioassay of silkworm in acid soils of Kalimpong Hills, India. *International Journal of Current Microbiology and Applied Sciences* **6**(1): 767-783.

Rasappan K, Kumar A and Satosh P 2015. Studies on sugarcane pressmud and distillery waste as a biofertilizer through composting. *International Journal of Chemical Sciences* **13**: 1333-1344.

Sarangi KB, Mudliar SN, Bhatt P, Kalave S, hakrabarty T and Pandey RA 2008. Compost from sugar mill and distillery spent wash for sustainable agriculture. *Dynamic Soil and Dynamic Plant* **2**(1): 35-49.

Sharma N, Hassan S and Ansal MD 2019. Incorporation of press mud: A sugar factory byproduct in semi-intensive carp polyculture system and its effect on fish growth and survival. *Journal of Entomology and Zoology Studies* **7:** 192-199.

Greenberg AE 1999. *Standard Methods for the Examination of Water and Wastewater,* American Public Health Association, American Water Works Association, Washington, DC (USA). p 354.

Yadav RL and Solomon S 2006. Potential of developing sugarcane by-product based industries in India. *Sugar Tech* **8**(2&3): 104-111.

Zhao Duli and Yang-Rui Li 2015. Climate change and sugarcane production: potential impact and mitigation strategies. *International Journal of Agronomy* **2015**: 1-10.

Received 14 June, 2020; Accepted 12 August, 2020

Indian Journal of Ecology (2020) 47(3): 619-623

Manuscript Number: 3054
NAAS Rating: 4.96

Influence of Various Doses of Fertiliser and Crop Geometry on Growth Parameters and Productivity of Late Sown Indian Mustard (*Brassica juncea* L.)

Naveen Rathi, Bikram Singh, V.S. Hooda, Harender, and Mohammed Mohsin[1]

Department of Agronomy, CCS Haryana Agricultural University, Hisar-125 004, India
[1]Department of Agronomy, MPUAT, Udaipur-313 001, India
E-mail: rathi.naveen93@gmail.com

Abstract: A field experiment was carried out at Regional Research Station, Bawal, Chaudhary Charan Singh Haryana Agricultural University, Hisar, to study the response of late sown Indian mustard (*Brassica juncea* L.) to varying fertilizer dose and crop geometry during the *rabi* season of 2015-16. The significantly higher number days to 50% flowering, days to completion of siliquae formation and days to maturity were observed in 115% RDF (Recommended dose of fertilizer *i.e.* 80 kg N + 30 kg P_2O_5 + 20 kg K_2O + 40 kg S ha^{-1}) over 70% RDF however, it was statistically at par with 85 and 100% RDF. Application of 115% RDF recorded significantly higher leaf area index, plant height and dry matter accumulation $plant^{-1}$ over 70% RDF at different growth period however, it was statistically at par with 85% and 100% RDF. Among different crop geometries, at different growth period 30 cm x 10 cm registered significantly higher leaf area index and plant height over closer spacing (25 cm x 25 cm) whereas, statistically superior dry matter accumulation $plant^{-1}$ was obtained in crop geometry of 25 cm x 25 cm over 30 cm x 10 cm. The higher grain yield was significantly higher (1370 kg ha^{-1}) with application of 115% RDF over 70% RDF however, it was statistically at par with 85 and 100% RDF. Among different crop geometries, 25 cm x 15 cm registered significantly higher seed yield (1461 kg ha^{-1}) over rest of the crop geometries.

Keywords: Fertilisers, Crop geometry, Phonology and Indian mustard

Rapeseed-mustard (*Brassica spp.*) is one of the most valuable oilseed crops of the world as well as India. Among the seven edible oilseeds cultivated in India, rapeseed-mustard contributes 28.6% in the total oilseeds production and ranks second after groundnut sharing 27.8% in the India's oilseed economy (Shekhawat et al 2012). In India, rapeseed-mustard occupy 5.99 million ha area with production of 6.31 million tones and productivity of rapeseed-mustard in India1053 kg ha^{-1} is very less as compared to world's productivity 1856 kg ha^{-1} (Anonymous 2015-16). Assuming an average oil recovery of 30% from major oilseeds, the country needs to produce at least 66 million tonnes of oilseed by 2020. The current annual production of edible oilseeds in the country fulfils only about 50% of the domestic requirement and the deficit is bridged through massive imports costing huge amount of foreign exchange. To overcome this chronic shortage, efforts are needed to increase productivity and production of edible oils in the country on sustainable basis. Under late sown condition, productivity declines primarily due to the shortening of vegetative and reproductive phase. Late sown Indian mustard is exposed to high temperature coupled with high evaporative demand of the atmosphere during the reproductive phase (ripening and grain filling) which consequently results in forced maturity and ultimately low productivity. High temperature in *Brassica* caused flower abortion with appreciable loss in seed yield (Alam et al 2014). Higher doses of fertilizer coupled with narrow crop geometry (inter and intra plant spacing) depleted more soil moisture as compared to lower doses of fertilizer in association with wider plant spacing. Temperature can't be manipulated easily under field conditions but by modifying fertilizer doses and crop geometry of late sown Indian mustard, soil moisture loss may be adjusted to meet out the evaporative demand of the atmosphere during reproductive phase.

Uniform distribution of crop plants over an area results in efficient use of nutrients, moisture, and suppression of weeds leading to high yield. In wider row spacing, solar radiation falling within the rows gets wasted particularly during the early stages of crop growth, whereas in closer row spacing upper part of the crop canopy may be well above the light saturation capacity but the lower leaves remain starved of light and contribute negatively towards yield. The dense plant population reduces the yield due to reduction in the photo-synthetically active leaf area caused by mutual shading (Shekhawat et al 2012). The productivity of individual plant is limited under late sown conditions owing to poor growth and development. Hence, higher plant population may compensate for reduction in seed yield (Kumari et al 2012). Late planted crop has low productivity due to restricted

vegetative growth therefore, selection of appropriate spacing and management of fertilizer doses under late sown condition play an important role in enhancing mustard productivity (Singh and Singh 2002). With the above aspects in view, present study was carried out with the objectives of effect of various fertilizers doses and crop geometry on phenology, growth, yield of late sown Indian mustard (*Brassica juncea L*).

MATERIAL AND METHODS

A field experiment was conducted at Regional Research Station of Chaudhary Charan Singh Haryana Agricultural University, Bawal in r*abi* (winter) season of 2015-16 located at 28º4' N latitude and 76º35' E longitude at an altitude of 266 meters above mean sea level. The soil of experimental field was loamy sand in texture, alkaline pH (7.5), low in organic carbon (0.46%), low in available N (105.16 kg ha^{-1}) and medium available P_2O_5 (10 kg ha^{-1}), K_2O (205 kg ha^{-1}) and neutral in soil reaction. The experimental site had been used over the years for continuous clusterbean- Indian mustard cropping. The experiment was laid out in split plot design with three replications involving four fertilizer dose two viz. F_1: 80 % RDF, F_2: 85 % RDF, F_3: RDF (recommended dose of fertilizer *i.e.* 80 kg N + 30 kg P_2O_5 + 20 kg K_2O + 40 kg S ha^{-1}), F4: 115 % RDF as main plots and six crop geometry as sub plots viz. C_1: 30 x 10 cm, C_2: 25 x 15 cm, C_3: 30 x 15 cm, C_4: 25 x 20 cm, C_5: 30 x 20 cm and C_6: 25 x 25 cm as sub plot treatments. In experiment gross plot size was 6.0 x 3.0 m with net plot size 4.5 x 2.0 m. Indian mustard variety RH 9801 was sown on 12th November 2015 at the depth of 4 to 5 cm. The recommended dose of fertilizers as per CCSHAU package of practices were applied 80 kg N ha^{-1} in the form of urea, 30 kg P_2O_5 ha^{-1} in the form of di-ammonium phosphate, 20 kg K_2O ha^{-1} in the form of muriate of potash and 40 kg S ha^{-1} in the form of gypsum. Half doses of nitrogen and full basal dose of phosphorus, potassium and sulphur as per treatments were applied at sowing. The remaining half dose of nitrogen was applied after first irrigation. After germination, thinning was done 21 days after sowing in order to maintain required spacing of plants within the row as per treatment (30 x 10 cm, 25 x 15 cm, 30 x 15 cm, 25 x 20 cm, 30 x 20 cm and 25 x 25 cm) to established plant population of 3.33, 2.66, 2.22, 2.00, 1.66 and 1.60 lakh plants ha^{-1}, respectively. Crop received good rainfall during the crop growth period. Recommended package of practices was followed for all other operations. Phonological stages were taken into consideration as suggested by Sylvester and Hakepeace (1984). Days taken to seedling emergence were reported by visual observation. After thinning three plants were selected randomly from each plot and tagged. All the observation for flowering and seed development were recorded only with the main raceme. For seed development, the lower 2/3 portion of main raceme containing siliquae was taken into consideration as there is a lot of variation in siliquae development on main raceme also. Leaf areas of selected plants were measured with the help of an electronic "Leaf Area Meter" at periodic intervals of 45, 70, 120 DAS and at harvest and mean values were calculated. The height of the main shoot was measured from the cotyledonary nodes to the top of shoot of the plant at periodic intervals of 45, 70, 120 DAS and at harvest from randomly selected plants tagged for these periodic observations. For dry matter three randomly selected plants were uprooted every time from each plot to record the dry matter production. These samples were chopped, sundried and then kept in an oven at 65±5 °C till a constant weight was achieved. The dried samples were weighed and average dry matter $plant^{-1}$ (g) was recorded. The crop harvested from net plot was tied into bundles for weighing and sun drying. After sun drying for 7 days, crop was threshed and yield $plot^{-1}$ was recorded.

RESULTS AND DISCUSSION

The number of days to germination did not show significant variation among different fertilizer doses and crop geometry. A significant increase was in the number of days to 50% flowering, days to completion of siliquae formation and days to maturity by the application of 85% RDF over 70% RDF as well as by crop geometry. The differences among 85, 100 and 115% RDF were found to be non-significant and the

Table 1. Effect of various treatments on phenology development of late sown Indian mustard

Treatments	Days to germination	Days to 50% flowering	Days to completion of siliquae formation	Days to maturity
Fertilizer doses				
70% RDF	5.50	53.5	102.9	132.6
85% RDF	5.66	53.9	104.5	133.1
100% RDF	5.66	54.2	104.8	133.4
115% RDF	5.77	54.4	105.0	133.8
CD (p=0.05)	NS	0.36	0.52	0.58
Crop geometry				
30 cm x 10 cm	5.33	52.0	102.0	130.6
25 cm x 15 cm	5.50	52.8	103.0	131.9
30 cm x 15 cm	5.66	53.5	104.1	133.0
25 cm x 20 cm	5.75	54.1	104.6	133.6
30cm x 20 cm	5.83	55.0	105.8	134.9
25 cm x 25 cm	5.83	55.4	106.1	135.8
CD (p=0.05)	NS	0.60	0.76	0.75

number of days from germination to maturity increased with increase in fertilizer doses. The days to 50% flowering, days to completion of siliquae formation and days to maturity increased from 53.5 to 54.4, 102.9 to 105.0 and 132.6 to 133.2 days respectively with increased fertilizer doses from 70 to 115% RDF. Similar results were reported by Kumar et al (2001) and Kumar et al (2002). Indian mustard sown at wider crop geometry of 25 x 25 cm took highest number days to 50% flowering (55.4), days to completion of siliquae formation (106.1) and days to maturity (135.3) as compared to closest crop geometries 30 x 10 cm. Similar finding in Indian mustard were also reported by Shivani and Kumar (2002) and Kumar et al (2004).

A significant variation in leaf area index, plant height and dry matter accumulation plant^{-1} was observed under various fertilizer doses at various crop growth stages. LAI increased up to 70 days crop stages, declining towards the maturity of crop with maximum increase between 45 and 70 days. LAI increase with successive increased in fertilizer doses from 70 to 115% RDF at all the crop growth stages. Plant height increased with the successive increase in fertility levels throughout the crop growth stage. A significantly higher plant height was recorded with application of 115% RDF over 70% RDF at 45, 70, 120 DAS and at harvest which was statistically at par with 100% RDF. Dry matter accumulation plant^{-1} increased steadily with the crop development with a maximum 70 to 95 DAS of crop stage. Dry matter accumulation plant^{-1} increased significantly with the increase in fertilizer doses during the crop growth stages. Application of 115% RDF recorded significantly higher dry matter accumulation plant^{-1} at all growth stages however, it was statistically at par with 100% RDF at 70, 120 DAS and at harvest. Various growth parameters increased with increased in fertilizer doses 70% to 115% RDF. This increased in growth parameters might be due to the better nutrition to the plant resulted in more plant height, better light interception and more photosynthesis thus resulting in higher dry matter production. Similar results are reported by Yadav et al (2010) and Ram et al (2013).

LAI and dry matter accumulation per plant under varying crop geometry differed significantly at 45, 70, 95 and 120 DAS. Narrow spacing (30 cm x 10 cm) resulted into significantly higher LAI over wider crop geometry 25 cm x 25 cm at 45, 70, 95 and 120 DAS and at harvest. The Dry matter accumulation was observed higher in wider crop geometry, at all growth stages of crop. These were due to the lesser space for lateral growth and inter plant competition for sunlight, moisture and nutrients as compared to wider crop spacing. These variation were also be observed by Pandey et al (2015) and Tyagi and Upadhyay (2016). However, the differences in LAI values under crop geometries were non-significant.

An increased seed yield, stover yield and biological yield was in various fertilizer doses at various crop growth stages (45, 70 and 120 DAS and at harvest). Application of 115% RDF recorded significantly higher seed yield over 70% RDF, however it was statistically at par with 85 and 100% RDF. Application of 115, 100 and 85% RDF increased in the seed yield to the tune of 10.5, 9.8 and 7.6% respectively over 70% RDF. This can be attributed to increase in fertilizer doses thus

Table 2. Effect of various treatments on leaf area index and plant height of late sown Indian mustard

Treatments	Leaf area index			Plant height (cm)			
	45 DAS	70 DAS	120 DAS	45 DAS	70 DAS	120 DAS	Harvest
Fertilizers							
70% RDF	0.54	1.71	1.34	27.5	110.8	179.5	181.1
85% RDF	0.62	1.86	1.46	28.0	111.7	181.2	183.4
100% RDF	0.63	1.87	1.48	28.1	112.0	181.3	183.6
115% RDF	0.64	1.88	1.49	28.3	112.2	181.4	183.8
CD (p=0.05)	0.03	0.05	0.08	0.44	0.12	0.27	0.20
Crop geometry							
30 cm x 10 cm	0.63	1.91	1.48	29.2	112.8	182.1	184.3
25 cm x 15 cm	0.63	1.88	1.47	29.0	112.6	181.8	184.0
30 cm x 15 cm	0.62	1.83	1.46	28.3	112.3	181.4	183.3
25 cm x 20 cm	0.61	1.82	1.44	28.2	111.6	180.6	182.9
30cm x 20 cm	0.60	1.78	1.42	27.4	110.9	180.0	181.9
25 cm x 25 cm	0.57	1.73	1.39	25.9	109.9	179.2	181.4
CD (p=0.05)	0.05	0.14	0.08	0.42	0.32	0.37	0.33

Table 3. Effect of various treatments on dry matter plant^{-1}, yield and harvest index of late sown Indian mustard

Treatments	Dry matter plant^{-1} (g)				Seed yield (Kg ha^{-1})	Stover yield (Kg ha^{-1})	Biological yield (Kg ha^{-1})	Harvest Index (%)
	45 DAS	70 DAS	120 DAS	Harvest				
Fertilizers								
70% RDF	1.86	11.30	38.41	39.48	1240	3831	5071	24.4
85% RDF	1.92	11.50	39.41	40.82	1334	3936	5270	25.3
100% RDF	1.98	11.58	39.62	40.93	1362	4059	5421	25.1
115% RDF	2.03	11.64	39.73	41.01	1370	4071	5451	25.1
CD (p=0.05)	0.02	0.10	0.24	0.18	70	69	139	NS
Crop geometry								
30 cm x 10 cm	1.85	11.32	38.81	40.06	1348	4128	5477	24.5
25 cm x 15 cm	1.89	11.42	39.05	40.31	1461	4326	5787	25.2
30 cm x 15 cm	1.93	11.52	39.19	40.53	1386	4146	5533	25.0
25 cm x 20 cm	1.97	11.55	39.41	40.68	1318	3928	5246	25.1
30cm x 20 cm	2.01	11.58	39.57	40.83	1243	3752	4995	24.8
25 cm x 25 cm	2.04	11.60	39.71	40.96	1203	3582	4785	25.0
CD (p=0.05)	0.03	0.14	0.34	0.32	61	65	126	NS

improving LAI and might have resulted in higher production of photosynthates and their translocation to sink (yield attributes), which results to the better yield. The increase in seed yield and its attributes with increase in fertilizer doses have also been observed by Singh *et al.* (2010).

Seed yield differed significantly under varying crop geometries. Highest seed yield was observed under the crop geometry (25 cm x 15 cm *i.e.* 2.66 lakh plants ha^{-1}) over all other crop geometries under study, by 5.4% to 21.4% higher seed yield over crop geometry of 30 cm x 15 cm and 25 cm x 25 cm (1.60 lakh plants ha^{-1}) respectively. Although the yield attributes per plant were better in case of wider spacing 25 cm x 25 cm but the yield per unit area was less because yield could not be compensated by loss in plant population as reported by Kumari et al (2012). Significantly higher stover and biological yields were in 85% RDF over 70% RDF, while the differences among 85, 100 and 115% RDF were non-significant. That the increased fertilizer doses resulting in increased plant height, number of primary branches, dry matter accumulation per plant and LAI, respectively which ultimately resulted into increase in stover and biological yield. Stover and biological yields under varying crop geometry differed significantly. Crop geometry 25 cm x 15 cm (2.66 lakh plants ha^{-1}) resulted into significantly higher stover and biological yields over all other crop geometries. Closer spacing because of much higher number of plants per unit area resulted in higher stover as well as biological yield. Harvest index don't differ significantly under varying crop geometry. Harvest index was not significantly influenced by different fertilizer doses (Table 3) though 85% RDF had higher harvest index (25.3 %) followed by 100 and 115% RDF. Similarly, varying crop geometry did not bring significant increase in harvest index.

CONCLUSIONS

The closer crop geometry 30 cm x 10 cm along with application of 115 % RDF recorded highest leaf area index and plant height whereas, highest dry matter accumulation plant^{-1} was obtained in 25 cm x 25 cm crop geometry. Highest grain, stover and biological yield were obtained with application of 115 % RDF in crop geometry of 30 cm x 10 cm.

REFERENCES

Alam MM, Begum F and Roy P 2014. Yield and yield attributes of rapeseed-mustard (*Brassica*) genotypes under late sown condition. *Bangladesh Journal Agricultural Research* **39**(2): 311-336.

Anonymous. 2016. http,//www.indiastat.com/agriculture/2.

Hegde DM 2009. Can Indian achieves self-reliance in vegetables oils? Proc *National Symposium on Vegetable Oil Scenario: Approaches to Meet the Growing Demand*. Indian Society of Oilseed Research, Rajinderanagar, India. Pp: 1-10.

Kumar A, Singh B, Yadav YP and Dhankhar OP 2001. Performance of four- rowed Indian mustard (*Brassica juncea*) mutant under different levels of nitrogen and phosphorous. *Indian Journal of Agricultural Sciences* **71**(6): 375- 377.

Kumar A, Singh B, Yashpal and Yadava JS 2004. Effect of sowing time and crop geometry on tetralocular Indian mustard (*Brassica juncea*) under south-west Haryana. *Indian Journal of Agricultural Sciences* **74**: 594-596.

Kumar R, Singh D and Singh H 2002. Effect of nitrogen and sowing dates on productivity of *Brassica* species. *Indian Journal of Agronomy* **47**(3): 411-417.

Kumari A, Singh RP and Yashpal 2012. Productivity, nutrient uptake and economics of mustard hybrid (*Brassica juncea*) under different planting time and row spacing. *Indian Journal Agronomy* **57**: 61-67.

Pandey N, Dubey SK and Singh G 2015. Response of Indian mustard

(*Brassica juncea*) genotypes under different planting geometry. *Current Advances in Agricultural Sciences* **7**(1): 79-81.

Ram M, Singh I and Kumar A 2013. Oil yield and quality parameters of Indian mustard as influenced by varieties, irrigation and fertilizer levels. *Haryana Journal of Agronomy* **19**(1): 47-49.

Shekhawat K, Rathore SS, Premi OP, Kandpal BK and Chauhan JS 2012. Advances in agronomic management of Indian mustard (*Brassica juncea* L.), An overview. *International Journal of Agronomy* 2012: 1-14.

Shivani and Kumar S 2002. Response of Indian mustard *(Brassica juncea*) varieties to sowing dates and row spacing in mid hills of Sikkim under rainfer conditions. *Indian Journal of Agronomy* **47**(3): 405-410.

Singh SK and Singh G 2002. Response of Indian mustard *(Brassica juncea*) varieties to nitrogen under varying sowing dates in eastern Uttar Pradesh. *Indian Journal of Agronomy* **47**: 242-248.

Singh Y, Singh T, Singh UN and Rajput PK 2010. Effect of nutrient management on yield, quality and economics of irrigated Indian mustard (*Brassica juncea*). *Indian Journal of Agricultural Sciences* **80**(8): 691-694.

Sylvester BR and Hakepeace PJ 1984. A code for stage of development in oil seed rapeseed (*Brassica napus* L.). In aspect of applied Biology, Agronomy, Physiology, Plant Breeding, Crop Protection of oilseed rape, Cambrridge.

Tyagi PK and Upadhyay AK 2016. Growth dynamics of Indian mustard (*Brassica juncea* L.) *cv.* Pusa Tarak a influenced by irrigation levels and row spacing. *Journal of Oilseed Brassica* **7**(1): 83-90.

Yadav RP, Tripathi ML and Trivedi SK 2010. Yield and quality of Indian mustard (*Brassica juncea*) as influenced by irrigation and nutrient levels. *Indian Journal of Agronomy* **55**(1): 56-59.

Received 25 May, 2020; Accepted 31 July, 2020

Indian Journal of Ecology (2020) 47(3): 624-629

Manuscript Number: 3055
NAAS Rating: 4.96

Economic Efficiency of Applying Environmentally Friendly Fertilizers in Production Technologies in the South of Ukraine

Ye. Domaratskiy, O. Kozlova and A. Kaplina

Kherson State Agrarian and Economic University, Ukraine, 73006, Kherson, Stritens'ka str. 23
E-mail: jdomar1981@gmail.com

Abstract: The study presents economic substantiation of applying environmentally friendly plant growth stimulators in combination with biological fungicides in sunflower production under conditions of the South of Ukraine. The field research was conducted at Kherson State Agricultural University (Ukraine) in 2016-2018 under conditions of dark chestnut alkaline soils with the humus content of 2.5% in the plough layer. The results of the three-year field research prove that the net profit reached the absolute maximum in the variant of the hybrid LG 5580 under conditions of applying the bio-fungicide Fitotsyd-r with the stimulator Ahrostymulin at the stage of budding and amounted to $1081/ha. In this case the cost price was the least-$141.6/ha, and the profitability level was the highest-196%.In the areas sown with the hybrid Tunca the variant with the combination of Fitotsyd-r and the growth stimulator Ahrostymulin also provided a positive result, but it yielded a little to the combination of the preparations Fitosporyn / Ahrostymulin: the net profit was $579.7/ha, the price cost made $203.4/ha and the profitability was 106 %. On the whole this analysis makes it possible to maintain that additional costs related to purchasing and applying fertlizers are totally compensated owing to the cost of an increase in the yield.

Keywords: Environmentally friendly fertilizers, Sunflower, Production costs, Product cost, Net profit, Profitability

The means of regulation of nutrient content in soils, nutrient intake by plants with different ratio is a system of nutrition regime. It has a radical impact on the level of supplying plants with mineral elements. But practice shows that mineral fertilizers do not solve all the problems related with the optimization of nutrition regime. During their growing season plants are under stress for quite a long time, their nutrition under such environmental conditions becomes less efficient (Jaspers and Kangasjärvi 2010). The task of a farmer is to provide suitable conditions for plants to overcome stress as fast as possible (Rady 2012, Hanserud et al 2018). There is a number of factors causing stress-reactions of plant organisms during the growing season. By the nature of impact they are divided into chemical (salts, gases, xenobiotics); biological (negative impact of pests, pathogenic agents, competition with other plants) and physical (excess or deficiency of moisture, temperature regime, light and radioactivity) (Whipps 1997, Goswami and Deka 2020). Under these conditions it is necessary to apply complex multi-functional fertilizers, containing mixtures of organic, humic and fulvic acids, a number of micro-elements in a chelated form in their formulation causing their fungicide action and activating microorganisms. It ultimately leads to stimulation of growth processes and contributes to the overcoming stress phenomena of plant organisms (Kumar et al 2015, Domaratskiy et al 2018, Domaratskiy et al 2019). The scientific research conducted in North America establishes that plant growth regulators applied in low concentrations are able to affect the division and growth of cells, their structure and functioning (Small and Degenhardt 2018). Direct application of such natural hormones and their synthetic analogs to plant stems, leaves and flowers increases their resistance to biotic and abiotic environmental factors, improves drought-resistance of crops and water-use efficiency (Rostami and Azhdarpoor 2019). The studies show that such fertilizers are capable of increasing nitrogen use efficiency, contribute to an increase in root weight and also stimulate the growth and development of lateral roots, assist in enhancing photosynthesis. These substances are usually applied in agriculture, viticulture and horticulture to increase yields under conditions of low agricultural background, moisture deficit and other unfavorable environmental factors (Siddiqi and Husen 2017, Adnan et al 2019).

Ukraine is one of the leaders in the world export of the products of sunflower processing. The world market expects to receive 5.1 million tons of Ukrainian sunflower oil this season that is by 16% more than the rate of the previous year. An increase in sunflower concentration in the structure of sown areas to 35% will have a negative impact on productivity that will decrease in all biological and economic groups. The gross yield of grains will fall from 27.0 to 20.9 million tons, and there will be an increase in that of sunflower seeds – from 4.5 to 5.8 million tons. Under such conditions the total cost of gross production of grain and oil crops will fall by $0.25 billion (from $3.04 to $2.79 billion). At first sight the

scheme of maximum use of sunflower in crop rotation is not threatening, but this approach is certainly insecure in terms of increasing effect of droughts and spread of specific diseases and pests (Moklyachuk et al 2019). Crop yield stability in agricultural production aimed at meeting demands of a continuously increasing population of the planet is possible only under conditions of applying fertilizers containing basic nutrients for plants. However, the use of such chemical substances has a negative impact on the environment and human health. Therefore, application of micro-fertilizers of biological origin is considered to be the best substitute for chemical fertilizers as an environmentally friendly method of growing crops and increasing soil fertility. These preparations intensify growth processes of plant organisms by means of different direct and indirect mechanisms of plant growth stimulation such as biological nitrogen fixation, production of various plant growth hormones, different hydrolytic ferments etc. Application of biological preparations increases the potential of vital nutrients supply in appropriate amounts to boost crop yields without damaging the environment (Kour et al 2020). The purpose of the study is to substantiate an economic component of using environmentally friendly preparations in technological schemes of sunflower production

MATERIAL AND METHODS

The field research was conducted in the research field of Kherson State Agricultural University in 2016-2018. The soil on the research plots is dark chestnut alkaline. The humus content is 2.5% in the plough layer of the soil, the content of slightly hydrolyzed nitrogen is 35, the content of movable phosphorus, 32 and that of metabolic potassium -430 mg/kg of the soil.The density of one-meter layer of the soil is 1.35, and its solid phases are 2.66 g cm^{-3}, the general porosity, 49-50%. The reaction of the soil solution in the topsoil is close to neutral (pH 7.0). It is alkaline closer to the profile (pH 7.4-7.9). The hydrolytic acidity is 0.36-1.9 mg-eq per 100 g of the soil. The soil permeability for the first hour of absorption is 1.3-2.2 mm/min. Groundwater is deeper than 5 m and does not affect soil-formation processes. The climate is moderate and arid. The average annual air temperature is 10.3^0 C, and accumulation of active air temperatures starts in the 3rd decade of March and finishes in the 2nd decade of November.The experimental research was carried out by means of a tree-factor field experiment: Factor A-preparations: control (clean water), Fitosporyn, Fitosporyn \ Hart Super, Fitosporyn / Ahrostymulin, FitoHelp, FitoHelp \ Hart Super, FitoHelp \ Ahrostymulin, Fitotsyd- r, Fitotsyd –r \ Hart Super, Fitotsyd-r \ Ahrostymulin; Factor B-sunflower hybrids of the company “Limagrein” (Tunca, LG 5580); Factor C-the period of applying preparations (seed treatment, the stage of budding). The seeds were treated according to the research scheme-a day before seeding, the plant treatment -at the stage of budding (9-10 pairs of true leaves). The plots were placed by the block-splitting method. The exchange rate of the NBU was 1$ – 24.32 UAH.

RESULTS AND DISCUSSION

Application of bio-preparations is related to the necessity of increasing production costs. Bio-fertilizers are substances with a low selling price. The calculation of the cost of fertilizers for treating sunflower seeds and plants is given in Table 1. It is necessary to add the cost of the crop treatment to the obtained results. Spraying the crops with 200 l/ha of the treatment solution costs $11.5/ha. Therefore, the total costs of applying Fitosporyn will be $14.1/ha; Fito Help –$19.4/ha; Fitotsyd-R – $15.4/ha. The stimulators were applied with bio-fungicides, therefore there were not additional costs. The main aim of economic evaluation is to compare the product cost and production costs (Table 2).

The calculation of the product cost with the determination of quality indexes was done for the sunflower with the fat content of 48%. This result was provided by the laboratory of the LLC “Nibulon”. If oil fat is lower by 1%, the price will be lower by 1/48*100 = 2.08%, and vice versa, the higher oil fat content is, the higher the price will be. But currently there is not such a system; therefore we used one price for all cases, $419.7. An important element of economic analysis is the calculation of direct production costs. At first, according to the regulations, we calculated the total costs for

Table 1. Calculation of the cost of fertilizers (prices on January, 1st 2019)

Fertilizers	Market price, US dollar/L	The dose of the fertilizer		The cost per 1 ha, US dollar	
		Per 1 t of seeds, l	Per 1ha of crops, l	Seed treatment	Plant treatment
Fitosporyn	6.6	0.15	0.4	0.1	2.6
Fito help	15.8	0.8	0.5	1.2	7.9
Fitotsyd-R	13.2	0.15	0.3	0.2	3.9
Hart super	33.7	0.02	0.8	0.1	26.9
Ahrostymulin	79	0.02	0.2	0.2	15.8

growing, harvesting and transporting sunflower products and additional costs related to purchasing and applying fertilizers, and also, to harvesting and transporting additional products. The seed cost of the hybrids Tunca - $131.6 per the sowing unit and LG 5580-$135.8 per the sowing unit are also referred to the difference in the costs. The production costs of the variants in the experiment were equal to $508.9 ha^{-1}. In our further calculations we added the cost of additional expenses, mentioned earlier, to this sum. Thus, the level of the costs for each variant of the experiment is the following (Table 3). The difference in the direct production costs between the control and the research variants reaches the maximum of $459.6 per hectare in the hybrid Tunca, and $5.1 per hectare in the hybrid LG 5580. It is worth noting that we calculated only direct production costs without considering the overheads: salaries for managers, tax payments, advertising, sales (Table 4).

The investigation of the degree of impact of these factors on economic efficiency is a complicated but a very important stage in the development of every enterprise in particular and Ukraine AIC on the whole. Examining the experience of agricultural activity and the level of profitability of agricultural

Table 2. Sunflower product cost depending on bio-fertilizers (average for 2016-2018)

Fertilizers	The period of applying	Tunca			LG 5580		
		Productivity, t/ha	The cost of 1 t of seeds, US dollar	The product cost, US dollar/ha	Productivity, t/ha	The cost of 1 t of seeds, US dollar	The product cost, US dollar/ha
Control (clean water)		2.26	419.7	948.6	2.8	419.7	1179
Fitosporyn	Seeds	2.4	419.7	1007	2.9	419.7	1200
	Budding	2.5	419.7	1070	3.3	419.7	1406
Fito Help	Seeds	2.4	419.7	1020	2.9	419.7	1196
	Budding	2.5	419.7	1057	3.4	419.7	1423
Fitotsyd-R	Seeds	2.3	419.7	982	2.9	419.7	1221
	Budding	2.4	419.7	1003	3.4	419.7	1422
Fitosporyn / Ahrostymulin	Seeds	2.5	419.7	1049	3.3	419.7	1376
	Budding	3.0	419.7	1267	3.6	419.7	1532
Fitotsyd-R / Ahrostymulin	Seeds	2.5	419.7	1049	3.4	419.7	1439
	Budding	2.7	419.7	1125	4.0	419.7	1632

Table 3. Level of the direct production costs for sunflower depending on the hybrids and fertilizers (average for 2016-2018), US dollar ha^{-1}

Fertilizers	Periods of application	Tunca				LG 5580			
		Total costs	Purchasing and applying fertilizers	Additional harvesting	In total	Total costs	Purchasing and applying fertilizers	Additional harvesting	In total
Control (clean water)		508.9	-	-	508,9	510.6	-	-	510.6
Fitosporyn	1*	508.9	0.1	6.0	515,0	510.6	0.1	10	520.7
	2*	508.9	14.1	12.3	535,3	510.6	14.1	14.6	539.3
Fito Help	1	508.9	1.2	5.1	515,2	510.6	1.2	8.3	520.1
	2	508.9	19.4	13.0	541,3	510.6	19.4	16.5	546.5
Fititsyd-R	1	508.9	0.2	5.3	514,4	510.6	0.2	7.7	518.5
	2	508.9	15.4	13.9	538,2	510.6	15.4	17.3	543.3
Fitosporyn / Ahrostymulin	1	508.9	0.28	15.9	525,08	510,6	0.28	16.7	527.6
	2	508.9	29.9	18.1	556,9	510.6	29.9	21.1	561.6
Fititsyd-R / Ahrostymulin	1	508.9	0.37	15.1	524,37	510.6	0.37	19.7	530.7
	2	508.9	19.4	16.7	545	510.6	19.4	20.8	550.8

1* – seed treatment; 2* – plant treatment at the stage of budding

production we maintain that it is necessary to create a correlation and regression model of profitability of sunflower production with application of bio-preparations. The data of the field research for 2016-2018 was used to conduct this research and create the model. The developing multiple regression taking into consideration the profitability of sunflower production Dependent variable was used to determine the profitability of sunflower. This index was chosen because it reflects efficiency and appropriateness of agricultural activity.In order to create a multi-factor correlation and regression model we suggested using three independent variables: X_1 – productivity, c/ha (an indirect index of soil fertility), X_2– production costs (US dollar per hectare), X_3 – the price of the products sold (US dollar for 1 centner))(an indirect index of product quality). The multiple regression was performed on the basis of the data of the field research conducted in the research field of Kherson State Agricultural University in 2016-2018. The model of the multifactor linear regression was created by means of the statistical method for measuring correlations (correlation and regression analysis).

To calculate the correlation coefficient the following formula is used (by the example of calculating the correlation x_2y):

$$rx_2y = \frac{x2y - \overline{x}_2\overline{y}}{\tilde{O}x_2 * \tilde{O}y}$$

The calculations of the correlation coefficients (the matrix of the pair correlation) are given in Table 5. The proximity of the correlation coefficients to 1 between some factors indicates to a strong connection between them or its multiplicative character. Considering the values of the matrix of the correlation coefficients can draw a conclusion that the most significant factors affecting profitability are the following: productivity, the price of the products sold and production costs.The initial factors were the ones having the coefficient of the pair correlation within the range of 0.4 to 0.9. The profitability of sunflower was chosen as a dependent variable, productivity per hectare, production costs and the price for 1 t were chosen as independent variables.First of all, assumed that correlation of the dependent variable with other variables is linear, i.e.

$$У = a_0 + a_1x_1 + a_2x_2 + a_3x_3$$

Unknown coefficients are determined by means of the method of least squares the essence of which is to minimize the sum of the squares of the deviations of the actual data from the theoretical data, obtained by the regression equation. The minimization criterion looks like this:

$$S = \Sigma(y - y_p)^2 \rightarrow \min .$$

Considering the function S as the function of the parameters a_0, a_1, a_2 and making mathematical transformations (differentiations), we have a system of equations:

$$\frac{\partial S}{\partial a_i} = 0, i = 0,1$$

Transforming this system, we have obtained a system of normal equations for the stage of seeds. Solving it we find necessary coefficients. On this basis we have obtained the

Table 4. The basic economic indicators of sunflower production with application of bio-preparations (the average for 2016-2018)

Fertilizers	Periods of aplyication	Tunca					LG 5580				
		Production costs, US dollar/ha	Product cost, US dollar/ha	Net profit, US dollar/ha	Product cost price, US dollar/ha	Relative level of profitability, %	Productio n costs, US dollar/ha	Product cost, US dollar/ha	Net profit, US dollar/ha	Product cost price, US dollar/ha	Relative level of profitability %
Control (clean water)		508.9	948.6	438.4	225.2	86	510.6	1179	668	181.7	131
Fitosporyn	Seeds	515.1	1007	492.3	214.6	96	520.7	1200	679.7	182.1	131
	Budding	535.5	1070	534.8	210.1	100	539.4	1406	866.7	161.0	161
Fito Help	Seeds	515.3	1020	504.6	212.1	98	520.1	1196	676.1	182.5	130
	Budding	514.4	1057	516.3	214.8	95	546.5	1423	876.4	161.2	160
Fitotsyd-R	Seeds	514.5	982.2	467.6	219.9	91	518.5	1221	702.9	178.1	136
	Budding	538.4	1003	464.7	225.2	86	543.4	1422	879.5	158.9	162
Fitosporyn / Ahrostymulin	Seeds	525.2	1049	524.1	210.0	100	527.6	1376	849	160.8	161
	Budding	557.0	1267	710.5	184.4	127	561.5	1532	970.4	153.8	173
Fitotsyd-R / Ahrostymulin	Seeds	524.5	1049	524.8	209.7	100	530.7	1439	908.9	154.7	171
	Budding	545.1	1124	579.7	203.4	106	550.8	1633	1081	141.6	196

function for Tunca and LG 5580 :

$У = 48.507 + 63.369x_1 - 0.0041x_2 - 0.005x_3$

$У = 117.977 + 77,83x_1 - 0.017x_2 + 6.84x_3$

The most complicated step is interpreting the equation, i.e. translating it from the language of statistics into the language of economics. The regression coefficient – the parameter a_0 is a reference point in the model on the diagram of the correlation field; the parameters a_1-a_3 show how the values of the dependent variable change on the average when the independent variable increases by the unit of its measurement. The more the value of the regression coefficient is, the more considerable impact this factor has on the dependent variable. The sign before the regression coefficient indicating to the character of the impact on the dependent variable has special importance.The coefficient of x_1 is equal to 77.83. It means that the dependent variable will increase by 77.83% when the productivity increases by 1%, the profitability will increase by 0.017% when the production costs per 1 t decrease by 1% and the profitability will increase by 6.84% when the selling price increases by 1%. Therefore it is necessary to check the adequacy of this model. The following variants are possible.

- This model is adequate on the whole on the basis of checking it by the F-test of Fisher, and all the regression coefficients are significant. Such a model can be used for making decisions and creating forecasts.
- The model is adequate by the F-test of Fisher, but some regression coefficients are insignificant. In this case the model is suitable for making some decisions, but it is not good for creating forecasts.
- The model is adequate by the F-test of Fisher, but all the regression coefficients are insignificant. Therefore the model is considered as totally inadequate.The coefficient of multiple correlation is 0.97, indicating that there is correlation of the dependent variable with the independent variables. But we cannot draw conclusions about the adequacy of the model on this basis.

The checking the adequacy of the model with testing the significance of each regression coefficient was done by means of Student's t-test:

$$t_p = \frac{|a_i|}{\sqrt{\sigma^2_{ai}}}, \pi e \sigma^2_{ai} = \frac{\sigma^2_y}{k}$$

The coefficient of the model will be considered as statistically significant if $t_p \geq t_{kp}$ =0.619.The calculated t_{pi} are equal to 2.107; 35.589; -0.222; -0.601 respectively, i.e. only a_1, a_2 meet the requirements of significance.By the F-test of Fisher we obtained F=45.12. Comparing it with the Table value of the Fisher-Snedecor distribution (F-distribution) F>F Table, where F Table=2.99 with the degree of probability of 95%. It proves that the model is adequate by the F-test of Fisher. The average approximation error ε =1.068%, though it should not exceed 12-15%. The coefficient of multiple correlation is rather high, the model is adequate on the whole on the basis of checking it by the F-test of Fisher, and all the regression coefficients are significant. The average error does not exceed the established norm. Therefore, such a model can be used for making decisions and plans or creating forecasts.

Table 5. Matrix of the pair correlation

Tunca	y	x_1	x_2	x_3
y	1	0.962	0.837	0.671
x_1	0.962	1	0.833	0.847
x_2	0.837	0.833	1	0.602
x_3	0.671	0.847	0.602	1
LG 5580	y	x_1	x_2	x_3
y	1	0.988	0.270	0.821
x_1	0.988	1	0.367	0.899
x_2	0.270	0.367	1	0.584
x_3	0.821	0.899	0.584	1

CONCLUSION

The main indicator of economic suitability of this or that measure is a net profit. Neither cost price, nor profitability, but a net profit determines the real difference between the product cost and the level of production costs. For three years of the field research this indicator reached the absolute maximum in the hybrid LG 5580 when the bio-fungicide Fitotsyd-r and the stimulator Ahrostymulin were applied at the stage of budding, and it made $1081. In this case the cost price was the least, $141.6, and the level of profitability was the highest –196%. The variant with the combination of Fitotsyd-r/Ahrostymulin also provided a positive result in the hybrid Tunca, but it yielded a bit to the combination of the preparations Fitosporyn/Ahrostymulin, and the net profit was $579.7, the cost price – $203.4 and the profitability, 106 %. On the whole this analysis makes it possible to receive evidence that additional costs, related to purchasing and applying fertilizers, are compensated by an increase in the yields.

REFERENCES

Adnan M, Islam W, Shabbir A, Khan KA, Ghramh HA, Huang Z, Chen H and Lu G 2019. Plant defense against fungal pathogens by antagonistic fungi with *Trichoderma* in focus. *Microbial Pathogenesis* **129**: 7-18.

Kour D, Rana KL, Yadav AN, Yadav N, Manish Kumar, Vinod Kumar, Vyas P, Dhaliwal HS and Saxena AK 2020. Microbial biofertilizers: Bioresources and eco-friendly technologies for agricultural and environmental sustainability. *Biocatalysis and*

Agricultural Biotechnology **23**: 1-11.

Domaratskiy EO, Bazaliy VV, Domaratskiy OO, Dobrovol'skiy AV, Kyrychenko NV and Kozlova OP 2018. Influence of mineral nutrition and combined growth regulating chemical on nutrient status of sunflower. *Indian Journal of Ecology* **45**(1): 126-129.

Domaratskiy Ye, Berdnikova O, Bazaliy V, Shcherbakov V, Gamayunova V, Larchenko O, Domaratskiy A and Boychuk I 2019. Dependence of winter wheat yielding capacity on mineral nutrition in irrigation conditions of southern Steppe of Ukraine. *Indian Journal of Ecology* **46**(3): 594-598.

Goswami M and Deka S 2020. Plant growth-promoting rhizobacteria-alleviators of abiotic stresses in soil: A review. *Pedosphere* **30**(1): 40-61.

Hanserud OS, Cherubini F, Ogaard AF, Müller DB and Brattebo H 2018. Choice of mineral fertilizer substitution principle strongly influences LCA environmental benefits of nutrient cycling in the agri-food system. *Science of The Total Environment* **615**: 219-227.

Jaspers P and Kangasjärvi J 2010. Reactive oxygen species in abiotic stress signaling. *Physiology Plant* **138**: 405-413.

Kumar A, Pathak AK and Guria Ch 2015. NPK-10:26:26 complex fertilizer assisted optimal cultivation of Dunaliella tertiolecta using response surface methodology and genetic algorithm. *Bioresource Technology* **194:** 117-129.

Moklyachuk L, Furdychko O, Pinchuk V, Mokliachuk O and Drag M 2019. Nitrogen balance of crop production in Ukraine. *Journal of Environmental Management* **246:** 860-867.

Rady MM 2012. A novel organo-mineral fertilizer can mitigate salinity stress effects for tomato production on reclaimed saline soil. *South African Journal of Botany* **81:** 8-14.

Rostami S and Azhdarpoor A 2019. The application of plant growth regulators to improve phytoremediation of contaminated soils: A review. *Chemosphere* **220**: 818-827

Siddiqi KS and Husen A 2017. Plant response to strigolactones: Current developments and emerging trends. *Applied Soil Ecology* **120**: 247-253

Small C and Degenhardt D 2018. Plant growth regulators for enhancing revegetation success in reclamation: A review. *Ecological Engineering* **118**: 43-51.

Whipps JM 1997. Developments in the biological control of soil-borne plant pathogens. *Advances in Botanical Research* **26**(C): 1-134.

Received 29 May, 2020; Accepted 26 August, 2020

Indian Journal of Ecology (2020) 47(3): 630-633

Manuscript Number: 3056
NAAS Rating: 4.96

INM in Rice Based Integrated Farming System Model for Food Security and Enhanced Productivity

B. Sudha, J. John, A.V. Meera and A. Sajeena

Integrated Farming System Research Station, Karamana
Thiruvananthapuram-695 002, India
E-mail: sudha.b@kau.in

Abstract: Agricultural production systems need to be tuned towards enhanced productivity for assuring food security. More important is that these systems should be based on resource conserving technologies like integrated nutrient management, for achieving sustainability. Integrated Farming System is a potential tool in realizing the goals of higher productivity and food security, based on resource recycling strategies. Research works carried out for five years suggest that the model is quite successful in diversifying crop production to achieve food security, ensures higher productivity and is quite eco-friendly in terms of on farm generation of nutrients, well in support of integrated nutrient management. On an average, the model could generate 190: 83: 90 kg of N, P and K nutrients, equivalent to 413 kg urea, 415 kg rock phosphate and 150 kg of muriate of potash. Substantial quantities of chemical fertilizers could thus be replaced. Diverse food products to the tune of 1436 kg rice, 1764 litres of milk, 1285 kg vegetables, 8605 eggs, 60 kg meat, 90 kg fish and 110 kg of mushroom could be generated annually from the model. The average productivity from this model was 10.22 t whereas rice crop alone yielded as low as 1.87 t. This model could be well adopted by lowland farmers of similar agro-climatic tracts for higher productivity and food security based on sustainable principles of crop nutrition.

Keywords: Rice, Productivity, Food security, INM, IFS

Agricultural scenario today urgently calls for a shift from resource degrading to resource conserving technologies, enhancement of crop productivity and maintenance of soil health for sustaining agriculture in long run. In this regard, crop nutrition, an important management aspect in agriculture needs special mention. Adhering to the use of chemical fertilizers alone for crop nutrition can deteriorate the soil organic carbon stocks and bring about a decline in fertility and productivity of soil. Besides, it pollutes the environment and hampers the soil ecosystem and biodiversity. Therefore, nutrient resources including chemical fertilizers, organic manures, crop residues, green manures and bio fertilizers need to be used in an integrated manner following a management technology which is practicable, economically viable, socially acceptable and ecologically sound. Since long, Integrated Nutrient Management (INM) has been well established as an excellent opportunity for sustainable soil health and crop productivity (FAO 2006)

Rice (*Oryza sativa* L.*)* is an important cereal crop grown across the world. As for rice in Kerala, cost of production is high mostly attributed to labour intensive nature of the crop and very high labour charges compared to other parts of the nation. The yields from the crop are moderate and the market price is not in proportion with the escalating production cost. Rice farming is thus turning a non-profitable venture and rice farmers are shifting towards other crops. However, rice continues to be the staple food of the state and the requirements are largely met from neighbouring states. An IF is a potential approach and powerful tool to meet the multiple objectives of enhanced productivity and food security. IFS aim at efficient resource recycling within the farm (Kumar et al 2012) for reducing costs and increasing farmer's income by integrating agriculture with various allied enterprises. These systems are often less risky on account of their diverse production. Important among all merits is the immense possibility for INM that IFS offers and hence the innumerable environmental benefits. Rice production if switched to IFS mode can ensure higher productivity, food security and assured returns and can encourage farmers continue with rice farming.

Integrated Farming System Research Station (IFSRS), functioning under Kerala Agricultural University at Thiruvananthapuram in Kerala, India is one among the network centers of All India Co-ordinated Research Project (AICRP) on Integrated Farming Systems, coordinated by Indian Institute of Farming Systems Research, Modipuram, India. The station has developed and validated integrated farming models matching to the major crops/cropping situations of Kerala. A successful rice based IFS model of 0.2 ha has been developed to suit the land area and other resources of marginal farmers of the State. Research results of four years suggest that the model is quite successful in

diversifying crop production to achieve food security, ensures higher productivity and is quite eco-friendly in terms of on farm generation of nutrients, well in support of INM.

MATERIAL AND METHODS

The experiment was carried out at the Integrated Farming System Research Station, Karamana, Thiruvananthapuram, Kerala, located at 8° 28'25"N Latitude and 76° 57'32"E Longitude. The soil type was riverine alluvium of sandy clay loam texture. The experimental site was lowland (5 m above mean sea level). The establishment of the IFS model was initiated during the year 2011-12. Components of the 0.2 ha model are detailed in Table 1.Medium duration (115 -120 days) rice variety Uma, released by KAU, having red grains and popular among rice farmers of the state was cultivated during the first and second crop seasons and in the third crop season, vegetables and green manures were raised in field. The allied enterprises included a dairy unit (1 cow and a calf) of crossbred nature (Jersey x Local). A pond of 2.5 m depth adjacent to the rice field was effectively utilized for fish cultivation (*Catla, Rohu, Mrigal* species). The dyke of the pond was utilized in raising vegetable crops. The fish were protected from birds by fixing nylon nets over the pond. This facility was also utilized in trailing climber vegetables over the pond, thereby effectively utilizing the available land. Another important component among allied enterprises was a duck unit which accommodated hundred egg purpose duck breeds (*Chara* and *Chempalli* species, indigenous to Kerala). Duck house was erected over the fish pond in effectively utilizing the vertical space. The droppings of duck directly went to fish pond and encouraged plankton growth which served as fish feed. A mushroom unit was part of this model and it effectively recycled a part of paddy straw generated in the model.

Observations on nutrients generated through bio recycling, fertilizer equivalent of generated nutrients, cost and energy saved on fertilizers, diverse production and system productivity expressed in terms of Rice Equivalent Yield (REY) were recorded. Nutrient generation was quantified based on the quantity of organic inputs produced for recycling multiplied with the content of respective plant nutrients. The energy equivalents of nutrients generated were further worked out based on the energy requirement for unit production of the plant nutrients as detailed by Chaudhary et al (2006). The yields from individual components of the system were separately worked out, gross income obtained from the system for each year was calculated and it was equated to Rice Equivalent Yield (REY) for respective years and compared with sole cropping of rice in an area of 0.2 ha. The diverse production from the model for the period under study were also quantified. These details are presented and discussed below.

RESULTS AND DISCUSSION

Nutrient generation: The stubbles of rice crop of both the seasons were incorporated into the field. The residues of maize raised as third crop were also recycled to the soil. On an average, 3025 kg of green manure daincha (containing 3.5% N) was incorporated in the rice field every year. Green manure crop was raised during the summer/third crop season and was soil incorporated by the onset of pre monsoon showers before the first crop season. During summer, the rice area was divided into three equal parts and daincha was raised in one third portions. The area under daincha crop was rotated every year so that the benefit of green manuring reached every inch of the paddy field, over the years. Crop residues generated from vegetables like okra grown during summer and as those obtained from the dyke

Table 1. Components of the rice based IFS model

Components	Net area (m^2)	Gross area (m^2)
First crop rice (medium duration var. Uma)	1500	1500
Second crop rice (medium duration var. Uma)	-	1500
Third season crops Vegetables (Okra) Fodder (Maize) Green Manure crop (Daincha)	-	1500
Fish - Catla, Rohu, Mrigal (Inclusive of pond and dyke area planted with vegetable crops - amaranthus, okra, brinjal, chilli, ash gourd, tomato and cowpea)	360	560
Mushroom unit	40	40
Duck house (Over the fish pond) egg purpose var. *Chara* and *Chempelli*	0	20
Cow unit : Cross bred (1+1)	100	100
Total	2000	5220

area of fish pond were composted and recycled in the system for crop nutrition. The organic outputs from dairy like cow dung, cow's urine and stall wash were quantified and recycled. Paddy straw obtained from the unit was used as dry fodder for cattle and substrate for mushroom production. Small quantities of paddy straw unfit for use as cattle feed due to mouldy growth especially collected during monsoon was composted and recycled. The nutrient rich silt that was excavated from the fish pond during summer season was utilized as organic manure for vegetable production in pond dyke. Duck droppings and fish excreta that were accumulated in the pond enriched the silt. All these nutrient sources were quantified and multiplied with respective nutrient contents and the nutrient generation in the model for different years of study were arrived (Table 2). On an average, the model could generate 190: 83: 90 kg of primary nutrients N, P and K equivalent to 413 kg urea, 415 kg rock phosphate and 150 kg of muriate of potash, respectively. The nutrient generation from the model is of substantial quantity and could substitute for a considerable portion of chemical fertilizers and is therefore instrumental in promoting INM. The energy and cost savings on chemical fertilizers achieved through plant nutrient generation (Table 3). Energy equivalent to 12054 Mega Joules could be saved and a cost reduction on fertilizers to the tune of Rs. 8980 per annum could be achieved in the model. Similar report on buildup of organic carbon stocks and nutrient recycling in soils has been documented by Babu et al (2016) who conducted long term INM trials under integrated farming.

Diverse production from the model: On an average, the system could generate diverse food products to the tune of 1436 kg rice, 1764 litres of milk, 1285 kg vegetables and 8605 eggs annually (Table 4). When compared to the annual requirement of a four member adult family under low cost diet management (Swaminathan 2010), the production is high allowing marketing of the surplus, offering possibilities of additional income. Apart from the above, meat and fish production (60 and 90 kg per year respectively) be achieved in the system. The ducks reared in the model started egg laying on attaining 6 months of age and remained productive almost till 3 years, with peak production usually around second year. On decline of productivity, these ducks were culled for meat. This explains the source of meat generation in the IFS model. Almost 700 numbers of fish reared in the pond (360m^2 inclusive of dyke area) contributed to fish production. On an average, 110 kg of mushrooms were also produced. Table 4 indicates that from sole cropping of rice in the same area, a production of 1040 kg of rice alone could be obtained. This definitely highlights the significance of IFS in diversifying production and ensuring food security.

Productivity of the system: System productivity equated in terms of Rice Equivalent Yield (REY) is depicted in Table 5. The average productivity of the IFS model over the years was 10. 22 t whereas sole crop of rice yielded as low as 1.87 t. The enhancement in productivity was 5.5 times higher in IFS compared to sole crop of rice. The improvement in crop productivity achieved in the system could be attributed to the soil restoring nutrient management techniques. Walia and

Table 2. On farm generation of major plant nutrients from 0.2 ha model (kg)

Nutrients (kg)	Period under study					
	2014-15	2015-16	2016-17	2017-18	2018-19	Average
Nitrogen	146	110	234	267	194	190
Phosphorus	43	43	108	133	88	83
Potassium	42	52	116	135	104	90

Table 3. Fertilizer and energy equivalent of nutrients generated, price equivalent of fertilizers saved

Year	Fertilizers (kg)			Energy equivalent of nutrients generated Mega joules)	Price equivalent of fertilizers saved (Rs.)
	Urea	Rock Phosphate	Muriate of Potash		
2014-15	318	215	70	4682	9606
2015-16	239	215	87	7482	4406
2016-17	509	540	194	16154	10190
2017-18	580	665	226	18539	12076
2018-19	420	440	174	13413	8620
Average	413	415	150	12054	8980

Table 4. Diverse food production (major items) from 0.2 ha model and rice equivalent yield (REY) of the model in comparison with sole crop of rice

Year	Rice (kg)	Milk (litres)	Vegetables (kg)	Eggs (nos)	Rice equivalent yield (kg / 0.2 ha)
2014-15	1704	2389	1171	11114	9.93
2015-16	1452	1828	1235	9546	8.51
2016-17	1286	2599	1764	7092	12.59
2017-18	1507	775	811	4411	8.86
2018-19	1231	1228	1442	10860	11.20
Average from IFS model	1436	1764	1285	8605	10.22
From sole crop of rice	1040	0	0	0	1.87
Annual requirement of a 4 member adult family as per diet plan under low management (Swaminathan 2010)	657	182.5	429	1096	-

Kaur (2013) observed that resource recycling is very effectively practiced in integrated farming and INM is well achieved in such systems contributing to sustained crop productivity. Kumar et al (2016) mentioned higher productivity from a sugarcane - ratoon cropping sequence by practicing INM. Sahu et al (2017) identified INM as one of the important approaches for sustainable crop production, attributed to improvement in soil quality, which could sustain crop production. This information clearly indicates the role of IFS in ensuring higher productivity from unit area of land thereby encouraging farmers to continue with their agricultural activities. Kumar et al (2018) could establish that multi component farming as in IFS can ensure substantial increase in productivity from agricultural systems all over India thereby contributing to food security of nation. Porpavai and Marimuthu (2018) reported considerable enhancement in productivity and profitability by way of integrating rice farming with allied enterprises like dairy, poultry and fish. Nutrient recycling contributed to considerable saving of chemical fertilizers and the soil was productively maintained after the experiment. Manures obtained from animal components served as organic inputs for INM.

CONCLUSION

The rice based integrated farming system model is highly successful in ensuring integrated nutrient management as well as in diversifying and enhancing production from unit area. The data suggests that diverse food production contributes to family nutrition and the surplus production beyond requirement could be marketed thereby enabling farmers to draw additional income. This model could be well adopted by lowland farmers of similar agro-climatic tracts for food security and higher productivity based on sustainable principles of crop nutrition.

Received 24 June, 2020; Accepted 19 August, 2020

ACKNOWLEDGEMENT

The financial and physical support provided by All India Coordinated Research Project on Integrated Farming Systems, ICAR and Kerala Agricultural University for the conducts of the experiment are duly acknowledged.

REFERENCES

Babu MV, Srihari NA, Reddy BS, Ravindrachary G and Rao CS 2016. Impact of long term integrated nutrient management on groundnut yield, soil properties and organic carbon stocks in scarce rainfall zone of Andhra Pradesh, India. *Indian Journal of Ecology* **43**(1): 452-454.

Chaudhary V, Gangwar B and Pandey D 2006. Auditing of energy use and output of different cropping systems in India. *Agricultural Engineering International: The CIGRE Journal* **8**: 01-13.

FAO 2006. Improving plant nutrient management for better farmer livelihoods, food security and environmental sustainability, pp.26-41. **In**: Y, Nino (ed), Proceedings of a *Regional workshop on plant nutrient management*, December 12-16, 2005, China Agricultural University, Beijing, China.

Kumar S, Bhatt BP, Dey A, Shivani Kumar U, Idris M and Mishra JS 2018. Integrated farming system in India: Current status, scope and future prospects in changing agricultural scenario. *Indian Journal of Agricultural Sciences* **88**(11): 1661-1675.

Kumar S, Singh S, Meena M and Dey SA 2012. Resource recycling and their management under integrated farming systems for lowlands of Bihar. *Indian Journal of Agricultural Sciences* **82**(6): 504-510.

Kumar R, Uppal S K and Walia SS 2016. Impact of integrated nutrient management strategies on productivity of plant and ratoon crops of sugarcane. *Indian Journal of Ecology* **43**(1): 415-419.

Porpavai S and Marimuthu R 2018. Development of integrated farming system model for marginal farmers of Cauvery delta zone. *Indian Journal of Ecology* **45**(1): 183-186.

Sahu G, Chatterjee N and Ghosh GK 2017. Integrated nutrient management in rice (*Oryza sativa*) in red and laterite soils of West Bengal. *Indian Journal of Ecology* **44**(3): 349-354.

Swaminathan M 2010. *Essentials of Food and Nutrition*. The Bangalore Printing and Publishing Company, Bangalore, India, 515p.

Walia SS and Kaur N 2013. Integrated farming systems-An eco-friendly approach for sustaining agriculture and environment: A review. *Greener Journal of Agronomy, Forestry and Horticulture* **1**(1): 001-111.

Indian Journal of Ecology (2020) 47(3): 634-637

Manuscript Number: 3057
NAAS Rating: 4.96

Effect of Integrated Nutrient Management on Nutrient Uptake by Lowland Cassava and Soil Physico-chemical Properties

A.P. Pooja and O.K. Swadija

Department of Agronomy, College of Agriculture
Thiruvananthapuram-695 522, India
E-mail: appoojaap@gmail.com

Abstract: An investigation was undertaken at College of Agriculture Vellayani, Thiruvananthapuram, Kerala during 2017-18 to study the effect of integrated nutrient management on nutrient uptake by lowland cassava and its effect on soil physico-chemical properties. The treatments consisted of three sources of organic manure (m_1 - FYM @ 12.5 t ha^{-1}, m_2 - FYM @ 6.25 t ha^{-1} + green manuring *in situ* and m_3 - poultry manure (PM) @ 2.5 t ha^{-1} + green manuring *in situ*), two levels of N (50 and 75 kg ha^{-1}) and two levels of P (25 and 50 kg P_2O_5 ha^{-1}) along with a uniform dose of 100 kg K_2O ha^{-1}. The 3 x 2 x 2 factorial experiment was laid out in randomized block design with three replications. The study revealed the superiority of the integrated nutrient management involving practice of green manuring *in situ* with cowpea, raised along with cassava for higher uptake of nutrients without depleting soil fertility. The application of PM @ 2.5 t ha^{-1} + green manuring *in situ* (m_3) + 75 : 25 : 100 kg NPK ha^{-1} registered the highest uptake of nutrients and tuber yield of cassava var. Vellayani Hraswa in lowlands with improvement in the physico-chemical properties of the soil after the experiment.

Keywords: Cassava, Lowland, Green manuring *in situ*, Uptake of nutrients, Soil fertility

Cassava (*Manihot esculenta* Crantz) belonging to the family Euphorbiaceae is the secondary staple food of Keralites. In the present scenario, short duration cassava varieties are being cultivated in lowlands where rice cultivation has been abandoned. Increasing cassava production for food diversification would be a way to achieve food security of our people. Among the short duration varieties of cassava, Vellayani Hraswa (5-6 months duration) is becoming popular due to its good cooking quality. According to Odedina et al (2012), crop and soil productivity can be sustained with the integration of different manures as a viable alternative to the single application of either manure or inorganic fertilizer for cassava. Scarcity of farmyard manure has necessitated studies on low cost soil fertility management practices for cassava like green manuring *in situ* which can add reduce the dose of FYM as well as N for the crop. Poultry manure is being commonly used by farmers in lowlands. In general, only smaller quantities of P is required for tuber crops. With this background, an investigation was undertaken at College of Agriculture, Vellayani, Thiruvananthapuram, Kerala to study the effect of integrated nutrient management involving different sources of organic manure and varying N and P levels on nutrient uptake and tuber yield of cassava in lowlands and physico-chemical properties of the soil after the experiment.

MATERIAL AND METHODS

The field experiment was conducted during September 2017 to February 2018 at Integrated Farming System Research Station, Karamana, Thiruvananthapuram, Kerala. The region has a humid tropical climate experiencing temperature of 24- 32°C and relative humidity of 86 per cent. A total of 90.2 cm rainfall has been received in 59 days during the cropping period. There was sufficient rainfall upto four months of the crop. Cassava var. Vellayani Hraswa released from College of Agriculture, Vellayani, Thiruvananthapuram, Kerala was used for the study. It has good cooking quality and contains 27.8 per cent starch and 53 mg kg^{-1} cyanogen (KAU 2016). It cannot tolerate drought and hence, it is suited to lowlands and rice fallows.

The treatments consisted of three sources of organic manure (M_1- FYM @ 12.5 t ha^{-1}, M_2- FYM @ 6.25 t ha^{-1} + green manuring *in situ* and M_3 - PM @ 2.5 t ha^{-1} + green manuring *in situ*), two levels of N (50 and 75 kg ha^{-1}) and two levels of P (25 and 50 kg P_2O_5 ha^{-1}) along with a uniform dose of 100 kg K_2O ha^{-1}. The experiment was laid out as 3 x 2 x 2 factorial experiment with three replications in randomized block design. Organic manures were applied at land preparation as per the treatments. Cassava var. Vellayani Hraswa was planted on ridges at a spacing of 90 cm x 90 cm after applying ½ N + full P + ½ K of the fertilizer dose as per treatments. Cowpea @ 30 kg ha^{-1} was sown on the two sides of the ridges in between cassava plants for green manuring *in situ* and was incorporated 50 DAP. Interculture, weeding and earthing up were done at 30, 50 and 70 DAP in all the plots along with top dressing (½ N + ½ K) for cassava at 50 DAP. Cassava was

harvested at six months after planting and treatment wise tuber yield was recorded.

Samples of stem, leaves and tuber collected for chemical analysis were dried separately in an air oven at 70 ± 5°C and ground to pass through 0.5 mm mesh. The N content of the samples was determined by modified micro Kjeldahl method (Jackson 1973). The P content was estimated calorimetrically (Jackson 1973) and K content by flame photometric method (Piper 1966). The total uptake of N, P, and K at harvest were calculated by multiplying the respective nutrient content in the stem, leaf and tuber and their corresponding dry weight. The uptake was expressed in kg ha^{-1}. Soil samples were taken from the experimental field area before and after the experiment. The composite sample from the experimental field before the experiment was analyzed for physical and chemical properties. After the experiment, composite samples were collected from each plot, air dried, powdered and passed through 2 mm sieve and analyzed for available N, P, and K status using the standard procedures (Table 1).

RESULTS AND DISCUSSION

Uptake of N, P and K by cassava var. Vellayani Hraswa, cultivated in lowland, varied significantly due to sources of organic manure (Table 2). Conspicuous variation in NPK uptake has been observed between plots in which FYM alone was applied and green manured plots. Green manured plots showed higher N, P and K uptake. Higher availability of nutrients due to decomposition of cowpea might have contributed to higher uptake of N, P and K in green manured plots. Among green manure treatments, the highest N, P and K uptake were recorded by PM @ 2.5 t ha^{-1} + green manuring *in situ*. Considering the effect on N, P and K uptake, Pamila (2003) observed that FYM could be substituted with PM for cassava var. Vellayani Hraswa as also observed in the present study. Levels of N significantly influenced the uptake of N, P and K while levels of P had significant influence only on N uptake (Table 2). Application of higher level of N (75 kg ha^{-1}) resulted in the highest N, P and K uptake. Similar results were reported by Pamila (2003). Application of 25 kg P_2O_5 ha^{-1} registered significantly higher N uptake. It could also be

Table 1. Physico- chemical properties of the soil of the experimental field prior to the study

Parameter	Value	Method
pH	5.2 (Strongly acidic)	pH meter with glass electrode (Jackson 1973)
Electrical conductivity (dS m^{-1})	0.19 (Safe)	Conductometry (Jackson 1973)
Organic carbon (%)	2.5 (High)	Wet oxidation method (Walkley and Black 1934)
Available N (kg ha^{-1})	249.91 (Medium)	Alkaline permanganate method (Subbiah and Asija 1956)
Available P (kg ha^{-1})	68.76 (High)	Bray's colorimetric method using ascorbic acid (Bray and Kurtz 1964)
Available K (kg ha^{-1})	257.56 (Medium)	Neutral normal ammonium acetate method (Hanway and Heidal, 1952)

Table 2. Effect of sources of organic manure and levels of N and P on nutrient uptake and yield of cassava var. Vellayani Hraswa in lowlands

Treatments	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})	Tuber yield (t ha^{-1})
Sources of organic manure (M)				
M_1 - FYM @ 12.5 t ha^{-1}	112.58	46.55	140.81	27.18
M_2 - FYM @ 6.25 t ha^{-1} + GM *in situ*	167.62	53.56	175.74	31.29
M_3 - PM @ 2.5 t ha^{-1}+ GM *in situ*	217.29	65.05	209.41	33.85
CD (p=0.05)	6.924	2.931	7.291	0.958
Levels of Nitrogen (N)				
N_1 - 50 kg ha^{-1}	150.08	49.74	160.90	29.33
N_2 - 75 kg ha^{-1}	181.57	60.37	189.74	32.21
CD (p=0.05)	5.659	2.393	5.953	0.782
Levels of Phosphorus (P)				
P_1 - 25 kg P_2O_5 ha^{-1}	170.36	55.60	174.11	31.05
P_2 - 50 kg P_2O_5 ha^{-1}	161.29	54.51	176.52	30.49
CD (p=0.05)	5.659	NS	NS	NS

inferred that application of 25 kg P_2O_5 is sufficient for higher P and K uptake. Mohankumar (2014) observed lower uptake of P compared to those of N and K. Reduction in yield due to skipping of P application has been reported (Essien 2009, Kim et al 2013). The ratio of removal of N, P and K by cassava in the present study, in general, was in the ratio 3:1:3 in agreement with the findings of Howeler (2017).

Tuber yield was significantly and positively correlated with N (r = 0.888), P (r = 0.877) and K (r = 0.665) uptake. As in the case of nutrient uptake, significant variation in tuber yield was noticed only due to the sources of organic manure and levels of N (Table 2). In the case of sources of organic manure, green manured plots registered higher tuber yield. Among green manuring treatments, the highest tuber yield of 33.85 t ha^{-1} was in PM @ 2.5 t ha^{-1} + green manuring *in situ* (m_3) followed by FYM @ 6.25 t ha^{-1} + green manuring *in situ*. The results suggested PM and green manuring *in situ* as alternatives to FYM for cassava cultivation for enhanced tuber yield. Pamila et al (2006) reported the highest tuber yield of cassava in lowlands with PM application compared to FYM. Significant increase in tuber yield was observed when N level was increased from 50 to 75 kg ha^{-1}. This is in conformity of the findings of Pamila (2003). Lower level of P (25 kg P_2O_5 ha^{-1}) resulted in higher tuber yields emphasizing low requirement of P for cassava. Similar to nutrient uptake, combined application of PM @ 2.5 t ha^{-1} + green manuring *in situ* + 75 kg N ha^{-1} + 25 kg P_2O_5 ha^{-1} recorded the highest tuber yield of 36.22 t ha^{-1} (Fig. 1).

Compared to the initial status (Table 1), post experiment soil analysis revealed an increase in soil pH, improvement in available N, considerable reduction in organic carbon and available K and a slight reduction in available P status (Table 3). Increase in soil pH due to addition of plant residues, cattle manure and PM in acid soil was also noticed by Naramabuye et al (2006). Significant variation in the physico-chemical properties of the soil after the experiment was observed due to sources of organic manure (Table 3). Green manured plots showed higher post-harvest soil fertility and availability of nutrients especially N which might be due to higher biological N fixation of cowpea and release of nutrients on decomposition of incorporated cowpea. Improvement in soil productivity by increasing the soil nutrient status by green manuring is widely reported. Among the sources of organic manure, PM @ 2.5 t ha^{-1} + green manuring *in situ* recorded significantly higher pH and organic carbon and available N, P and K status in the soil after the experiment. Levels of N and P had significant influence only on available P status in the soil. Higher P

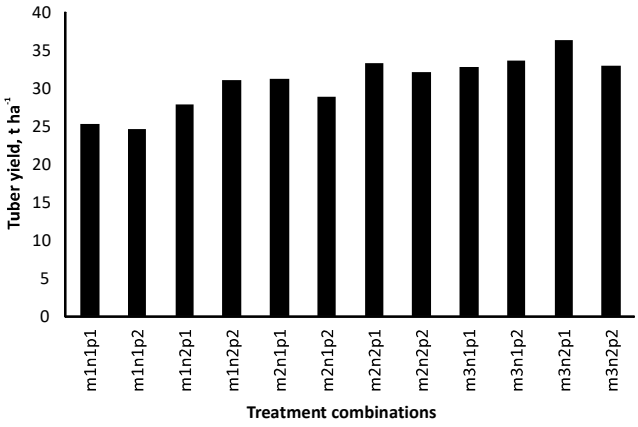


Fig. 1. Effect of treatment combinations on tuber yield (t ha^{-1})

Table 3. Effect of sources of organic manure and levels of N and P on physico-chemical properties of the soil after the experiment

Treatments	Soil pH	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Sources of organic manure (M)					
M_1	5.99	1.73	251.92	58.54	204.67
M_2	5.86	1.85	284.43	56.20	216.29
M_3	6.28	1.95	300.04	64.17	228.04
CD (p=0.05)	0.180	0.069	18.049	3.569	16.516
Levels of nitrogen (N)					
N_1	6.11	1.82	274.59	56.26	218.75
N_2	5.98	1.87	283.00	63.02	213.90
CD (p=0.05)	NS	NS	NS	2.918	NS
Levels of phosphorus (P)					
P_1	6.02	1.84	276.03	55.37	221.21
P_2	6.05	1.85	281.57	63.90	211.46
CD (p=0.05)	NS	NS	NS	2.918	NS

status was registered by 75 kg N ha^{-1}. The result of the effect of levels of N on nutrient uptake corroborated with the findings of Pamila (2003). Available P status increased when the level of P was increased from 25 to 50 kg P_2O_5 ha^{-1} which might be due to reduced P uptake at higher level of P.

CONCLUSION

The application of PM @ 2.5 t ha^{-1} + green manuring *in situ* (m_3) resulted in the highest N, P and K uptake and tuber yield. Significantly higher N, P and K uptake and tuber yield were registered by application of 75 kg N and 25 kg P_2O_5 ha^{-1} registered significantly higher N uptake and tuber yield. Compared to the initial status, an increase in soil pH and an improvement in available N status was observed after the experiment. However, considerable reduction in organic carbon and available K status and a slight reduction in available P status were noticed. Among the treatments, application of PM @ 2.5 t ha^{-1} + green manuring *in situ* + 75 : 25 : 100 kg NPK ha^{-1} registered the highest uptake of nutrients and tuber yield of cassava in lowlands with improvement in the physico-chemical properties of the soil after the experiment.

REFERENCES

Bray RH and Kurtz LT 1964. Determination of total, organic and available forms of phosphorus in soils. *Soil Science* **59**: 39-45.

Essien BV 2009. Influence of NPK fertilizer on cassava anthracnose disease (CAD). *Crop Science* **13**: 6-13.

Hanway JJ and Heidal H 1952. Soil analysis methods as used in Iowa State College Soil Testing Laboratory. *Iowa College Agricultural Bulletin* **57**: 1-13.

Received 15 May, 2020; Accepted 19 August, 2020

Howeler RH 2017. Nutrient sources and their application in cassava cultivation. Available: http://doi.org/10.19103/AS.2016.0014.35 [12 January 2018].

Jackson ML 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi, p. 991.

KAU (Kerala Agricultural University) 2016. *Package of Practices Recommendations: Crops* (15th Ed.). Kerala Agricultural University, Thrissur, Kerala, p.392.

Kim LO, Besar O and Aseri MP 2013. Crop residues types and placement methods on mineralization of soil organic matter. *Soil Microbiology* **48**: 1222-1228.

Mohankumar C R 2014. Cultural and manurial requirements of cassava. pp. 5-41. **In**: Mohankumar CR, Nair GM, George J, Ravindran CS and Ravi V. (eds), *Production Technology of Tuber crops.* ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala, India.

Naramabuye FX, Haynes and Richard J 2006. Effect of organic amendments on soil pH and Al solubility and use of laboratory indices to predict their liming effect. *Soil Sci*ence **171**(10): 754-763.

Odedina J, Ojeniyi S and Odedina S 2012. Integrated nutrient management for sustainable cassava production in south western Nigeria. *Archives Agronomy Soil Science* **58**(1): 1132-1140.

Pamila VR 2003. *Integrated nutrient management for short duration cassava in lowlands*. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, Kerala, India.

Pamila V, Swadija OK and Pushpakumari R 2006. Performance of short duration varieties of cassava in lowlands as influenced by different organic manures and nitrogen levels. *Journal of Root Crops* **32**(2): 171-174.

Piper CS 1966. *Soil and Plant Analysis*. University of Adelaide, Australia, p.368.

Subbiah BV and Asija GL 1956. Rapid procedure for estimation of available nitrogen in soils. *Current Science* **25**: 259-260.

Walkely A and Black JA 1934. An examination of the Degtijareff method for determining soil organic matter and a proposed modification of the chromic acid filtration method. *Soil Science* **37**: 93-101.

Indian Journal of Ecology (2020) 47(3): 638-644

Manuscript Number: 3058
NAAS Rating: 4.96

Water Erosion of the Slopes of Tayyar Drainage Basin in the Desert of Muthanna in Southern Iraq

Bashar F. Maaroof and Hashim H. Kareem

Department of Geography, Faculty of Basic Education, University of Misan
E-mail: basharmaaroof78@gmail.com

Abstract: This study examines the most important phenomenon of water erosion of Wadi Al-Tayyar basin, one of the seasonal valleys in the lower valley area of the south Iraqi desert, near the Iraqi-Saudi border. It is located in the southern part of Sawa lake, which has an area of 2522.921 km² and a 447.537 km perimeter. Among the most important natural factors that have been analyzed are those affecting the creation and formation of this phenomenon, such as the geological structure, slope system, climatic elements, water resources and natural plants. The rain proves to be partially inefficient when it comes to collision damage, due to the fact that the basin occurs in a semi-arid climate characterized by relatively low precipitation. There is a wide spread of plate tectonic erosion, especially in the area around the springs, due to the prevalence of relatively flat land among similar contouring sectors. This leads to the gathering of water in form of a shallow layer with a relatively large area. There is a noticeable variation in the number of water torrents between the basins, as the generally highest number found in the main Tayyar basin reached 645 torrents, whereas the lowest value was at the secondary Tayyar basins, being 79 ones. Another variation is that in the total length of the gullies within the drainage basin.

Keywords: Water erosion, Drainage basins, Geomorphological processes, Geographical Information System (GIS)

Water erosion is considered to be one of the essential and most significant processes in geomorphological studies, merely for its important effects on the shaping of the earth's surface (Kisic et al 2018). The intensity of water erosion varies from one part to another depending on the abundance of rain and the intensity of the rainstorm, the larger amount of rain, and the more water will be flowing on the surface of the drainage basin. These could be in form of sheet runoffs, rills, gullies, streams or rivers, thus eventually increasing erosion. Studying this phenomenon and determining its causes, factors of origin, intensity, and spatial distribution consequently leads to taking the necessary and effective steps to limit its damages. Huge attention has been devoted in terms of research in many countries around the world. Many earlier worker observed the study attempt the evaluation of parameters accuracy to determine erosion factor and calibrate appropriate model by investigating 14 stations in all around Iran for 23 years according to Wischmeier and Smith model for erosion (Sadeghi and Tavangar 2015). Morgan and Mnomezulu studied gully erosion of the valley slopes located in central Switzerland (Morgan and Mngomezulu 2003), while Dabek et al. (2014) have been studied and analysed water erosion processes of the mountain slopes in zklarska Poręba Forestry in Netherlands, Holze and et al (2015) studied water erosion in rather humid areas in selected locations in western United States and suggested a classification of erosion patterns for the region. In addition, (Al-Abdan, Raheem Hameed, Al-Samarrai 2008) studied the rain erosion of the slopes of the Hamrin hills in northern Iraq, using Geographic Information Systems (GIS), (Hasan 2000) examined the water erosion in the basin of the Darbendikumspan Valley northeast Erbil-Iraq, in terms of its drainage network. The current research aims to identify the most significant natural factors that evoked water erosion at Wadi Al-Tayyar basin in the desert of Muthanna in southern Iraq.

MATERIAL AND METHODS

The phenomenon of water erosion in Wadi Al-Tayyar basin was analyzed an interpretation of its main types, spatial patterns of spreading, formation factors, and essential geomorphological processes of influence. This is done by relying on geospatial data such as the digital elevation model (DEM) type (SRTM) with a resolution of 30 * 30m, issued by the US Department of Defense, and satellite imagery from the American satellite LANDSAT ETM + 8BANDS for the year 2013, with a distinctive accuracy of 30m, and topographic maps scale 1: 100,000 issued by the General Authority for Iraqi Survey and Geological Maps. Additional data sources were the hydrological scale 1/250000 issued by the Iraqi Geological Survey, and the data collected through the field study. These data were analyzed using the GIS and remote sensing software package (Arc GIS V.10.4.1 program) Earth GIS V.1.3, Global Mapper V.11, Surfer V.10, Google Earth Pro V.7.1, and SAS Planet V.16 to download high-resolution satellite imagery, after which a spatial database was created

for the research area. Topological analyses and spatial conformity of all layers were performed, after which the transition was made to the next stage of geomorphological analysis and interpretation of the studied phenomenon, using models that explain the interaction between the factors and the process itself, and its structuring and formation of different forms of water erosion and their spread patterns. So as to calculate the rain-erosion rates of Wadi Al-Tayyar basin, the modified Fournier Index (1977) (De Luis et al 2010) is used as an indicator in the form of a mathematical equation 1:

$$FI = (P)\,2 / P \ldots\ldots\ldots\ldots (1)$$

Where, (FI) stands for index, (P) 2 represent the monthly rain amount, (P) represents the annual total of rain. If the result is less than 50, then the drift intensity is weak. Whenever F exists within 50-500, this indicates that it has a moderate drift, and the ranges (500-1000) and (more than 1000) refer to a high drift and intensively high drift, respectively. To measure the intensity of the gully in the Wadi Al-Tayyar basin, an equation (2) introduced by (Bergsma 1983) was used to measure the intensity of the gullies in the river basins. It has been applied to the main Tayyar valley basin and secondary basins, after the number and length of gullies for the riverine network were measured. The area occupied by these gullies in each secondary basin was measured through the interpretation of high-resolution satellite visualizations, topographic maps and field data for the main and secondary basins, using the following equation:

$$AE = \sum Aw / A \times 100 \ldots\ldots\ldots\ldots (2)$$

Where:

AE: Average Gully Erosion

∑Aw: Total Gully lengths (km)

A: Area of Basin (km^2)

Study area: Wadi Al-Tayyar basin is located in the western parts of Al-Muthanna desert in southern Iraq. It is bordered by the north and northeast by the city of Samawah, to the east by the Wadi Abu Hadair basin, to the south by the Wadi al-Faraj basin and the Iraqi-Saudi border (Fig. 1). The basin extends between the latitude circle (30 15-31 15) and the longitude (44 07 - 45 05), and Wadi Al-Tayyar basin, one of the seasonal valleys in the Lower valley area of the south Iraqi desert, is located in the southern part of Sawa lake, which has an area of 2522.92 km² and a 447.537 km perimeter. The total basin length is 150km starting from its upper sources near the Iraqi-Saudi border and ending with its estuary in the southwestern parts of Sawa lake, as the height at the basin ranges between 20 and 170 m above sea level, running from the southwest towards the northeast (Fig. 2 and 3).

Various geological formations are found within the basin, differing in their properties and areas, such as wind sediments spread in the northern parts of the basin which result from wind erosion processes in the region (Fig. 4), and expand in form of sandy layers containing sand, silt and gypsum, having different depths from one place to another

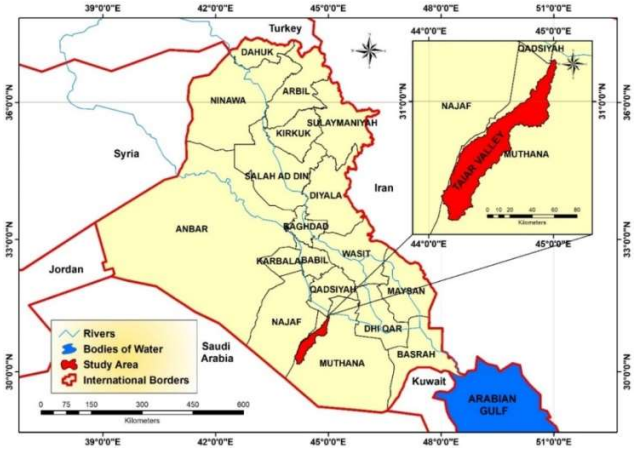


Fig. 1. Wadi Al-Tayyar in Iraq, the area of study

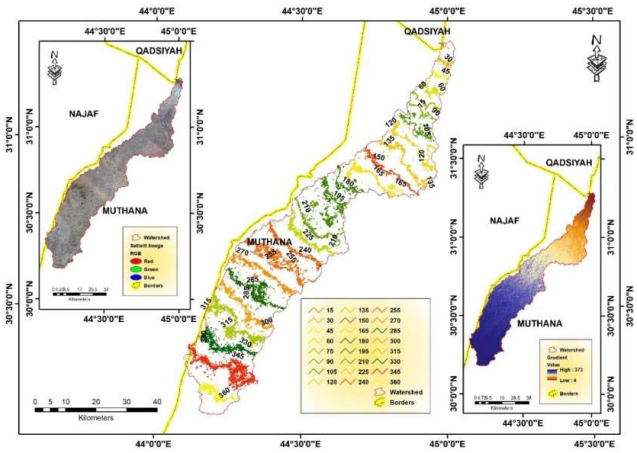


Fig. 2. Regression system of Wadi Al Tayyar Basin

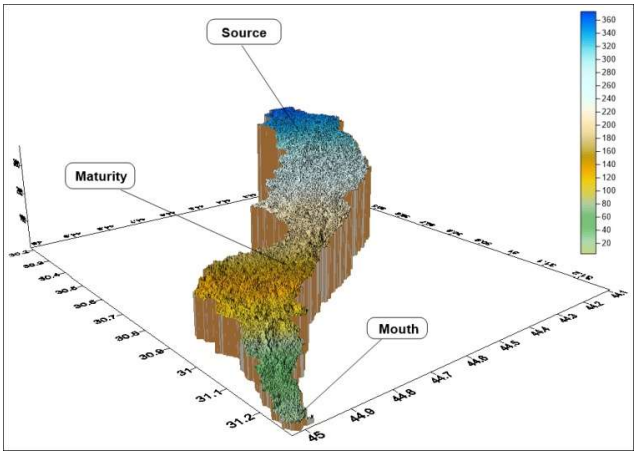


Fig. 3. Morphological model of Wadi Al-Tayyar basin

(Al-Jiburi and Al-Basrawi 2009). The middle Dammam formations are found in the central parts of the basin, as they are merely broken rocks and conglomerates covered by a layer of limestone, chalky and phosphate stones, while in the southern parts, the Jil formations date back to the lower Eocene era, formed within a shallow marine environment, and consist of chalky limestone and marl rocks that have coarse crystals nodes, the thickness of which is estimated between 60 - 88m (Jassim and Goff 2006).

Most climatic studies indicated that the basin is located within the semi-arid climate, and is characterized by a variation in temperatures, as temperatures increase during the summer months (June, July and August) and reach the highest rate in the month of July (35.7), and decrease during the winter season (December, January and February) and recorded the lowest values in January (11.2). The study area is also characterized by the seasonal annual and monthly rainfall, which falls over relatively long periods of time, and occurs as large rain showers that quickly turn into floods. It is restricted between October and May, with an annual average of 8.2 mm, without being distributed regularly over this period, as it was 4 mm in October, whereas, it reached 23.4 mm in January, and then began to decline from February onwards 11.7 mm (Table 1).

Wadi Al-Tayyar basin is one of the dry valleys within the lower valleys in southern Iraq, and it lacks a permanent source of flow due to its location within the semi-arid climate, as water does not run through it until after exposure to a rainstorm. The rainstorm provides it with the quantity of water that can flow into the main basin and the secondary basins (Fig. 5). The greater part of it is lost by evaporation, transpiration and infiltration into the ground. The lack and scattering of the natural plant has led to an increase in the effectiveness and activity of the different geomorphological processes (erosion, transport and sedimentation), as the slopes and edges of the valleys are in such a case highly susceptible to overall erosion processes (water and wind), landslides and rock falls (Zachar 2011). The quantity and quality of the natural plant in the basin varies from one place to another depending on natural conditions, and can generally be divided into two types. The first are annual plants, which are often small-sized herbaceous plants that grow in a particular season of the year when the conditions are appropriate, and they represent 75% of the total natural flora in the basin. Among the most important types are: Tephrosia, Bromus, Capparis and others species (Fig. 6). The second type is perennial plant that grows permanently and grows by various means such as by extending their long roots inside the soil or its small leaves that help to resist drought and reduce the transpiration rate, these plants regrow with the beginning of the rainy season, and represent 25% of the total natural cover of the basin. Examples of its most common types are Artemisia, Haloxylon, Rhanterium, Schanginia, Tamarix and others species.

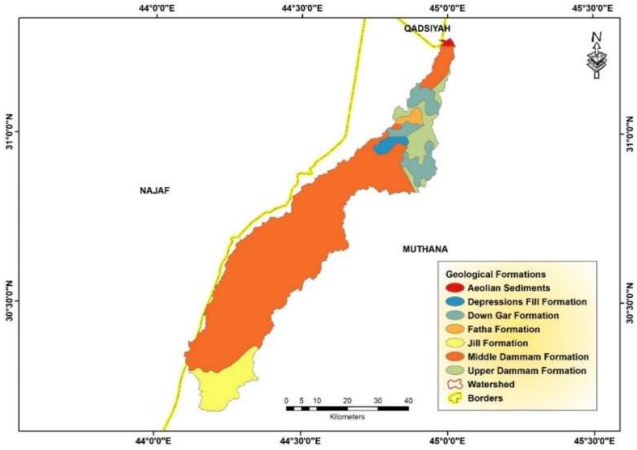


Fig. 4. Geological formations of Wadi Al-Tayyar basin

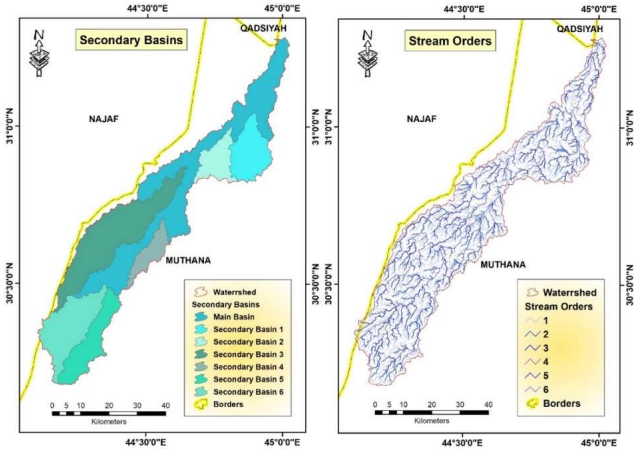


Fig. 5. The riverine levels and secondary basins of Wadi Al-Tayyar basin



Fig. 6. The natural plants in the central parts of the basin

RESULTS AND DISCUSSION

The results showed the highest value for rain erosion was recorded in January (5.58), and the lowest value in October (0.16), sheet erosion due to field observation was wide spread in the valley, rills erosion was diagnosed through the number of water torrents for the main Tayyar basin which reached 645 as the highest value in the main basin, while its number in secondary Tayyar basin 4 reached 79 torrents, which was the lowest value. As for the other secondary basins, these numbers varied were 168, 111 and 409 torrents for each of the secondary basins 1, 2 and 3, respectively (Table 3), and gullies erosion showed there is a clear variation in the rate of width and depth gullies, as some of them do not exceed 2 m in width and no more than 15 m in length, whereas others exceed these dimensions as shows (Table 4). The gullies may be subjected to extinction due to the process of refining materials and accumulating them, as these transported materials impede the development of the gullies.

Rain erosion: Rain erosion is caused by raindrops that turn into torrents after coming into contact with the surface of the earth, through their quantities, kinetic energy, frequency, and duration of their fall, causing uprooting and transfer of soil particles from one place to another (Annab 2006). The raindrops erode soil grains by separating and extracting them from the surface in order to be transferred over varying but relatively limited distances (Holz et al 2015). This process depends on a number of factors, especially the geological structure, as there is a clear variation in the types of geological formations in the basin where formations prevail wind sediments in the water of the basin. This spreads in form of sandy layers with different thicknesses, consisting of silt, sand, and gypsum, are more responsive to raindrops. The Middle Dammam parts also prevail in the central parts of the basin, usually in form of broken rocks and conglomerates, and are more solid than the previous one and thus less responsive to rain erosion processes. This is a clear indication that the variation in rock hardness directly affects the rain erosion rates (Fig. 7).

There is a clear effect of the slope factor, for the higher slope, the more likely for the raindrops to be affecting and vice versa. The climate factor also has an influential role by increasing the amount of rain and the duration of its fall, for floods that are exposed to large amounts of rain during a long period of time are more vulnerable to rain erosion. An additional factor is the size of raindrops, the greater the size, the more chance there is to increase rates of erosion (Al-Abdan et al 2008) As for the vegetation, it is no less important than any other factor mentioned here when it comes to its effect on this phenomenon. The higher area of vegetation, the lower rates of rain erosion and vice versa (Zhang et al 2004). After hitting the soil surface, raindrops scatter large quantities of soil particles in the air and move them to distances relatively farther from their original location, and a part of them sprinkles more than once, eventually leading to soil collapse. As well, the hydraulic impact of raindrops in this situation increases in quantity, which leads to a corresponding increase in the volume of water runoff on the slopes, consequently increasing the rates of water erosion (Al Abdan et al 2008). After applying modified Fournier Index (1977) equation (1), which is based on the monthly averages for Samawah climate station which is located in the northern part of the basin, the results indicated a weak vulnerability to rain erosion, which is naturally caused by the occurrence of the basin within the semi-dry climate, characterized by relatively little rainfall. There is a relative temporal variation in the rates of rain erosion, where the highest value was found in

Table 1. Rates of climatic elements according to the data of Samawah climatic station (1973-2014)

Month	Average temperature (ºC)	Rainfall (mm)
January	11.2	23.4
February	13.6	11.7
March	18	11.6
April	24.3	11
May	30.2	11
June	33.8	–
July	35.7	–
August	35.1	–
September	32.4	–
October	26.4	4
November	18.7	12.2
December	13.3	13.9

Table 2. Rain tendency according to the modified Fornair Index (1977) (Fornier-Arnoldos) for the monthly averages for the climate station in Samawah

Month	Average rainfall for Samawah Station (mm)	Average fornier index
October	4	0.16
November	12.2	1.51
December	13.9	1.97
January	23.4	5.58
February	11.7	1.39
March	11.6	1.73
April	11	1.23
May	11	1.23
Annual Total	98.8	14.8

Table 3. Basin spaces, numbers, total lengths, and rates required for the water slopes of Wadi Al-Tayyar basin and secondary basins

Name of Basin	Average rill erosion	Total length of rills	Number of Rills	Area
Secondary basin 1	68.48	156.1	168	227.9
Secondary basin 2	69.73	105.5	111	151.3
Secondary basin 3	70.88	406.8	409	574
Secondary basin 4	68.31	80.72	79	118.2
Secondary basin 5	74.88	178.3	166	238.1
Secondary basin 6	66.1	228.3	240	345.4
Main Tayyar Basin	70.59	612.7	645	868

January (5.58), and the lowest value was recorded in October (0.16) due to the seasonal variation of rainfall (Table 2).

Sheet erosion: This type of erosion has commonly been found within the area of study, due to the prevalence of the flat lands within the similar contouring sectors, which leads to the gathering of water in the form of a shallow layer with a relatively wide area (Mathur and Sundaramoorthy 2019), increases the slope regularity and the amount of falling rain and weak soil susceptibility (Hua Lu et al 2003). A slight slope here contributes to the movement of the floodwater, carrying with it fine rocky particles to relatively lower places. Due to the drought conditions experienced by the drainage basin, the water soon fades away, either through evaporation which is the prevailing situation, or through leakage in case of high porosity, leaving behind the sedimentary granules of various sizes (Ayyanna, et al 2019) (Fig. 8). Moreover, this type of erosion causes the loss of soil organic and nutrients, which leads to a continuous decline in soil productivity, and this inevitably leads to the emergence of other types of water erosion, because the lower layers of the soil are less resistant to erosion than the upper layers (Prosdocimi et al 2016).

Rills erosion: It is the second stage among the processes of water erosion, and begins after the end of the first stage (sheet erosion), where the water moves to steeper areas within the river basin. Sometimes it is rather difficult to distinguish between the two types of erosion due to the complex geological conditions on the one hand and practical simplicity of the hydration and its weakening on the other hand (Lu et al 2003). It is often possible to distinguish between them by noting that the second type begins with the formation of lower strips with a slight decrease, often not exceeding 70 cm. This type of water erosion is spread in the upper parts of the basin, that is, in the source area (Fig. 9 and 10), which is a result of severe water erosion operations in this region, due to the lack of vegetation and the effect of weathering operations, all contributing to the forming of rock debris and the disintegration of soil pellets ready for transportation and sedimentation. The degree of slope in this area increases the

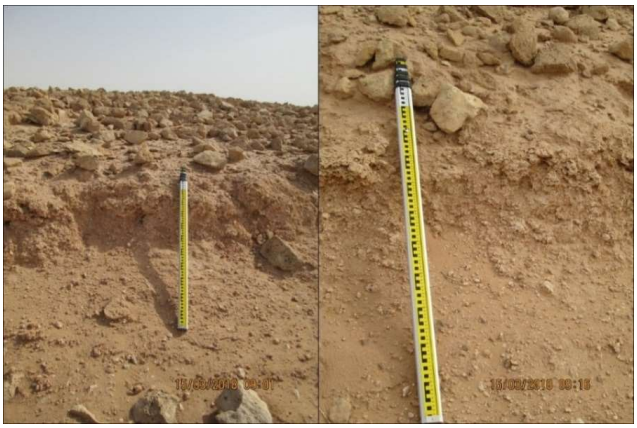


Fig. 7. Collisional rain erosion in the central parts of the basin

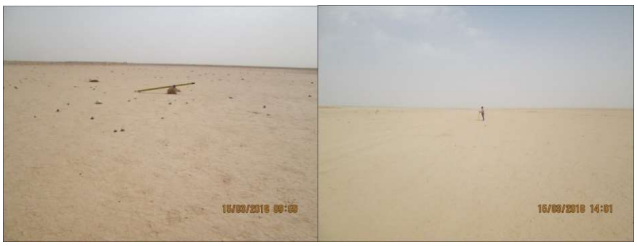


Fig. 8. Sheet erosion in the upper parts of the basin

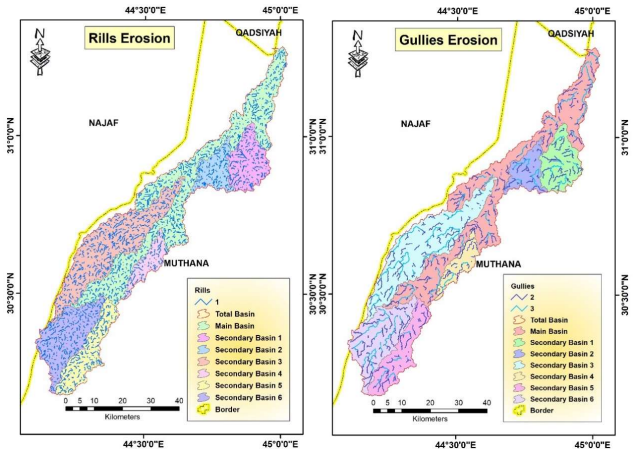


Fig. 9. Rill and gully erosion in the main and secondary basins of Wadi Al-Tayyar

effectiveness of these operations (Richard 2007). Through field reviews and numerical interpretation of remote sensitivity data, there is a clear variation in the numbers of water torrents. The number of water torrents for the main Tayyar basin reached 645, the highest value was in the main basin, while its number in Secondary Tayyar basin 4 reached 79 torrents, which is the lowest value. As for the other secondary basins, these numbers varied, were (168), (111) and (409) torrents for each of the secondary basins (1), (2) and (3), respectively (Table 3).

This is applicable to all secondary basins, as well as the factor of geological structure. Water torrents are located in areas of rocky weakness, which are often in the form of low depth striped areas. Additional factors of influence include climatic ones, especially rainfall and the natural vegetation. The secondary basins were characterized by a remarkable variation in the total lengths of water torrents, whereas in the main Tayyar valley it reached 612,715km, being the highest value. In secondary Tayyar basin 4, it reached 80,722km being, the lowest value (Table 3). The differences between the values of the other secondary Tayyar basins, was 74.875m / km^2 in secondary basin 5, while it reached 66.097 m / Km^2 in secondary basin 6, and the reason for this is due to the same factors mentioned above.

Gullies erosion: It is the third stage of water erosion, and it starts after the water rills meet with each other to form a higher river level and the resulting surfaces are called gullies and are more extensive and longer than the preceding (Rill). This naturally leads to an increase in the amount of runoff water in it, consequently increasing the erosion capacity that works to deepen and expand those gullies so that they are of clear dimensions (Fig. 9 and 11). The runoff water has a great ability to flood the rock fragments and conglomerates (Morgan and Mngomezulu 2003). The gullies are affected by the length and degree of slope, the area of the vegetation cover, the nature of the rock formation and the severity of precipitation, as these factors directly or indirectly control the emergence and composition of these gullies. There is a clear variation in the rate of width and depth, as some of them do not exceed 2 m in width and no more than 15 m in length, whereas others exceed these dimensions much. The gullies may be subjected to extinction due to the process of refining materials and accumulating them, as these transported materials impede the development of the gullies.

There is a clear variation in the total lengths of the gullies excavated in the drainage basin, which ranged between (64.998) km in secondary basin 4 to (404.984) km in the main basin (Table 4). This naturally reflects the activity of the processes of water erosion affected by the slope factor. The lower the slope, the longer the grooves increase, indicating that there is a negative correlation. In addition to the influence of the geological structure, the secondary basins were slightly different, for the secondary Tayyar basins 1, 2 and 3 reached 119,340, 70,744, and 273,007 km each, respectively. There is a variation in the rates of gullies at the level of all secondary basins, as it reached 58.110 m / km^2 for secondary basin 6, which is the highest value, and 44.152 m / km^2 for secondary basin 5, which is the lowest value. According to Bergsma's classification (Table 5), all the basins of the study area fall within the scope of very low erosion, and the reason for this is due to the region's suffering from the length of droughts that lead to less rainfall, and thus less water flow within the water network, resulting in weak water erosion and formation of gullies, in addition to the actual shortage that the basin suffers from a general relative decline. This led to a less concentrated flow, yet not preventing the creation and formation of gullies in the study area to a certain extent.

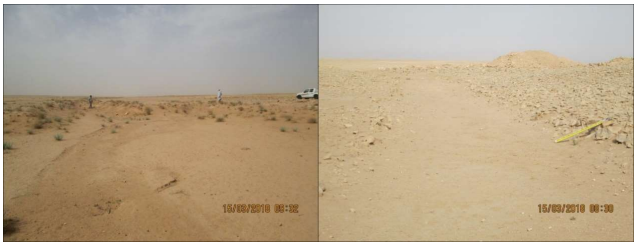


Fig. 10. Rill Erosion in the upper parts of the basin (upstream area)



Fig. 11. Gullies erosion in the central parts of Wadi al Tayyar Basin

Table 4. Total length and average gullies erosion rates for Wadi Al-Tayyar main and secondary basins

Name of basin	Average gullies erosion	Total length of gullies	Area
Secondary basin 1	52.357	119.340	227.934
Secondary basin 2	46.758	70.744	151.297
Secondary basin 3	47.565	273.007	573.957
Secondary basin 4	55.003	64.998	118.170
Secondary basin 5	44.152	105.132	238.112
Secondary basin 6	58.110	200.717	345.407
Main Tayyar basin	46.654	404.984	868.044

Table 5. Bergsma's classification of erosion degrees

Average erosion rate	Erosion level	Erosion degree
0 – 400	Very low	1
401 – 1000	Low	2
1001 – 1500	Average	3
1501 – 2600	High	4
2601 – 3700	Very high	5
3701 – 4700	Strong	6
More than 4700	Very strong	7

CONCLUSIONS

The results indicated that weak ability of rain to have an impact on the plates, resulting from the occurrence of the basin in the semi-arid climate, which is characterized by relatively low rainfall rate. There is a relative temporal variation in the rates of rain erosion in the basin. There is a widespread prevalence of sheet erosion, especially in the upstream area due to the rule of relatively flat lands within identical contouring sectors, which leads to the gathering of water in the form of a shallow layer with a relatively wide area. The secondary basins were distinguished by a clear variation in the total lengths of water rills, this naturally reflects the activity of water erosion affected by the slope factor, there is a variation in the rates of gullies erosion at the level of all secondary basins, according to Bergsma's classification, all the basins of the study area fall within the scope of the very low erosion rate.

ACKNOWLEDGMENTS

The financial, technical and scientific support provided by the University of Misan - Iraq, and the presidency and members of the scientific committee in the Department of Geography at Faculty of Basic Education - University of Misan is acknowledged.

REFERENCES

Al-Abdan RH and Al-Samarrai MJ 2008. Rain erosion of the slopes of the hills of hamrin hills using the Geographic Information Systems (GIS) Technology. *Journal of the College of Arts* **19**(81): 321-367.

Al-Jiburi HK and Al-Basrawi NH 2009. Sratigraphy of Iraqi Southern Desert. *Iraqi Bulltein Geology Ministry* (Special Issue: Geology of Iraqi Southern Desert): p 77-91.

Annab R 2006. *Estimating the Risk of Erosion in the Temgad Basin and Its Impact on the Madiyat Kidd Dam - A Multi-Criterion Approach*. University of Colonel Hajj Lakhdar, Algeria.

Ayyanna BS, Ra R and Harish BB 2019. Land use land cover change detection using remote sensing and geographic information system in canal command area, Karnataka. *Indian Journal of Ecology* **46**(4): 683-690.

Bergsma E 1983. Rainfall erosion surveys for conservation planning, *ITC Journal* **2**: 166-174.

Dabek P, Romuald Z, Bartłomiej Ć and Jakub S 2014. Analysis of water erosion processes using terrestrial laser scanning. *Acta Geodynamica et Geomaterialia* **11**(1): 45-52.

Hasan AA 2000. Water erosion in the Derbandexpan Valley, Northeast of Erbil, in the meaning of the draining network. *Journal of the College of Arts* **58**(6): 385-397.

Holz DJ, Karl WJ, Pamela JE and Jon ES 2015. Soil erosion in humid regions: A review. *Journal of Contemporary Water Research & Education* **154**(1): 48-59.

Jassim SZ and GoffJ C 2006. *Geology of Iraq, Dolin , Halvini 2732,Prague and Moravian Museum, Zelny trh 6, Czech Republic.*

Kisic I, Igor B, Zeljka Z and Darija B 2018. Effects of soil erosion by water under different tillage treatments on distribution of soil chemical parameters. *Soil and Water Research* **13**(1): 36-43.

Lu H, Moran CJ and Prosser MR 2003. Predicting sheetwash and rill erosion over the Australian continent. *Australian Journal of Soil Research* **41**(6): 1037-1062.

De Luis M, González-Hidalgo JC and Longares LA 2010. Is rainfall erosivity increasing in the mediterranean Iberian Peninsula? *Land Degradation and Development* **21**(2): 139-144.

Morgan RPC and Mngomezulu D 2003. Threshold conditions for initiation of valley-side gullies in the middle veld of Swaziland. *Catena* **50**(2-4): 401-414.

Mathur Manish and Sundaramoorthy S 2018. Evaluation of degradation assessment studies: Attributes applicable to various geographical regions. *Indian Journal of Ecology* **46**(4): 714-721.

Prosdocimi M, Cerdà A and Tarolli P 2016. Soil water erosion on mediterranean vineyards: A Review. *Catena* **141**: 1-21.

Richard JH 2007. *Fundamentals Of Geomorphology*. Taylor & Francis, UK.

Sadeghi SH and Shahla T 2015. Development of stational models for estimation of rainfall erosivity factor in different timescales. *Natural Hazards* **77**(1): 429-443.

Zachar Dušan 2011. *Soil Erosion*. Elsevier, Netherland.

Zhang B, Yan Sheng Y and Zepp H 2004. Effect of vegetation restoration on soil and water erosion and nutrient losses of a severely eroded clayey plinthudult in southeastern China. *Catena* **57**(1): 77-90.

Received 12 June, 2020; Accepted 19 August, 2020

Indian Journal of Ecology (2020) 47(3): 645-649

Manuscript Number: 3059
NAAS Rating: 4.96

Daily Gauge-Discharge Estimation using ANN and Wavelet-ANN Models for Muri Station, Jharkhand

Anuradha Kumari, Manish Kumar*, Abhishek Kumar[1] and Anupam Amitabh[2]

Department of SWCE, G.B.P.U.A.&T., Pantnagar-263 145, India
[1] Indian Agricultural Research Institute (ICAR-IARI), Pusa, New Delhi-110 012, India
[2]Dr. Rajendra Prasad Central Agricultural University, Bihar-848 125, India
**E-mail: manishcae2k11@gmail.com*

Abstract: The artificial neural networks (ANNs) and wavelet-based artificial neural networks (WANN) models were considered for time series modeling of daily discharge for Muri site situated at Subernrekha river basin of Jharkhand. The observed daily time series for gauge and discharge data from 2009 to 2013 were used for simulation of input and output data in which 70% of data were used for train the model while 30% were used for test the model. The input for gauge discharge modeling was selected from different combinations made from lagging the Gauge and Discharge data by using the gamma test. The best input combination with least gamma value was used as input for both the models. The correlation coefficient (r) and mean square error (MSE, cumec) was adopted to evaluate the model's performance. For the best WANN model, the value for 'r' and MSE was 0.9667 and 0.000206 respectively. For the best ANN model, the value for 'r' and MSE is 0.94892 and 0.001960 respectively. Based on the comparison of both algorithms, the WANN model has superior performance than the ANN model in estimating daily discharge.

Keywords: Gamma test, ANN, Wavelet ANN, Muri, Correlation coefficient, MSE

Accurate estimation and prediction of river flow for both short and long terms is essential to various activities in hydrological and water resources management, such as monitoring pollutant load, calculating sediment transport, controlling flood and drought, determining environmental flows, power generation, reservoir operation, and agricultural irrigation. Sufficient flow in a river not only guarantees socio-economic development but also maintain a healthy river system. River flows, like many other natural processes, are governed by dynamical and nonlinear physical mechanisms or systems that have various independent variables, primarily precipitation, temperature, evaporation, water use for socio-economic growth, river channel seepage, as well as forest vegetation coverage and soil characteristics in the catchment. A variety of methods have been developed to predict the flow of a river, including time series methods (linear and nonlinear), conceptual models, physical models, artificial neural network (ANN) models, and models integrating two or more of these approaches. ANN's employ in estimation and prediction of suspended sediment has recently been worked out (Agarwal et al 2005, Cigizoglu and Alp 2006). The simulation of an ANN model to estimate and predict SSC in rivers, achieved by training the ANN model to extrapolate several stream data collected from reliable sources (Nagy et al 2002, Kumar et al 2016, Kumari et al 2018). An ANN model employed to simulate runoff and sediment yield in Nagwan watershed in India (Raghuwanshi et al 2006). Seven-year data was used for simulation in which a five-year data set was employed for training while the two-year data set was considered for testing the model. Using the above training data set linear regression-based daily and weekly runoff and suspended sediment yield prediction models were also developed and were tested using the testing data set. ANN models performed better than the linear regression models in predicting both runoff and sediment yield on a daily and weekly simulation scale. Integrating artificial neural network (ANN) with wavelet transform to reinforce its modeling performance is not a very recent approach. However, there are many ways in combining these two methods. The early study using wavelet neural networks (WANNs) is on hydrology carried out by (Coulibaly et al 2000). Neural network was used to forecast annual discharge. The authors analyzed sea-level pressure and various meteorological data in Iceland in time-frequency resolution with the continuous wavelet transform to correlate those with discharge data and obtained better results compared to Fourier transform-based classical time-frequency methods. The main purpose of this paper was to develop a WANN hybrid modeling approach to predict daily discharge for Muri station of the Subernrekha river basin, Jharkhand as a case study.

MATERIAL AND METHODS

Study area and data collection: Muri is a census town in the

Ranchi district in the Indian state of Jharkhand and is located on the bank of Subarnarekha River and the study area lies on latitude 23°22'37.46" N and longitude 85°51'47.62"E. The hydrological data, gauge (m) and discharge (cumec) was collected from portal www.india-wris.nrsc.gov.in for five years (2009-2013) from June to September and discharge were taken for analysis. The total data was divided into two sets: (i) training data set consists of 70% of total data which was used for development of the model and rest 30% of total data was used for testing to check the prediction capability of models used in the study. The time-series graphical representation of total available data sets of gauge and discharge versus time shown in Figure 1.

Statistical analysis: The statistical analysis of gauge (m) and discharge (cumec) of all data, training, and testing sets which includes various statistical parameters like mean, median, minimum and maximum value, standard deviation, C.V. and skewness. These statistical parameters show the variability of data over the entire time series. When dividing the data set into training and testing subsets, it is necessary to cross-validate the data have same statistical population. Because of high skewness coefficient, there has been a considerable negative effect on ANN performance. Therefore, skewness coefficients are low for both calibration and validation sets for the given station and this is appropriate for simulation of given data sets. The standard deviation values for the datasets show that values are farther from zero means variability in data is more and hence variation of data from mean value is more.

Artificial neural network: Among the applied neural networks (i.e. Multilayer Perceptron Neural Network, MLNN), the feed-forward neural networks (FFNN) with backpropagation algorithm were used as network type (Malik et al 2018, Adamala et al 2019). Input, hidden and output layers are the main parts of this type of neural network. The neurons in each layer are connected through a link which is mathematically represented by weight in the network. This weight is the measure of the connection between the two nodes and are changed in different steps of learning to minimize a chosen error function which is generally mean squared error (MSE) and ultimately to make the network applicable to any unknown sample. The conventional, the hyperbolic tangent sigmoid transfer function was used to calculate a layer's output from its net input.

Wavelet transform: The study used discrete wavelet transform (DWT) for data decomposition because continuous wavelet transform (CWT) calculates wavelet coefficients at every possible scale, which is time-consuming and also produces abundant data. DWT decompose the input data and preprocessed before analysis. In contrast,

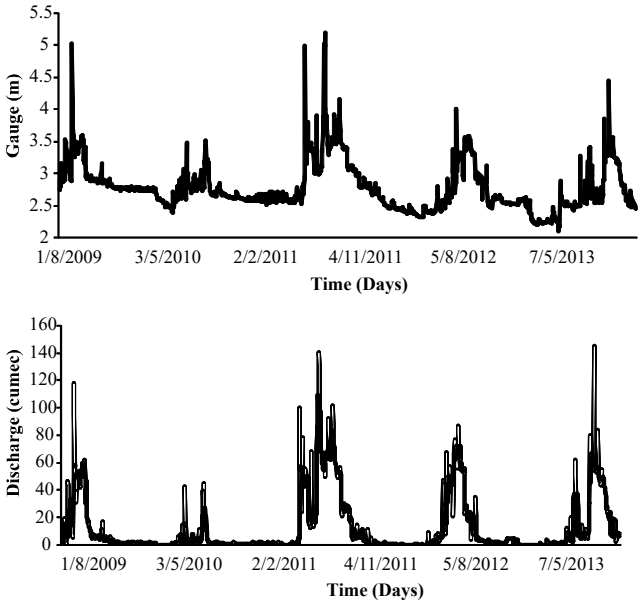


Fig. 1. Time series plot of gauge and discharge (5 years) for Muri Site, Jharkhand

DWT is more efficient for analysis because it limits the scaling factor and shifting factor of the basic wavelet function to only discrete values, while the analysis accuracy is retained. DWT has been particularly used as a computational technique for extracting information about non-stationary signals in recent years (Daubechies 1990, Kim et al 2006).

The original discrete-time series $C_0(t)$ can be resolved by Haar à trous decomposition algorithm (Wang and Ding, 2003) as:

$$C_r(t) = \Sigma_{(l=0)}^{\wedge(+\infty)} h(l)\, Cr_{-1}(t+2^r) \quad (r = 1, 2, 3, \ldots..,n) \quad \ldots(1)$$

$$W_r(t) = C_{r-1}(t) - C_r(t) \quad (r = 1, 2, 3, \ldots, n) \ldots (2)$$

in which, h(l) is the discrete low pass filter, $C_r(t)$ and $W_r(t)$ ($r = 1, 2, 3, \ldots.$) are scale coefficient (background information) and wavelet coefficient (detailed information) at resolution level respectively.

Murtagh et al (2004) used non decimated haar algorithm which is exactly same as the Haar-à trous algorithm, except that the low pass filter h(l) (1/16, 1/4, 3/8, 1/4,1/16) , is replaced by simpler filter (1/2, 1/2) and named it as Haar à trous algorithm.

Accordingly, on substituting, h (l) = {(½; l = -1@ ½; (l=0)} in Eqn (1), it becomes to,

$$C_r(t) = \Sigma_{(l=0)}^{\wedge(+\infty)} h(l)\, Cr_{-1}(t+2^r) + 1/2\, C_{r-1}(t) \quad \ldots(3)$$

Or

$$C_r(t) = ½\, [C_{r-1}(t) + C_{r-1}(t-2^r)] \quad \ldots (4)$$

Let the original (zero resolution level) discrete data sets of rainfall of the daily events is represented by $C_0(p, t)$, using Eqn. (3) the scale coefficients and wavelet coefficients [$C_r(p, t)$, $W_r(p, t)$], for original rainfall discrete time series $C_0(p, t)$ were resolved as,

$C_r(p, t) = 1/2 [C_{r-1}(p, t) + C_{r-1}(p, t-2^r)]$ (r = 1, 2, 3, ….,n) (5)

$W_r(p, t) = C_{r-1}(p, t) - C_r(p, t)$ (r = 1, 2, 3, …,n) (6)

It is possible to reconstruct the original hydrological time series in term of sub-time series of wavelet and scale coefficient $\{W_1(t), W_2(t), W_3(t)\ldots\ldots W_r(t), C_1(t), C_2(t),\ldots C_r(t)\}$. The wavelet reconstruction of the original time series, in term of obtained coefficients, is given by (Wang and Ding, 2003) as;

$C_0(t) = C_r(t) + \Sigma_(p=0)\hat{}(r) W_p(t)$ …(7)

Eqn. (7) provides a reconstruction formula for original time series, called as Haar-à trous reconstructing algorithm. It is clear from the equation (6) that except the scale coefficient $C_r(t)$, r represents resolution level, other scale coefficients, i.e $C_1(t)$, $C_2(t)\ldots\ldots C_r(t)$ does not have any significance in original data. That is for r = 3, the obtained sub time series coefficients for observed time series will comprise the time series of $[\{W_1(t)\},\{W_2(t)\},\{W_3(t)\},\{C_3(t)\}]$ and for r = 4, the obtained sub-time series coefficient will comprise the time series of $[\{W_1(t)\},\{W_2(t)\},\{W_3(t)\},\{W_4(t)\},\{C_4(t)\}]$ for the development of the model.

Gamma test: To estimate the minimum standard error between each input-output dataset with continuous nonlinear model's gamma test was used.

$Y = A\Delta + \Gamma$…(8)

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

Model development: The daily discharge data was predicted with the help of various combinations of two days lag gauge data (G_t, G_{t-1}, and G_{t-2}) and with two days lag discharge (Q_{t-1}, and Q_{t-2}) for the study area and current-day discharge (Q_t) considered as output. In designing all mathematical and artificial intelligence modeling, the selection of an appropriate combination of input parameters is the most sensible phase. The best input combination for the model development was selected based on gamma test in which least gamma value assigns best input combination.

Table 2. Gamma test of various combinations of input variables

Input parameters	Gamma Test Statistics			
	Gamma (r)	SE	V_{ratio}	Mask
G_t, G_{t-1}, G_{t-2}, Q_{t-1}, Q_{t-2}	0.0037226	0.00036057	0.014891	11111
All- Q_{t-2}	0.0040817	0.00047318	0.016327	11110
All- Q_{t-1}	0.0049757	0.0005757	0.0019903	11101
All- G_{t-2}	0.0045762	0.00071172	0.018305	11011
All- G_{t-1}	0.0046843	0.00042677	0.018737	10111
All- G_t	0.025081	0.002576	0.10032	01111

The value of various input combinations of different parameters like gamma value, standard error (SE), and V_{ratio} which was computed using Wingamma software (Table 2). The best input combination was used for modeling. Two model artificial neural networks (ANN) and wavelet-based artificial neural network (WANN) was developed for predicting daily discharge modeling (Rafiq et al 2015). Their performance evaluation of the above two models was evaluated by two indices using correlation coefficient (r) and mean square error (MSE). The equation for correlation coefficient (r) and mean square error (MSE) is given in the equation

$r = \Sigma_(i=1)\hat{}n [(Q"_{oi}"-(Q)'_o')(Q"_{pi}"-(Q)'_p')]/(\sqrt{}\Sigma_(i=1\hat{}n [(Q"_{oi}"-(Q)"_o")\hat{}2)(\sqrt{}\Sigma_(i=1\hat{}n [(Q"_{pi}"-(Q)"_p")\hat{}2$

Where Q_{oi} and Q_{pi} is the observed and simulated discharge values (Q_t) for i^{th} dataset. *N* is the total number of observations while $Q"_o"$ and $Q"_p"$ is the mean of observed and simulated ($Q_{t)}$ values, respectively.

RESULTS AND DISCUSSION

The combination (G_t, G_{t-1}, G_{t-2}, Q_{t-1}, Q_{t-2})has least value of gamma, standard error, and variance ratio i.e. 0.0037226, 0.00036057 and 0.014891 respectively were selected as input for the models. The results for the ANN and WANN are provided details of performance indices of various models obtained in WANN and ANN (Table 3).

Table 1. Statistics analysis for training, testing and all data set

Statistical parameter	Training data		Testing data		All data	
	G (m)	Q (cumec)	G (m)	Q (cumec)	G (m)	Q (cumec)
Mean	2.8166	11.876	2.698	15.016	2.778	12.818
Median	2.740	1.804	2.59	3.987	2.680	2.061
Minimum	2.32	0.0	2.10	0.0	2.10	0.0
Maximum	5.2	140.0	4. 44	145.0	5.20	145.0
Std. Dev.	0.3649	21.336	0.3675	22. 446	0.370	21.716
C.V.	0.1295	1.796	0.136	1. 494	0.133	1.694
Skewness	1.8883	2.3098	1.202	1.936	1.611	2.182

Model Performance

Artificial Neural Network (ANN): Based on the models performed, four models were obtained in ANN which were 5-1-1, 5-4-1, 5-8-1, and 5- 12-1. The three sections represent inputs, a hidden layer with neurons and output. The value of the correlation coefficient for varies from 0.94377 to 0.95704 for training data set and for testing data set the value of the correlation coefficient varied from 0.92744 to 0.94892 for testing dataset. Meanwhile, other performance evaluation, mean square error (MSE) for training data set varied from 0.00180 to 0.00206 and that for testing dataset was varied from 0.001960 to 0.002150. The based on the results of performance evaluation of various models obtained for ANN, the model 5-12-1 structured model performed better than others. Since, the value of correlation coefficient (r) and mean square error (MSE) for testing datasets were obtained 0.94892 and 0.001960 respectively. (Fig. 2 and 3) that the model consistently underestimated or overestimated the high amount of observed discharge. The regression equation obtained for observed and predicted daily discharge was y = 0.9237x - 0.3353 and R^2 was obtained 0.9043.

Wavelet Artificial Neural Network (WANN): Based on model performed, there were four models developed for WANN analysis namely 20-1-1, 20-4-1, 20-8-1, and 20-12-1. Due to the decomposition of input data by wavelet algorithm, the number of input data was increased to 20. Therefore, the structure 20-8-1 reveals that 20 represents numbers of input for the model, 8 represents number of neurons in hidden layer and 1 represents output of the model. The results showed that the value of correlation coefficient varies from 0.9684 to 0.9761 for training data set. Thus for testing data set, the value of correlation coefficient varies from 0.9398 to 0.9667. Meanwhile, the value for mean square error (MSE, g/l) for training data set varied from 0.00095 to 0.00117, and that for testing dataset was varies from 0.000206 to 0.026410. The results of performance evaluation of various models obtained for WANN, the model 20-8-1 structured model performed better than others. Since the value of correlation coefficient (r) and mean square error (MSE) for testing dataset was obtained 0.9667 and 0.000206 respectively (Fig. 4 and 5). The model consistently underestimated or overestimated the high amount of observed discharge. The regression equation obtained for observed and predicted daily discharge was y = 1.0115x + 0.7997 and R^2 was obtained $R^2 = 0.9549$.

Comparison of WANN and ANN models: Based on performance evaluation indices i.e. correlation coefficient and mean square error obtained for best model of both ANN and WANN model, the WANN model predicted more comparable than the ANN model (Table 3). Since, the value

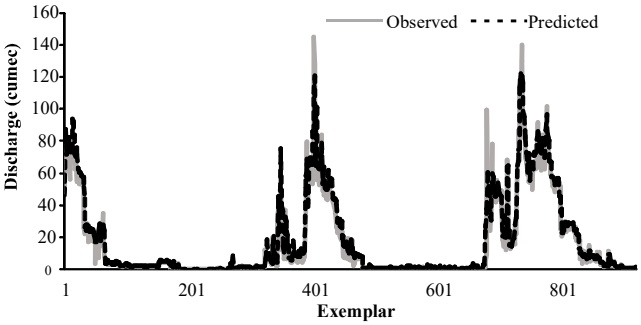


Fig. 2. Time series plot of observed and predicted discharge (cumec)

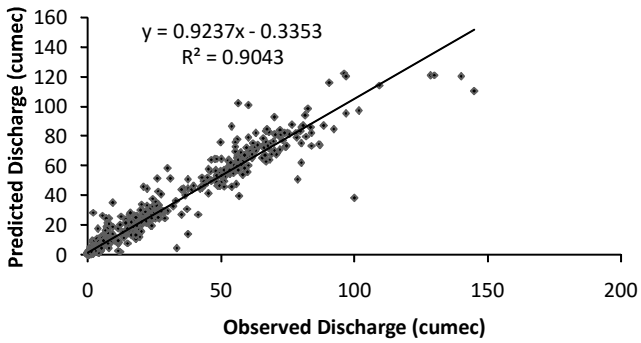


Fig. 3. Scatter plot for observed and predicted discharge (cumec)

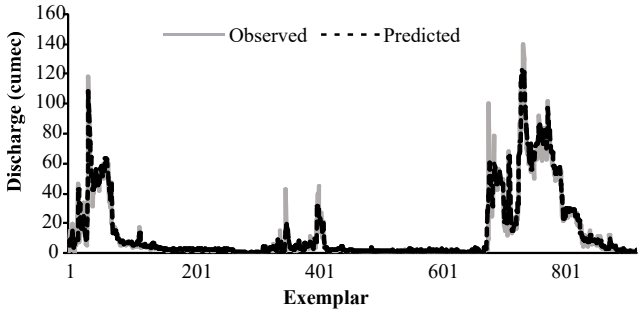


Fig. 4. Time series plot of observed and predicted discharge (cumec)

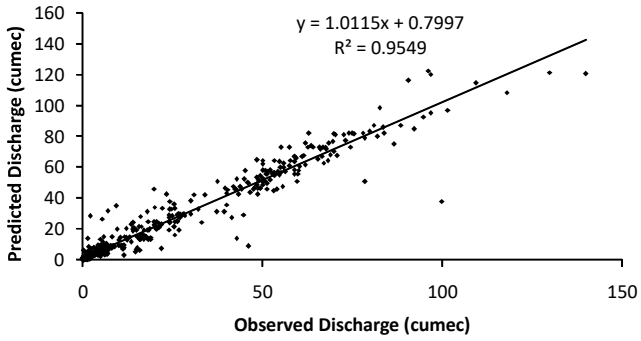


Fig. 5. Scatter plot for observed and predicted discharge (cumec)

Table 3. Correlation coefficient (r) and MSE in daily discharge prediction

Model	Training		Testing	
	r	MSE	r	MSE
Wavelet				
20-1-1	0.9684	0.00117	0.9660	0.001413
20-4-1	0.9707	0.00108	0.9607	0.001353
20-8-1	0.9761	0.00098	0.9667	0.000206
20-12-1	0.9751	0.00095	0.9398	0.026410
ANN				
5-1-1	0.94377	0.00206	0.94860	0.002150
5-4-1	0.95704	0.00158	0.92744	0.003161
5-8-1	0.95432	0.00180	0.94820	0.002395
5-12-1	0.95018	0.00183	0.94892	0.001960

for correlation coefficient (r) lies in the range 0.9398 to 0.9667, meanwhile, the value of MSE lies in the range 0.000206 to 0.026410 for WANN model. The value for correlation coefficient (r) lie in the range 0.92744 to 0.94892, meanwhile, the values of MSE lie in the range 0.001960 to 0.002150 for ANN model. The WANN models performed better than ANN model on the basis performance evaluation. The advantage of the WANN model over ANN is that the input data are pre-processed using wavelet analysis to eliminate noise. Therefore, it is clear that WANN predicted better than ANN model.

CONCLUSIONS

In this present study, there was an endeavor to estimate accurate gauge-discharge modeling for Muri site within Subernrekha river basin, Jharkhand using two algorithms i.e. ANN and WANN. The observed daily time series for gauge and discharge data from 2009 to 2013 were used for simulation of input and output data in which 70% of data were used for train the model while 30% were used for test the model. The input for gauge discharge modeling was selected from different combination made from lagging the Gauge and Discharge data by using gamma test. The correlation coefficient (r) and mean square error (MSE, cumec) was adopted to evaluate the model's performance. Based on the comparison of both algorithms, the results indicated that WANN model has superior performance than ANN model in estimating daily discharge.

Received 31 May, 2020; Accepted 12 August, 2020

REFERENCES

Adamala S, Babu BH and Gangaiah B 2019. Modelling dissolved oxygen concentration using artificial neural networks. *Indian Journal of Ecology* **46**(3): 455.

Agarwal A, Singh RD, Mishra SK and Bhunya PK 2005. ANN-based sediment yield models for Vamsadhara river basin (India). *Water Sa* **31**(1): 85-100.

Cigizoglu HK and Alp M 2006. Generalized regression neural network in modelling river sediment yield. *Advances in Engineering Software* **37**(2): 63-68.

Coulibaly P, Anctil F, Rasmussen P and Bobée B 2000. A recurrent neural networks approach using indices of low-frequency climatic variability to forecast regional annual runoff. *Hydrological Processes* **14**(15): 2755-2777.

Daubechies I 1990. The wavelet transforms, time-frequency localization and signal analysis. *IEEE transactions on information theory* **36**(5): 961-1005.

Kim CK, Kwak IS, Cha EY and Chon TS 2006. Implementation of wavelets and artificial neural networks to detection of toxic response behavior of chironomids (Chironomidae: Diptera) for water quality monitoring. *Ecological Modelling* **195**(1-2): 61-71.

Kumar SP and Mazumdar D 2016. Application of artificial neural network for modeling rice pest and natural enemy for Nadia District of West Bengal. *Indian Journal of Ecology* **43**(2): 449-454.

Kumari P, Kumar P and Singh PV 2018. Rainfall-runoff modelling using artificial neural network and adaptive neuro-fuzzy inference system. *Indian Journal of Ecology* **45**(2): 281-285.

Malik A, Kumar A and Rai P 2018. Weekly pan-evaporation simulation using MLP, CANFIS, MLR and climate-based models at Pantnagar. *Indian Journal of Ecology* **45**(2): 292-298.

Murtagh F, Starck JL and Renaud O 2004. On neuro-wavelet modeling. *Decision Support Systems* **37**(4): 475-484.

Nagy HM, Watanabe KAND and Hirano M 2002. Prediction of sediment load concentration in rivers using artificial neural network model. *Journal of Hydraulic Engineering* **128**(6): 588-595.

Rafiq A, Makroo HA and Hazarika MK 2015. MATLAB Toolbox for mathematical modelling of drying kinetics of tomato. *Indian Journal of Ecology* **42**(2): 444-448.

Raghuwanshi NS, Singh R and Reddy LS 2006. Runoff and sediment yield modeling using artificial neural networks: Upper Siwane River, India. *Journal of Hydrologic Engineering* **11**(1): 71-79.

Wang W and Ding J 2003. Wavelet network model and its application to the prediction of hydrology. *Nature and Science* **1**(1): 67-71.

Indian Journal of Ecology (2020) 47(3): 650-654

Manuscript Number: 3060
NAAS Rating: 4.96

Annotated Checklist of Brachyuran Crabs of Karwar Mangroves, West Coast of Karnataka, India

Pradnya D. Bandekar and V.S. Kakati

Department of Studies in Marine Biology
Karnatak University Post Graduate Centre, Kodibag, Karwar-581 303, India
E-mail: pradnyakumari07@gmail.com

Abstract: The brachyuran crab fauna from six stations of Kali estuary mangroves, Karwar was surveyed during 2019-2020. All 30 species of brachyuran crabs belonging to 24 genera representing 8 families were recorded; crabs belonging to the family Grapsidae, Ocypodidae, Portunidae is the most dominant group represented by a total of 21 species. Out of these, three species are considered as commercial crabs and they are *Scylla serrata*, *Thalamita crenata*, *Charybdis annulata*. Scylla species like *Scylla serrata*, *S. tranquebarica* are caught in large quantities from Karwar mangroves; their checklist and distributions are given.

***Keywords*:** Brachyura, Decapods, Mangrove, Kali estuary, Karwar

The mangrove crabs are those that live among mangroves. These brachyuran crabs form very conspicuous, colorful and bio-ecologically very important faunal constituents in estuarine forests, and belongs to different species and families. The Indian mangroves are endowed with a rich fauna of edible crustaceans, the dominant genera being Scylla, Sesarma and Uca. The mud crabs (Scylla sp.) constitute up to 80% of the macro faunal biomass. The mangrove ecosystem provides nursery and breeding ground for most of the marine and estuarine fin and shell fishes (Satheeshkumar et al 2009). The crabs play a significant role in detritus formation, nutrients recycling and in the overall dynamics of the ecosystems, together with annelids and nematodes living in the sediment (Funde et al 2009). Degradation of mangrove leaf litter by crabs, particularly sesarmids play a major link between primary and secondary producers (Khan et al 2005). The mangrove crabs are omnivorous and their diet particularly depends on mangrove leaves; they prefer the leaves of Rhizophora and Avicennia (Soundarapandian et al 2008). Brachyuran crabs comprise of approximately 6793 species worldwide and due to their great abundance, they are considered as one of the most relevant groups of marine benthos (Nag et al 2008), both in terms of biomass and community structure. Crabs are good food for marine, brackish life as well as to human beings as a good protein source (Sarvannan et al 2008) and important part of food chain. The mangrove crabs have been well studied over the years. The reports for 19 different species of brachyuran crabs were identified from the mangrove forest area of Gulf of Kuchh (Trivedi et al 2012). The brachyuran crab fauna of Saurastra coast is also studied well and 25 species of brachyuran crabs have been reported (Trivedi et al 2013). The 14 crabs of Muthupettai mangroves of south east coast have been reported (Maharajan et al 2015). The fifteen mangrove crabs of Karwar reported (Bandekar et al 2011) are good sources of information. The association of brachyuran crabs with mangrove flora, and their behavior, feeding and ecology are of great interest to biologist (Raut et al 2005). The crabs play a significant role in the food chain. The present study is to document and distribution of brachyuran crabs from Karwar Mangroves, Karnataka, India.

MATERIAL AND METHODS

Sites and sample collection: The present study carried out from 6 mangrove sites of Karwar located in Kali estuary. The mangrove area lies within the margins of latitude 14.8387 longitude 74.1205 in the Kali estuary spreading around 12km stretch (Fig. 1).

The brachyuran crabs collected during January 2019 - January 2020 were collected by hand picking using forceps and plastic container; burrowing intertidal crabs were collected by digging the sandy soil. The quadrant methods (1 m^2) also followed to collect crabs from sandy muddy and vegetation area. Mangrove tree climbing crabs also collected. Brachyuran crabs were preserved using 10% formalin and identified up to species level using the taxonomic keys of (Kakati 1980, Sethuramalingam and Khan 1991, Systema Brachyuroum Part I Ng et al 2008) WORMS (World Register of Marine Species), Marine Species Identification Portal, National Institute of Oceanography, Marine Biodiversity Database of India and Marine Species Identification Portal also used to identify mangrove flora.

RESULTS AND DISCUSSION

Of the 15 species of mangroves reported from

Karnataka as many as 13 species are present in this region. Most abundant mangroves are *Avicennia* (3 species), *Bruguiera* (2 species), *Rhizophora* (2 species), *Sonneratia* (2 species) and one species of *Aegiceras*, *Excoecaria*, *Lumnitzera* and *Kandelia* (Nayak and Bhandary 2010) (Table 4). Among these *Rhizophora apiculata, Avicennia officinalis, Sonneratia alba and Excoecaria agallocha* are the dominant species. All the 13 species of mangrove were recorded from Devbag and Mavinhole creek. *Avicennia marina, Acanthus ilicifolius, Sonneratia alba, S. caseolaris,* Rhizophora spp. were dominant in Sunkeri mangrove forest (Table 4). The 30 species of crabs were identified and they belong to 24 genera of 8 families (Table 2). The crabs belonging to the 3 families Grapsidae, Ocypodidae and Portunidae were the dominant forms. Grapsidae family showed rich diversity followed by Ocypodidae, Portunidae and Xanthidae family from all the study sites (Table 3).

Sediment was predominantly sandy at Devbag with high salinity; this area is closer to estuarine mouth. Devbag and estuarine mouth recorded totally 29 and 21 species of crabs. The species of Ocypoda were dominant in Devbag station. *Scopimera proxima, Pseudograpsus elongatus, Philyra malefactrix* and *Neorhynchoplax demeloi* were restricted towards the estuarine mouth. Sunkeri and Hankon represented 17 and 12 species of crabs respectively. The species like *Varuna litterata* and *Pseudosesarma edwardsi* were recorded in Hankon in low saline area. *Uca* and *Dotilla* sp. were found abundantly in all the seasons. Non-mangrove crabs like *Grapsus albolineatus, Ocypode cordimonas, O.ceratopthalmus, Ozius rugulosus, Philyra malefactrix, Ashtoret lunaris, Portunus pelagicus, Portunus sanguinolentus, Charybdis annulata, Plagusia squamosa* were found in Devbag area.

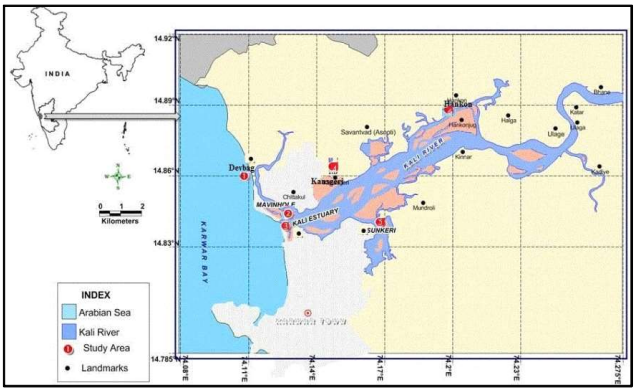


Fig. 1. Map showing the locations of the mangroves area in (Kali estuary) Karwar Coast

Mangrove environment supports diversified biota based on a variety of habitat, abundance sunlight and nutrient run off from the land. 38 species of brachyuran crabs in both natural Pitchavaram and artificially developed mangroves of Vellar estuary which has an area of 1,200 ha (18 species of Grapsidae and 7 species of Ocypodidae at Pitchavaram mangroves; while 8 species of Grapsidae and 3 species of Ocypodidae at Vellar mangroves) were reported by Khan et al (2005). Fifteen species of brachyuran crabs from mangroves at Pondicherry were recorded by Satheeshkumar et al (2011), Saravanakumar et al (2007) reported 13 species of brachyuran crabs in the arid zone mangroves off Gulf of Kachh. Systematic studies on the brachyuran crabs of Pondicherry coast are poorly known. In the present study 30 species of brachyuran crabs (10 non-mangrove crabs and occasionally found crabs) were recorded at Kali estuarine mangroves of Karwar coast.

In the earlier records from the same area 21 brachyuran crabs were reported (Kakati 1980) and 15 species recorded by Bandekar et al (2011). There is seasonal fluctuation in the population density of crabs and *Uca annulepis,* Sesarmid crabs caught during monsoon, *Scylla serrata, Scylla tranquebarica*, *Thalamita crenata,* during post monsoon. *Charybdis annulata, Portunus pelagicus, Portunus saguinolentus* mostly observed near Devbag and estuarine mouth region. The high brachyuran crab diversity and the presence of a number of species in this region suggest that mangrove ecosystem in Karwar is not much disturbed, needs to be conserved. The maintenance of the undisturbed areas should be a basic objective for the management and represents a more constant brachyuran crab diversity and highest abundance and sustains the production of commercial important species such as *Scylla serrata,*

Table 1. Details of study locations

Sampling sites	Mangrove zonations	Locations (coordinates)	Extent (hectare)	Substratum
Devbag (Mangrove/marine)	Rhizophora zone	14° 50'41"N,70° 07'18" E	2.5	Sandy
Mavinhole	Sonneratia and Avicennia zone	14° 50'39"N,74° 07"44"E	10.5	Sandy silty
Kodibag (estuarine mouth)	Sonneratia and Rhizophora zone	14°50'20.7"N,74°07'42.6"E	1.00	Silty, clay, sandy
Kansageri	Rhizophora zone	14°51'28"N,74° 09'08"E	2.6	Silty, clay
Sunkeri	Sonneratia and Rhizophora zone	14° 50'18" N, 74° 10'03" E	18.5	Sand, silt, clay
Hankon	Rhizophora zone	14° 52'53"N,74° 10'47" E	8.0	Sandy, clay

Table 2. Checklist of estuarine brachyuran crabs of Kali estuary (+=Present) (-=Absent)

Species and families	Stations					
	1	2	3	4	5	6
Leucosiidae						
Philyra malefactrix (Kemp 1915)	+	+	+	-	-	-
Matutidae						
Ashtoret lunaris (Forskal 1775)	+	-	-	-	-	-
Hymenosomatidae						
Neorhynchoplax demeloi (Kemp1917)	+	+	+	-	-	-
Portunidae						
Scylla serrata (Foraskal 1775)	+	+	+	+	+	+
S. tranquebarica (Fabricius 1798)	+	+	+	+	+	-
Thalamita crenata (Ruppell 1830)	+	+	+	+		
Portunus sanguinolentus (Herbst 1783)	+	-	+	-	-	-
P. (Portunus) pelagicus (Linnaeus 1758)	+	-	+	-	-	-
Charybdis (Charybdis) annulata (Fabricius 1798)	+	-	+	-	-	-
Xanthidae						
Epixanthus frontalis (H. Milne Edwards 1834)	-	-	-	+	-	-
Eurycarcinus orientalis (A. Milne Edwards 1867)	+	+	+	+	+	-
Ozius rugulosus (Stimpson 1858)	+	-	+	-	+	-
Pinnotheridae						
Viridotheres gracilis (Burger 1895)	+	+	+	+	+	+
Ocypodidae						
Uca (Celuca) lacteal annulipes (H. Milne Edwards)	+	+	+	+	+	+
U. (Gelasimum) vocans hesperiae (Crane 1975)	+	+	+	+	+	+
U. (Tubuca) dussumieri(H.Milne Edwards 1852)	+	+	+	+	+	+
Macrophthalmus (Macrophthalmus) Parvimanus (Guerin 1839)	+	+	+	+	+	+
M. (Macrophthalmus) brevis (Herbst 1804)	+	+	+	+	+	+
*Scopimera proxima (*Kemp 1919)	+	+	+	+	-	-
Dotilla myctiroides (H. Milne Edwards	+	+	+	+	+	-
Ocypode cordimanus (Latreille 1818)	+	+	+	-	-	-
O. ceratophthalmus (Pallas	+	+	+	-	-	-
Grapsidae						
Grapsus albolineatus (Latrelli 1812)	+	-	-	-	-	-
Metopograpsus latifrons (White 1847)	+	+	+	+	-	-
M. messor (Forskal 1775)	+	+	+	+	+	+
Varuna litterata (Fabricius 1798)	+	+	+	+	+	+
*Pseudograpsus elongatus (*A. Milne Edwards 1873)	-	+	+	-	-	-
P. intermedius (Chhapgar 1957)	-	-	-	+	+	-
Parasesarma plicatum (Latreille 1803)	+	+	+	+	+	+
Clistocoelomalanatum (Alcock 1900)	+	+	+	+	+	+
Pseudosesarma edwardsi (de Man 1888)	+	+	+	+	+	+
Plagusia squamosa (Lamark 1790)	+	-	-	-	-	-
Total	29	21	24	21	16	12

Table 4. Distribution of mangrove species along Kali estuarine study site (+=Present) (-=Absent)

Mangrove species	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Family: Rhizophoraceae						
Rhizophora mucronata (Lamark)	+	+	+	+	+	+
R. apiculata (Blume)	+	+	+	+	+	+
Bruguiera cylindrica (L.) Blume	+	+	-	-	-	-
B. gymnorrhiza (L.) Lamark	+	+	-	+	-	-
Kandelia candel (L.) Druce	+	+	-	+	+	+
Family: Avicenniaceae						
Avicennia marina (Forsk.) Vierh	+	+	+	+	+	+
A. officinalis (Linn.)	+	+	+	+	+	+
A. alba (Blume)	+	+	+	-	-	-
Family: Sonneratiaceae						
Sonneratia caseolaris (L.) Engler	+	+	+	+	-	+
S. alba (Smith)	+	+	+	+	+	-
Family: Acanthaceae						
Acanthus ilicifolius (L.)	+	+	-	+	+	+
Family: Combretaceae						
Lumnitzera racemosa (Willd)	+	+	-	+	-	-
Family: Euphorbiaceae						
Excoecaria agallocha (Linn.)	+	+	-	+	+	+
Family: Myrsinaceae						
Aegiceras corniculatum (L.) Blanco	+	+	-	+	+	-

Table 3. Family-wise genus and species of brachyuran crabs in Karwar mangroves

Family	Number of genera	Number of species
Grapside	8	10
Ocypodidae	5	9
Portunidae	4	6
Xanthidae	3	3
Leucosiidae	1	1
Matutidae	1	1
Hymenosomatidae	1	1
Pinnotheridae	1	1

Thalamita crenata, S. tranquebarica, Portunus pelagicus, and *P. sanguinolentus.* The present annotated checklist of mangrove brachyuran crab species are the baseline data intended to guide systematic work in this area.

CONCLUSION

The mangrove forests are known as nursery ground and high productive area of coastal ecosystem. Crabs play a major role in mangrove ecosystem. The present study focused on the 30 species of brachyuran crabs, with 14 mangrove flora. The thick mangrove forest of Karwar supports the great diversity of brachyuran crabs. Grapsidae, Ocypodiade and Portunidae are the dominant crab families among mangrove crabs.

REFERENCES

Bandekar PD and Kakati VS 2011. Biodiversity of crabs in Karwar mangrove environment West Coast of India. *Recent Research in Science and Technology* ***3***(4): 01-05.3

Funde AB, Naik SD, Mohite SA 2009. Contribution to the biology of the mud crab *Scylla serrata* of Ratnagiri Maharastra. *Aquaculture* **10**(1): 73-79.

Kakati VS 1980. *Crabs of Kawar*. Ph. D. thesis, Karnatak University, Dharwad.

Khan SA, Raffi SM and Lyla PS 2005. Brachyuran crab diversity in natural (Pitchavaram) and artificially developed mangroves (Vellar estuary). *Current Science* **88**(8): 1316-1324.

Maharajan A, Ganapiriya V, Shanmugavel K 2015. Brachyuran crab diversity in Muthupettai mangroves on southwest coast of Tamil nadu. *International Journal of Fisheries and Aquatic Studies* **2**(5): 30-31.

Nayak VN and Bhandary JM 2010. *A field guide to the mangroves of the Kali estuary, Uttar Kannada, Booklet*. Published by Karnataka Forest Department Karwar Division, Karwar.

Ng PK, Guinot LD and Davie PJF 2008. Systema Brachyurorum: Part I. An annotated checklist of extant brachyuran crabs of the world. *Raffles Bulletin of Zoology* **17**(1): 1-286.

Raut DT, Ganesh NV, Murthy SS and Raman AV 2005. Macro benthos of Kakinada Bay in the Godavari delta, East coast of India: comparing decadal changes. Estuarine, *Coastal Shelf Science* **62**(4): 609-620.

Saravanakumar A, Serebiah JS, Thivakaran GA and Rajkumar M 2007. Benthic macro faunal assemblage in the arid zone mangroves of Gulf of Kachch-Gujarat. *Journal of Ocean University of China* **6**(3): 303-309.

Saravanan KR, Ilangovan K and Khan AB 2008. Floristic and macro faunal diversity of Pondicherry mangroves, South India. *Tropical Ecology* **49**(1): 91-94.

Satheeshkumar P and Khan AS 2009. Seasonal Variations in Physico-chemical parameters of water and sediment characteristics of Pondicherry Mangroves. *African Journal Basic and Applied Science* **1**(1-2): 36-43.

Satheeshkumar P and Khan AS 2011. An annotated checklist of brachyuran crabs from Pondicherry Mangroves, South East Coast of India. *World Journal of Zoology* **6**(3): 312-317.

Sethuramalingam S and Khan AS 1991. Brachyuran crabs of Parangipettai coast. *Annamalai University*, India 1-193.

Soundarapandian PN, Samuel NJ, Ravichandran S and Kannupandi T 2008. Biodiversity of Crabs in Pichavaram Mangrove Environment. *International Journal of Zoological Research* **4**(2): 113-118.

Trivedi JN, Gadhavi MK and Vachhrajani KD 2012. Diversity and habitat preference of brachyuran crabs of Gulf of Kachchh, Gujarat, India. *Arthropods* **19**(1): 13-23.

Trivedi JN and Vachhhrajani KD 2013. Distribution and Diversity of brachyuran crabs along the coastal region of Junagadh district, Gujarat. *Research Journal Marine Science* **1**(2): 8-11.

Received 12 June, 2020; Accepted 19 August, 2020

Indian Journal of Ecology (2020) 47(3): 655-662

Manuscript Number: 3061
NAAS Rating: 4.96

Influence of Organic and Inorganic Farming Practices on Production Potential and Soil Health under Different Cropping Systems in Mid Himalayan Region

Ashish Kumar, J.P. Saini, Arvind Chahal* and Pankaj Chopra

Department of Agronomy, Forages and Grassland Management
CSK HPKV, Palampur, Kangra-176 062, India
**E-mail: chahal.arvind92@gmail.com*

Abstract: The effect of different farming practices and cropping systems on equivalent yield and soil health was observed from *Kharif* 2014 to *Rabi* 2015-16. Organic farming practice resulted in significantly highest MGEY, whereas, maize–wheat and mash–wheat remained at par with each other in terms of MGEY. The same treatment remained par with integrated farming practice resulted in significantly higher uptake of N, P, K over inorganic farming practice. A reduction of 7.2% in bulk density was recorded under organic farming practice, while inorganic farming practice resulted in an increase of 1.6% over its initial value at the end of experiment. Soil organic carbon and microbial biomass carbon increased by 30 and 53%, respectively under organic farming practice, while, inorganic farming practice resulted in a decrease of microbial biomass carbon by 1.06% over its initial value. Organic farming practice resulted in an increase of about 24, 50 and 28% in available N, P and K, respectively over its initial value, while its corresponding values under inorganic farming practice were 15, 35 and 20%. Legume based mash–gram cropping system improved the available N, P, K and soil physical and biological properties over all other cropping systems.

***Keywords*:** MGEY: Maize grain equivalent yield, Organic farming, Soil organic carbon, Microbial biomass carbon

In the anxiety of increasing food production to meet the need of ever increasing population of India, there had been excessive use of agrochemicals for the last 50 years and least attention was given to ecological agriculture. No doubt, India kept pace with increasing population production has increased from around 50.81 to 286.05 million tonnes from 1960's to 2018-19, respectively (Anonymous 2019). However, the danger signals have started coming sooner than expected. Many of our highly productive soils started showing signs of declining productivity. The effect of prolonged and overuse of chemicals than required resulted in human health hazards and imbalances of natural resources. In contrast to modern production systems, organic agriculture represents a deliberate attempt to make the best use of local natural resources. The ecological or biological agriculture, aimed to create integrated, environmentally and economically viable agriculture systems in which maximum reliance is placed on locally or farm-derived renewable resources, and the management of ecological and biological processes (Nagar et al 2016). There is a limited data available on comparative yield, soil health and economics of crop production with pure organic versus inorganic farming in different cropping systems. So, keeping the agro-ecosystem maintenance and diversification in view, this comparative study under organic, integrated and chemical farming practices on soil health and production potential of different cropping systems under mid Himalayan conditions was undertaken.

MATERIAL AND METHODS

The experiment was laid out in a split plot design with three replications. The treatments consisted of three farming practices *i.e.* M_1- inorganic farming practice (RDF), M_2- integrated farming practice {Vermicompost (5 t ha^{-1} for cereals and 2.5 t ha^{-1} for pulses) + 50% RDF through chemical fertilizers} and M_3-organic farming practice (soil treatment with jeevamrit (10%), seed treatment with biofertilizers + vermicompost @10 t vermicompost ha^{-1} for cereals and 5 t vermicompost ha^{-1} for pulses followed by 3 sprays of organic liquid manure (vermiwash 10%) at 15 days interval) in main plots and four cropping systems *i.e.* S_1- maize–wheat , S_2- maize–gram, S_3- mash–wheat and S_4- mash–gram cropping systems in sub-plots. For comparison between cropping sequences, the yields of crops were converted into maize-grain equivalent yield (MGEY) on price basis (Rana et al 2011). The composite soil samples from 0-0.15 m depth were collected with the help of tube auger before and after the completion of the crop cycle. The soil samples were air dried, processed and analyzed for different chemical properties *viz.* pH, bulk density, organic carbon, microbial biomass carbon, available N, P, and K following standard methods (Jackson 1973, Singh 1980, Walkley and

Black 1934, Vance et al 1987, Subbiah and Asija 1956, Olsen et al. 1954, Black 1965). Plant samples were analyzed for nutrient uptake *viz.* total N, P and K following standard methods (Jackson 1973 and Black 1965).

RESULTS AND DISCUSSION

Maize grain equivalent yield (MGEY): MGEY was significantly affected by different farming practices during both the years (Table 1). Organic farming practice (M_3) resulted in significantly highest MGEY followed by integrated farming practice (M_2), whereas, Inorganic farming practice (M_1) resulted in significantly lowest MGEY during both the years. The higher MGEY under organic farming practice (M_3) was owed to high yields of pulses under organic management and also to their higher prices over cereals. Maize–wheat (S_1) cropping system resulted in significantly highest MGEY in the first year of experiment. This was followed by mash-wheat (S_3) and maize–gram (S_2) cropping systems. In the second year maize–wheat (S_1) remaining at par with mash–wheat cropping system (S_3) resulted in significantly higher MGEY. These were followed by mash–gram (S_4) and maize–gram (S_2) cropping system which did not differed significantly. Mash–gram (S_4) cropping system resulted in lowest MGEY during both the years. The higher tonnage of cereals under maize-wheat cropping system was the prime cause of higher MGEY under this sequence. Abadi et al (2012) and Jaybhay et al (2015) reported superiority of maize green equivalent yield under organic farming practice over conventional farming practice which attributed to balanced and gradual release of plant nutrients and increased water holding capacity under organic management to support growth,

Nutrients uptake: Nutrient (NPK) uptake was found to be significantly higher under farming practice (M_2) which remained at par with organic farming practice (M_3) at the end of first as well as second year (Table 1). However, inorganic farming practice (M_1) resulted in lowest nitrogen, phosphorous and potassium uptake. This continuous supply

Table 1. Effect of treatments on maize grain equivalent yield (kg ha^{-1}), protein yield (kg ha^{-1}) and nutrient uptake by crops (kg ha^{-1})

Treatments	MGEY	N Uptake		P Uptake		K Uptake	
		Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
2014-15							
Farming Practices (M)							
Inorganic (M_1)	6319.94	73.92	75.49	13.95	14.21	31.97	39.09
Integrated (M_2)	7036.73	87.26	81.63	16.25	16.08	35.15	42.89
Organic (M_3)	7310.99	83.06	82.64	15.75	16.33	35.90	42.16
CD (p=0.05)	198.15	3.89	2.50	0.77	0.68	2.06	0.52
Cropping Systems (S)							
Maize-wheat	7957.34	107.34	113.88	22.63	24.97	44.97	67.85
Maize-gram	6181.78	105.61	43.78	22.53	5.67	45.60	14.55
Mash-wheat	7564.65	56.54	117.08	8.07	25.66	23.61	68.29
Mash-gram	5853.12	56.17	44.95	8.03	5.85	23.17	14.82
CD (p=0.05)	305.99	5.60	3.07	0.80	0.68	2.85	1.26
2015-16							
Farming Practices (M)							
Inorganic (M_1)	6618.26	79.76	72.85	14.67	14.81	32.87	39.51
Integrated (M_2)	7288.77	90.68	78.57	16.80	16.68	36.52	43.19
Organic (M_3)	7571.40	90.82	81.21	16.29	16.94	36.89	42.64
CD (p=0.05)	222.90	4.37	1.63	0.88	0.43	1.71	0.72
Cropping Systems (S)							
Maize-wheat	8001.11	112.76	108.70	23.37	25.72	46.33	67.90
Maize-gram	6303.77	111.01	44.30	22.90	5.98	46.13	15.20
Mash-wheat	8000.63	62.69	112.63	8.76	26.69	24.74	68.67
Mash-gram	6332.39	61.88	44.55	8.65	6.19	24.50	15.35
CD (p=0.05)	278.73	5.49	3.18	0.84	0.76	2.65	1.21

of N, P and K throughout the crop growth periods from inorganic sources in the early stages and the slow and continuous release of nutrients from the organic sources in the later stages of the crop growth resulted in highest nutrient uptake under integrated farming practice. Devi et al (2011) and Kanwar and Paliyal (2004) also reported similar results.Maize–wheat cropping system (S_1) resulted in significantly highest nutrient uptake than rest of the crop sequences under study during both the years. This was followed by mash–wheat (S_3), maize–gram (S_2) and mash–gram (S_4) sequences in descending order of nitrogen, phosphorous and potassium uptake. Maize and wheat responded well to the application of various nutrient sources and removed maximum nutrients from soil and higher biomass yields also contributed to higher uptake of nutrients. Also, the higher biomass yields of cereals than pulses might be ascribed to higher uptake of nutrients in cereals. Prasad et al (2010), Kumar and Dhar (2010) and Manjhi et al (2014) reported significant improvement in nutrients uptake by maize-wheat sequence which might be due to improved physiological and metabolic functions, which in turn responsible for better expression of growth parameters.

Soil Properties

Soil pH: Soil pH was highest under organic farming practice (M_3), which was followed by integrated farming practice (M_2) and inorganic farming practice (M_1) at the end all the four cropping seasons (Table 2). Soil pH decreased with the application of chemical fertilizers and was maintained or increased with conjoint application of manures and fertilizers or organic manures alone over initial pH value of 5.1. Marked decline in soil pH due to the application of chemical fertilizers alone could be attributed to the acid producing nature of nitrogenous fertilizers that upon nitrification release H^+ ions which are potential source of soil acidity. Hati et al (2008) and Prasad et al (2010) reported significantly higher pH under organic farming practice in maize-wheat crop sequencewhich might be due to moderating effect of organic manures as it decreases the activity of exchangeable Al^{3+} ions in soil solution due to chelation effect of organic molecules.Among cropping systems, highest soil pH was recorded in maize-wheat system (S_1), which was followed by mash–wheat (S_3), while, maize–gram (S_2) and mash–gram (S_4) observed similar values of pH after *Kharif* 2014. The highest soil pH was recorded under maize–wheat cropping system (S_1), which was followed by mash–wheat (S_3), maize–gram (S_2) and mash–gram (S_4) cropping systems at the end of *Kharif* 2015. Similar trend was also observed at the end of *Rabi* 2014-15 and *Rabi* 2015-16, where highest values of soil pH were recorded under maize-wheat system (S_1). Maize – wheat (S_1) cropping system resulted in higher soil pH in both *Kharif* and *Rabi* seasons of year 2015-16. The cropping sequence involving pulses only (S_4) registered lower soil pH when compared with all cereal crop sequence (S_1) over the course of two years which might be due to the fact that legumes remove more calcium and magnesium (replaced with hydrogen) than some grasses, such as maize. Pulse crops have the ability to reduce the pH of soil in the rhizosphere and make micro-environment favourable for nutrient availability (Hue 1992).

Bulk density: Bulk density of soil (0-0.15 m depth) responded significantly to different treatments during both the years (Table 2). The data reported that significantly highest bulk density was observed under inorganic farming practice (M_1), which was followed by integrated farming practice, whereas, significantly lowest bulk density was recorded under organic farming practice (M_3) at the end of *Kharif* 2014 and *Kharif* 2015. Similar trend was also reported after *Rabi* 2014-15 and *Rabi* 2015-16, where, inorganic farming practice (M_1) resulted in significantly highest bulk density over other treatments. Organic farming practice (M_3) was able to manage significantly lowest bulk density at the end of two years. A significant reduction in bulk density at the end of two years by 2.4, 7.2 and 1.6 % was recorded under integrated (M_2), organic (M_3) and inorganic farming (M_1) practices, respectively over its initial value of 1.25 Mg m^{-3}. Marginal reduction in bulk density in organic and integrated management plots over chemical management could be ascribed to the increased root biomass production that might have increased organic matter content of the soil. Chaudhary and Thakur 2007, Sharma et al. 2007 and Verma et al. 2010 also reported similar findings. The maize –wheat (S_1) and maize–gram (S_2) cropping systems remaining at par with each other resulted in significantly higher soil bulk density over rest of the crop sequences after *Kharif* 2014 and *Kharif* 2015. Similarly, significantly higher bulk density was recorded under maize–wheat (S_1) which remained at par with maize–gram (S_2) followed by mash–wheat (S_3) and significantly lowest bulk density was recorded under mash–gram (S_4) cropping system at the end of *Rabi* 2014-15 and *Rabi* 2015-16. At the end of *Rabi* 2015-16, a reduction in bulk density to the tune of 1.6, 1.6 and 2.4 % was recorded under maize–wheat (S_1), maize–mash (S_2) and mash–wheat (S_3) cropping systems, respectively over its initial value of 1.25 mg m^{-3}.Bulk density responds to change in management over a long period of time. The crop sequences which returns sizeable amount of residues to soil usually resulted in lower bulk density. The results are in agreement with that of Ganeshamurthy et al (2006).

Soil organic carbon: Organic carbon content differed significantly under different treatments during all the cropping

seasons (Table 2). Organic farming practice (M_3) resulted in significantly highest soil organic carbon, which was followed by integrated farming practice (M_2) and inorganic farming practice (M_1) resulted in significantly lowest soil organic carbon after *Kharif* 2014 and *Kharif* 2015. Also, similar trend was observed at the end of *Rabi* 2014-15 and *Rabi* 2015-16. There was significant build-up of organic carbon under organic and integrated farming practices at the end of second year as compared to initial value. At the end of two years, inorganic farming (M_1), integrated farming (M_2) and organic farming (M_3) practices increased the organic carbon content of the soil to the tune of 11.41, 22.11 and 30.14 %, respectively over its initial value of 7.1 g kg^{-1}. Vidyavathi et al (2011) also observed the increase of organic carbon with addition of organic manures due to stimulating effect of organics on growth and activity of microorganisms. Higher production of root biomass might have increased the organic carbon content (Subramanian and Kumaraswamy 1989). Slow rate of organic matter decomposition in wet temperate zone could be another reason for build-up of soil organic carbon (Sharma et al. 2002). Similar results were reported by Tabassum et al (2010) and Kumar and Singh (2010).

Among the cropping systems, mash–gram (S_4) remaining at par with mash–wheat (S_3) resulted in significantly higher soil organic carbon over other cropping systems at the end of *Kharif* 2014 and *Kharif* 2015. Soil organic carbon was highest in mash–gram cropping system (S_4) followed by mash–wheat (S_3) and maize-gram (S_2) cropping system at the end of *Rabi* 2014-15. However, the differences among the treatments were not significant. At the end of *Rabi* 2015-16, mash–gram (S_4) remained at par with mash–wheat (S_3) resulted in significantly higher soil organic carbon over rest of the cropping sequences. The maize-wheat (S_1) cropping system resulted in lowest soil organic carbon after the completion of all the crop cycles. The data also revealed a definite build-up of organic carbon in all the treatments over its initial value of 7.1 g kg^{-1} at the start of experiment *i.e.* before *Kharif* 2014. Data further revealed that all cropping systems *viz*., maize–wheat, maize–gram and mash–wheat increased the organic carbon content of the soil by 18.45, 20.28 and 22.39 %, respectively, over its initial value. Pulses add significant amount of organic residues to the soil in the form of root biomass and leaf litter, being rich in nitrogen, facilitate decomposition of crop residues in soil and increases microbial activity. The results are in conformity with that of Venkatesh et al (2012) and Singh et al (1996).

Microbial biomass carbon: Microbial biomass carbon content differed significantly under various treatments in all the cropping seasons (Table 2). Organic farming practice (M_3) remaining at par with integrated farming (M_2) resulted in significantly higher microbial biomass carbon over Inorganic farming practice (M_1) at the end of *Kharif* 2014. The data further reported that organic farming practice (M_3) resulted in significantly highest microbial biomass carbon over rest of the treatments, which was followed by integrated farming (M_2) and inorganic farming practice (M_1) at the end of *Kharif* 2015. Similarly, soil biomass carbon was significantly highest in organic farming practice (M_3), which was followed by integrated farming and lowest was under inorganic farming practice (M_1) at the end of *Rabi* 2014-15 and *Rabi* 2015-16.

Table 2. Effect of treatments on soil pH, bulk density (Mg cm^{-3}), soil organic carbon (g kg^{-1}), microbial biomass carbon (µg g^{-1} soil)

Treatments	Available nitrogen (kg ha^{-1})				Available phosphorous (kg ha^{-1})				Available potassium (kg ha^{-1})			
	2014-15		2015-16		2014-15		2015-16		2014-15		2015-16	
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
Farming Practices (M)												
Inorganic (M_1)	223.61	230.95	238.42	241.25	22.43	25.48	27.01	29.14	175.44	182.35	194.69	205.09
Integrated (M_2)	235.77	244.96	252.11	260.13	25.08	28.95	31.48	35.06	186.05	200.41	214.67	228.25
Organic (M_3)	234.02	243.34	250.12	258.10	24.18	28.05	30.18	32.72	182.81	191.58	205.13	219.58
CD (p=0.05)	0.91	0.89	0.34	0.95	0.49	0.27	0.27	0.34	0.42	0.35	0.61	0.25
Cropping Systems (S)												
Maize-wheat (S_1)	225.61	230.73	236.81	238.98	22.07	25.34	27.33	29.13	178.04	185.41	195.64	207.78
Maize-gram (S_2)	229.67	242.11	246.92	257.37	22.77	28.73	27.80	33.93	181.13	194.80	204.80	221.79
Mash-wheat (S_3)	236.18	242.32	251.35	255.15	24.78	25.91	30.84	30.39	182.85	190.30	208.07	218.67
Mash-gram (S_4)	233.07	243.83	252.44	261.13	25.97	30.00	32.24	35.77	183.71	195.28	210.79	222.33
CD (p=0.05)	0.46	0.61	0.51	1.11	0.22	0.14	0.22	0.48	0.37	0.26	0.35	0.49
Initial value	208.05 kg ha^{-1}				21.50 kg ha^{-1}				170.33 kg ha^{-1}			

Data further revealed that the organic farming (M_3), integrated farming (M_2) and inorganic farming (M_1) practices increased the microbial biomass carbon of the soil by 53.44 and 36.42 %, respectively over its initial value of 75.50 µg g^{-1} soil. The higher microbial biomass pool size may accumulate after regular addition of manures and crop residues under organic practices. Lundquist et al. (1999) also observed higher microbial biomass carbon as an indicator of carbon availability in soil under organic practices. This might be due to the supply of additional mineralizable and readily hydrolysable carbon as a result of organic matter application resulting in higher microbial activity and in turn higher microbial biomass carbon. These results are in close conformity with those of Nagar et al (2016) and Chandrashekhar (2012).

The data revealed that mash-gram (S_4) observed highest value of microbial biomass carbon over rest of the treatments. This treatment was followed by mash–wheat (S_3), maize – gram (S_2) and maize-wheat (S_1) after *Kharif* 2014. However, the differences among the treatments were not significant. At the end of *Kharif* 2015, microbial biomass carbon was significantly highest in mash-gram (S_4), which was followed by mash–wheat (S_3) and maize–gram (S_2), while lowest microbial biomass carbon was recorded in maize–wheat (S_1) cropping system. The data further reported that soil microbial biomass carbon was significantly highest under mash–gram (S_4), while it was followed by mash–wheat (S_3) and maize–gram (S_2) cropping system at the end of *Rabi* 2014-15 and *Rabi* 2015-16. The highest increase of about 34.07 % was recorded under mash–gram (S_4) cropping system at the end of experiment over its initial value. S_3, S_2 and S_1 cropping systems also recorded increase in microbial biomass carbon to the tune of 31.23, 28.45 and 24.03 µg g^{-1} soil, respectively over its initial value of 75.5 µg g^{-1}soil. The significantly lowest soil microbial biomass carbon was recorded under maize–wheat cropping system (S_1) at the end of both the crop cycles. A definite build-up of soil microbial biomass carbon was observed in all the treatments over its initial value of 75.5 µg g^{-1}. The inclusion of pulses in the cereal based system sequestered more organic carbon, maintained better soil health and higher soil microbial biomass carbon than fallow and cereal rotation. Venkatesh et al (2012) made similar observation in a crop rotation system involving legumes.

Available nitrogen: The different farming practices and cropping sequences significantly influenced the available nitrogen status of soil (Table 3). The highest available nitrogen was reported under integrated farming practice (M_2) at the end of *Kharif* 2014 and *Kharif* 2015. The same treatment was closely followed by organic farming practice (M_3) at both the crop cycles. Similarly, available nitrogen status of the soil was significantly highest in integrated farming practice (M_2), which was followed by organic farming practice (M_3) at the end of *Rabi* 2014-15 and *Rabi* 2015-16. Data further showed that at the end of two years integrated farming (M_2) recorded about 56 % higher available N as compared to 50 % increase under organic management (M_3) over inorganic management (M_1). Lowest values of available N were recorded in inorganic farming practice (M_1) at the end of crop cycles. The increase in available N due to organic manure application might be attributed to the greater multiplication of microbes caused by the addition of organic

Table 3. Effect of treatments on available nitrogen, phosphorous and potassium content in soil (Kg ha^{-1})

Treatments	Available nitrogen (kg ha^{-1})				Available phosphorous (kg ha^{-1})				Available potassium (kg ha^{-1})			
	2014-15		2015-16		2014-15		2015-16		2014-15		2015-16	
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
Farming Practices (M)												
Inorganic (M_1)	223.61	230.95	238.42	241.25	22.43	25.48	27.01	29.14	175.44	182.35	194.69	205.09
Integrated (M_2)	235.77	244.96	252.11	260.13	25.08	28.95	31.48	35.06	186.05	200.41	214.67	228.25
Organic (M_3)	234.02	243.34	250.12	258.10	24.18	28.05	30.18	32.72	182.81	191.58	205.13	219.58
CD (p=0.05)	0.91	0.89	0.34	0.95	0.49	0.27	0.27	0.34	0.42	0.35	0.61	0.25
Cropping systems (S)												
Maize-wheat (S_1)	225.61	230.73	236.81	238.98	22.07	25.34	27.33	29.13	178.04	185.41	195.64	207.78
Maize-gram (S_2)	229.67	242.11	246.92	257.37	22.77	28.73	27.80	33.93	181.13	194.80	204.80	221.79
Mash-wheat (S_3)	236.18	242.32	251.35	255.15	24.78	25.91	30.84	30.39	182.85	190.30	208.07	218.67
Mash-gram (S_4)	233.07	243.83	252.44	261.13	25.97	30.00	32.24	35.77	183.71	195.28	210.79	222.33
CD (p=0.05)	0.46	0.61	0.51	1.11	0.22	0.14	0.22	0.48	0.37	0.26	0.35	0.49
Initial value	208.05 kg ha^{-1}				21.50 kg ha^{-1}				170.33 kg ha^{-1}			

materials for the conversion of organically bound N to inorganic form (Walia and Kler 2006). Among cropping systems, the highest amount of available N in mash–wheat cropping system (S_3) was significantly superior over rest of the treatments after completion of *Kharif* 2014 and *Kharif* 2015. It was closely followed by mash–gram (S_4) and maize–gram (S_2) cropping system. However, the significantly highest available N was recorded under maize–gram (S_4) at the end of *Rabi* 2014-15 and *Rabi* 2015-16, which was followed by mash–wheat (S_3) and maize–gram (S_2) cropping system. Significantly lowest available N was recorded under maize–wheat cropping system (S_1) at the end of crop cycle. At the end of the experiment the highest increase of about 25.54 % was recorded under mash–gram cropping system (S_4). Also, the S_3, S_2 and S_1 cropping systems recorded increase in available N to the tune of 22.67, 23.74 and 14.89 %, respectively over its initial value of 208 kg ha^{-1}. Similar result was found by Patra et al (2011) and Nagar et al (2016).

Available phosphorus: The different treatments have significant effect on available P content of soil during both the years (Table 3). The values of available P in integrated farming practice (M_2) were significantly superior over rest of the farming practices at the end of *Kharif* 2014 and *Kharif* 2015. Available P followed similar trend after *Rabi* 2014-15 and *Rabi* 2015-16, where integrated farming practice (M_2) resulted in significantly highest values over rest of the treatments. All farming practices *i.e* inorganic, integrated and organic increased the available P content by 35.33, 63.07 and 52.19 %, respectively over its initial value. The highest amount of soil available P in mash–gram (S_4) cropping system was significantly superior over rest of the treatments after termination of *Kharif* 2014 and *Kharif* 2015. This treatment was closely followed by mash–wheat (S_3) cropping system. Similar trend was followed after *Rabi* 2014-15 and *Rabi* 2015-16, where the soil available P was significantly highest under mash–gram (S_4) cropping system over rest of the crop sequences. Significantly lowest available P was recorded under maize–wheat (S_1) cropping system after completion of both the experiments. A marked build up in available P over initial status of 21.5 kg ha^{-1} was observed under all the treatments involving different farming practices and cropping sequences at the termination of two years of cropping cycle. At the end of the experiment the highest increase of about 66.37 % was recorded under mash–gram cropping system (S_4). Also, the S_3, S_2 and S_1 cropping systems recorded increase in available P to the tune of 41.35, 57.81 and 35.49 %, respectively over its initial value of 21.5 kg ha^{-1}. This might be due to the release of organic acids during decomposition which in turn helped in releasing phosphorus through solubilizing action of native phosphorus in the soil. The organic matter also forms a cover on sesquioxides and makes them inactive and thus reduces the phosphate fixing capacity of the soil and release of ample quantity of phosphorus (Tandon 1987). The results are in agreement with those of Urkurkar et al (2010), Thakur et al (2011).

Available potassium: Available potassium (K) was also affected significantly by different treatments during both the years (Table 3). The available K was significantly higher in integrated farming practice (M_2) over rest of the treatments at the end of *Kharif* 2014 and *Kharif* 2015. Similar trend was also followed after *Rabi* 2014-15 and *Rabi* 2015-16, where significantly highest available P was under integrated farming practice (M_2). This treatment was followed by organic farming practice (M_3) during both the seasons. In general, integrated and organic farming practices (M_2 and M_3) recorded significantly higher available K content over inorganic practice (M_1). There was an overall increase in available K content over its initial value of 170.33 kg ha^{-1} under all the treatments. All farming practices *i.e* inorganic, integrated and organic increased the available K content by 20.41, 34.00 and 28.91 per cent, respectively over its initial value at the end of two years. Increase in available potassium due to addition of organic manures may be ascribed to the reduction of potassium fixation and release of potassium due to interaction of organic matter with clay, besides the direct potassium addition to the pool of soil (Urkurkar et al 2010). Mann et al(2006) and Kumar and Singh (2010) reported significant improvement in available potassium with incorporation of green manures along with FYM,Available potassium increased under all the cropping systems. The highest amount of soil available K under mash–gram (S_4) cropping system was significantly highest over rest of the treatments at the end of *Kharif* 2014 and 2015and was closely followed by mash–wheat (S_3) cropping system during both the years. Similar trend was followed after *Rabi* 2014-15 and 2015-16, where the soil available K was significantly highest under mash–gram (S_4) cropping system over rest of the crop sequences. Significantly lowest available K was recorded under maize–wheat (S_1) cropping system after completion of both the experiments. All the cropping systems registered an increase in available K over it initial values at the end of the experiment. At the end of the experiment the highest increase of about 30.53 percent was recorded under mash–gram cropping system (S_4). Also, the S_3, S_2 and S_1 cropping systems recorded increase in available K to the tune of 28.38, 30.21 and 21.99 percent, respectively over its initial value of 170.33 kg ha^{-1}.The nutrient management practices had significant effect on soil fertility status. The available N, P_2O_5 and K_2O showed build up in soil over the years under both organic and integrated nutrient

management practices (Table 3). The available nutrients were significantly high under integrated and organic farming practices compared to inorganic practices. The available nutrients in soil had significant effect of cropping systems (Table 3). Wherever the legume crop was grown both in *Kharif* and *Rabi* seasons recorded significantly higher available nutrient in soil than with non-legume crops. This is due to nodulation of legume crops which fixes atmospheric N and N content in soil increases. As there is synergistic relation of N with P, K this helps in increasing the nutrient content in soil irrespective of nutrient management practices. The results are in line with the findings of Kadam et al (2010) and Das et al (2010).

CONCLUSION

Integrated and inorganic farming practice resulted in higher yields of cereal crops *i.e.* maize and wheat. However, yield of pulse crops *i.e.* mash and gram was higher in organic farming practice over both integrated and inorganic farming practice. As the prices of pulses are higher than cereals, this led to significantly highest maize grain equivalent yield (MGEY) under organic farming practice. Application of organic manures either alone or with chemical fertilizers improved soil physical, chemical and biological properties as it managed significantly lowest soil bulk density, higher soil organic carbon, microbial biomass carbon and it also had moderation effect on soil pH along with higher soil available NPK. Among cropping systems, mash–gram resulted in lowest soil bulk density, highest organic and microbial biomass carbon.

REFERENCES

Abadi AL, Siadat SA, Bakhsandeh AM, Fathi G and Alemi Saied KH 2012. Effect of organic and inorganic fertilizers on yield and yield components in wheat (*T. aestivum and T. durum*) genotypes. *Advances in Environmental Biology* **6**: 756-762.

Anonymous 2019. *Pocket Book of Agricultural Statistics* 2019.Government of India Ministry of Agriculture & Farmers Welfare, Department of Agriculture, Cooperation & Farmers Welfare, Directorate of Economics & Statistics, New Delhi, p. 27.

Black CA 1965. *Methods of soil analysis* Part-I, American Society of Agronomy. Madison, Wisconsin, USA.

Chandrashekhar P 2012. Effect of different resource conservation technologies on soil properties and productivity of cotton in vertisols.MSc thesis, Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharastra, India.

Chaudhary SK and Thakur RB 2007. Efficient farmyard management for sustained productivity of rice (*Oryzasativa*)-wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agricultural Sciences* **77**: 443-444.

Das A, Patel DP, Munda GC and Ghosh DK 2010. Effect of organic and inorganic sources of nutrients on yield, nutrient uptake and soil fertility of maize (*Zea mays*)-mustard (*Brassica campestris*) cropping systems. *Indian Journal of Agricultural Sciences***80**: 85-88.

Devi KN, Singh MS, Singh NG and Athokpam HS 2011. Effect of integrated nutrient management on growth and yield of wheat (*Triticum aestivum* L.). *Journal of Crop and Weed* **7**: 23-27.

Ganeshamurthy AN, Masood Ali and Srinivasarao C 2006. Role of pulses in sustaining soil health and crop production. *Indian Journal of Fertilisers* **1**: 29-40.

Hati KM, Swarup A, Mishra B, Manna MC, Wanjari RH, Mandal KG and Misra AK 2008. Impact of long-term application of fertilizer, manure and lime under intensive cropping on physical properties and organic carbon content of an Alfisol.*Geoderma* **148**: 173-179.

Hue NV 1992. Correcting soil acidity of a highly weathered Ultisols with chicken manure and sewage sludge. *Communications in Soil Science and Plant Analysis* **23**: 241-264.

Jackson ML 1973. *Soil Chemical Analysis*. Prentice Hall Inc. Englewood Cliffs, New Jersey, USA

Jaybhay SA, Taware SP, Varghese Philips and Idhol BD 2015. Crop management through organic and inorganic inputs in Soybean (*Glycine max* (L.) Merill) based cropping systems. *International Journal of Advanced Research* **3**: 705-711.

Kadam SR, Amrustsagar VM and Deshpande AW 2010. Influence of organic nitrogen sources with fulvic acid spray on yield and nutrient uptake of soybean on inceptisol. *Journal of Soils and Crops* **20**: 58-63.

Kanwar K and Paliyal SS 2004. Influence of phosphorus management and organic manuring on uptake and yield of chickpea (*Cicer arietinum*). *Himachal Journal of Agricultural Research* **30**: 38-43.

Kumar A and Dhar S 2010. Evaluation of organic and inorganic sources of nutrients in maize (*Zea mays*) and their residual effect on wheat (*Triticum aestivum*) under different fertility levels. *Indian Journal of Agricultural Sciences* **80**: 364-371.

Kumar V and Singh AP 2010. Long-term effect of green manuring and farmyard manure on yield and soil fertility status in rice-wheat cropping system. *Journal of the Indian Society of Soil Science***58**: 409-412.

Lundquist EJ, Scow KM, Jackson LE, Uesugi SL and Johnson CR 1999.Rapid response of soil microbial communities from conventional low input and organic farming system to a wet/dry cycle. *Soil Biology and Biochemistry* **31:** 1661-1675.

Manjhi RP, Yadava MS and Thakur R 2014. Effect of integrated nutrient management on crop productivity and changes in soil fertility in maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping sequence. *Indian Journal of Agronomy* **59**: 371-376.

Mann KK, Brar BS and Dhillon NS 2006. Influence of long-term use of farmyard manure and inorganic fertilizers on nutrient availability in a TypicUstochrept. *Indian Journal of Agricultural Sciences* **76**: 477-480.

Nagar RK, Goud VV, Kumar R and Kumar R 2016. Effect of organic manures and crop residue management on physical, chemical and biological properties of soil under pigeon pea based intercropping system. *International Journal of Farm Sciences* **6**: 101-113.

Olsen SR, Cole CV, Watanbe FS and Dean LA 1954. *Estimation of available phosphorus in soils by extraction with sodium bicarbonate.* USDA. circ. 939: 19-33.

Patra PS, Sinha AC and Mahesh SS 2011. Yield, nutrient uptake and quality of groundnut (*Arachis hypogaea*) kernels as affected by organic sources of nutrient. *Indian Journal of Agronomy* **56**: 237-241.

Prasad J, Karmakar S, Kumar R and Mishra B 2010. Influence of integrated nutrient management on yield and soil properties in maize-wheat cropping system in an Alfisol of Jharkhand. *Journal of the Indian Society of Soil Science* **58**: 200-204.

Rana, SS, Sharma HL, Subehia SK, Negi SC and Sharma SK 2011. Promising cropping systems for mid hill agro climatic conditions of Himachal Pradesh. *Himachal Journal of Agricultural Research* **37**: 138-148.

Sharma M, Mishra B and Singh R 2007.Long-term effects of fertilizers and manure on physical and chemical properties of a Mollisol. *Journal of the Indian Society of Soil Science* **55**: 523-524.

Sharma SP, Subehia SK and Sharma PK 2002. *Long-term effects of chemical fertilizers on soil quality, crop productivity and sustainability.* Research Bulletin CSK Himachal Pradesh Krishi Vishvavidyalaya, p.33.

Singh RA 1980. *Soil Physical Analysis*. Kalyani Publishers, Ludhiana, India.

Singh Y, Choudhary DC, Singh SP, Bhardwaj AK and Singh D 1996. Sustainability of rice (*Oryza sativa*) - wheat (*Triticum aestivum*) sequential cropping through introduction of legume crops and green manure crop in the system. *Indian Journal of Agronomy* **41**: 510-514.

Subbiah BV and Asija GL 1956. A rapid procedure for estimation of available nitrogen in soils. *Current Science* **25**: 259-260.

Subramanian KS and Kumaraswamy K 1989. Effect of continuous cropping and fertilization on chemical properties of soil. *Journal of the Indian Society of Soil Science* **37**: 171-178.

Tabassum S, Sammy RK, Vaishya UK, Singh M and Biswas AK 2010. Changes in organic and inorganic forms of nitrogen in a TypicHaplustert under soybean-wheat system due to conjoint use of inorganic fertilizers and organic manures. *Journal of the Indian Society of Soil Science* **58**: 76-85.

Tandon HLS 1987. Phosphorus research and agricultural production in India, Fertilizer Development and Consultation Organization (FDCO), New Delhi.

Thakur R, Sawarkar SD, Vaishya UK and Singh M 2011. Impact of continuous use of inorganic fertilizers and organic manure on soil properties and productivity under soybean-wheat intensive cropping of a Vertisol. *Journal of the Indian Society of Soil Science* **59**: 74-81.

Urkurkar JS, Tiwari A, Shrikant Chitale and Bajpai RK 2010. Influence of long-term use of inorganic and organic manures on soil fertility and sustainable productivity of rice (*Oryza sativa*) and wheat (*Triticum aestivum*) in Inceptisols. *Indian Journal of Agricultural Sciences* **80**: 208-212.

Vance ED, Brookes PC and Jenkinson DS 1987. An extraction method for measuring soil microbial biomass carbon. *Soil Biology and Biochemistry* **19**: 703-707.

Venkatesh MS, Hazra KK, Ghosh PK, Praharaj CS and Kumar Narendra 2012. Long-term effect of pulses and nutrient management on soil carbon sequestration in Indo-Gangetic plains of India. *Canadian Journal of Soil Science* **93**: 127-136.

Verma G, Mathur AK, Bhandari SC and Kanthaliya PC 2010. Long-term effect of integrated nutrient management on properties of a TypicHaplustept under maize-wheat cropping system. *Journal of the Indian Society of Soil Science* **58**: 299-302.

Vidyavathi, Dasog GS, Babalad HB, Hebsur NS, Gali SK, Patil SG and Alagawadi AR 2011. Influence of nutrient management practices on crop response and economics in different cropping systems in a vertisol. *Karnataka Journal of Agricultural Science* **24**: 455-460.

Walia SS and Kler DS 2006. Effect of farm yard manure on soil properties in maize-wheat system. *Journal of Research Punjab Agricultural University* **43**: 292-295.

Walkley A and Black CA 1934. An examination of wet acid method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* **37**: 29-38.

Received 04 June, 2020; Accepted 19 August, 2020

Indian Journal of Ecology (2020) 47(3): 663-667

Manuscript Number: 3062
NAAS Rating: 4.96

Use of Immobilized Polyphenol Oxidase in Removal of Phenol from Some Aqueous Solutions

M.A. Alsoufi and R.A. Aziz[1]

Department of Evaluating Products, Market Research and Consumer Protection Center
University of Baghdad, Baghdad, Iraq
[1]Department of Science, College of Basic Education, University of Al-Mustansiriah, Baghdad, Iraq
E-mail: alsoufim@mracpc.uobaghdad.edu.iq

Abstract: The aim of this study was the removal of phenol from aqueous solutions by using immobilized Polyphenol oxidase onto activated bentonite clay by glutaraldehyde. The efficiency of immobilization was 85% from the original enzyme amount. pH profile of free and immobilized enzyme was 6.5 and 7.0, respectively. The optimum temperature of both enzymes was 30°C. Immobilized PPO was stored at 4°C for 21 day without decrease in activity, while retain about 89% of its activity after 30 day of storage. In addition, it retained above 100% of its initial activity after 20 cycles and over than 62% after 30 continuing usages. Immunized PPO completely removal 10 mM of phenol and 4-chlorophenol after 5 and 7h of incubation, respectively.

Keywords: Immobilized enzymes, Polyphenol oxidase, Bentonite, Removal of phenol compounds, Enzymes applications

Polyphenol oxidase (PPO) (PPO; monophenol, dihydroxy-L-phenylalanine oxygen oxidoreductase, EC1.14.18.1) belongs to the oxidoreductase enzymes and is a type of metalloproteins due to its have Cu ion in active site, as well as, it's a type of glycoprotein due its contain a carbohydrate group that linked by covalent bond with the enzyme molecule (Dincer et al 2002). The enzyme catalyzes two types of oxidation reactions, the first is the conversion of monophenols to *o*-diphenol by adding a hydroxylation group, while the second type of reaction is oxidized by the resulting compound to the multiple quinones *o*-quinones causing the characteristic color (brown gradation) of these reactions, whose intensity depends on the enzyme activity and the availability of conditions to complete its work (Goulart et al 2003). PPO is a widespread enzyme in nature, such as, sunflower seeds, papaya, potatoes, mint leaves, prawns, tobacco leaves, safflower, coffee, peaches, bananas, phoenix leaves and prickly lettuce as well as many other sources (Al-Soufi 2010). This enzyme is responsible for the occurrence of enzymatic browning reactions in plants during the handling, manufacturing and storage of fruits and vegetables, ppo will be oxidizing mono and di phenolic compounds to quinone compounds that give brown or its gradation depending on the nature of the oxidized compounds (Wuyts et al 2006); which lead to do modified this compounds in plant tissue and food products, causing damage in products and loss of nutritional value as a result these reactions, which resulting in economic losses that effect both of producer and the consumer (Erat et al 2005). Polyphenols are chemical compounds that including a many structures types of small molecules that it present in various industries such as food, pharmaceutical, petrochemicals, plastics and other chemicals industries (Al-Soufi 2011) so, these compounds lead to produce toxicity in the nature and naturals sources even at low concentrations, If disposed without proper treatment which lead to causes serious health hazards for humans and animals that can be acute and chronic effects. such us irritation of the skin, gastrointestinal, central nervous systems, liver and kidney and other risks for public health (Sun et al 2015, Villegas et al 2016).

Bentonite (montmorillonite) clay is a 2:1 dioctahedral (smectites in general) which considered one of the most popular clay rocks in the world which it used in many industrials applications, in immobilized enzymes technique this clay was use as a support material, due to its possession of acidic nature that its necessary for providing acidic sites for binding of enzymes through NH_2 group (Alsoufi 2018), and possibility for activate and link with glutaraldehyde to making covalent bond between clay and enzyme that it's very important for stability of immobilize enzymes (Al-Soufi 2015), in this regard, this clay has been used to immobilize many enzymes for usage in different applications (Al-Soufi 2015 2018). Due to the existence of this clay in huge quantities in the Western Desert for Republic of Iraq, this study aimed to use bentonite for immobilized PPO, and study some of its characteristics and its application for removal of phenol from aqueous solutions.

MATERIAL AND METHODS

All experiments were conducted in University of

Baghdad, Iraq and University of Al-Mustansiriah, Iraq during 2019. Lyophilized powder of polyphenol oxidase (PPO) (EC1.14.18.1) was obtained from a previous study by Al-Soufi (2010), sodium acetate buffer 0.05M pH 6 was used to dissolve of the enzyme. Bentonite was obtained from local markets of Baghdad, Iraq.

Polyphenol oxidase assay: Catechol was used as a substrate for determination of free and immobilized PPO activity according to the following equation:

$$\text{PPO activity (Unit/mL)} = \frac{\Delta A420\ mm}{0.001 \times t}$$

Where:

ΔA420nm: Absorbance (nm) at final reaction time-Absorbance (nm) at initial reaction time;

0.001: Amount of change in absorbance at 420nm. $minute^{-1}$ for reaction solution at 25°C;

t: Reaction time (in minutes).

The reaction was beginning at 25°C by adding 0.1 mL of free PPO or equal amount (w/v) of immobilized PPO to the 2.9 mL of reaction solution which containing from 0.01 M Catechol in phosphate buffer (0.05 M, pH 7.0), the reaction was continued for 3min, then ΔA_{420nm} was used for calculation of activity. The unit of enzymatic activity is defined as the amount of enzyme that causes a change in absorbance by 0.001unit/min under standard conditions of reaction (Coseteng and Lee 1987, Al-Soufi 2011).

Estimation of protein: Protein (mg/ml) was estimated according to the method described by Bradford (1976).

Activation of clay: Bentonite was activated by stirring with 10% of 3-APTES solution in acetone (v/v) for 1h at room temperature. Then mixture was filtered, washed by acetone and dried at 80°C. The mixture was treated with 10% aqueous glutaraldehyde solution (v/v) for 1h and filtered, washed, dried at 25°C and stored in 20mM phosphate buffer pH 7.0 at 4°C until use (Al-Soufi 2019).

Immobilization of polyphenol oxidase: Activated bentonite was mixed with equal volumes of enzyme (10mg/ml) in phosphate buffer 0.05M pH 7 and stirred for 1 hour at 4°C, then centrifuged at 10000rpm for 10min at 4°C, the supernatant (free enzyme) was removal and precipitate (immobilize enzyme) was washed three times with 50mL of 0.05M phosphate buffer pH 7; centrifuge was used after each wash to ensure removal all free enzyme. The immobilized enzyme was stored in 0.05 M potassium phosphate buffer pH 7 at 4°C until use (Alsoufi and Aziz 2019).

Immobilization efficiency: Immobilization efficiency of polyphenol oxidase was calculated with the following equation (Kocaturk and Yagar 2010).

$$\text{Immobilization efficiency (\%)} = \frac{\text{IMA}}{\text{FA}} \times 100$$

Where: IMA: Immobilization enzyme specific activity (U/mg); FA: Free enzyme specific activity (U/mg).

Effect of pH on PPO activity: The effect of pH on the activity of the free and immobilized polyphenol oxidase was determined by different buffer solutions containing catechol as a substrate include 0.05M of sodium acetate, sodium phosphate and Tris/HCl buffer to obtain pH range between 4-5.5, 6-7 and 7.5-9 respectively. The activity was determined at 30°C by using 0.5ml and 10mg of free and immobilized enzyme, respectively. The relative activity (%) was estimated according to the method described by Al-Soufi (2011).

Effect of temperature on PPO activity: Free and immobilized polyphenol oxidase activity was estimated at a different range of temperature 30-75°C using 0.05M potassium phosphate buffer solution pH 7 containing 0.01M catechol for 10 min. The relative activity (%) was estimated by Al-Soufi (2011).

Estimation of phenolic compounds: Phenolic compound concentration (mg\mL) was estimated according method of Alsoufi (2016b) by using folin-ciocalteau method, and gallic acid (3,4,5-trihydroxybenzoic acid) that it was used to prepare standard curve with a concentration between 10-100mg\ml, absorbance at 765nm was used for measuring all samples.

Estimation of removal of phenolic compounds: The activity of immobilized PPO on the removal of phenolic compounds was studied by an add 2.5gm of immobilized enzyme (10 mg/ml) (25 U/mg) to the 500ml of the 10Mm of phenol and 4-chlorophenol and incubation at 30°C and 50rpm for 10h, then estimation of remaining phenolic compounds concentration (%) as a method of Al-Soufi (2018).

Effect of storage on enzyme activity: Immobilized PPO was stored for 30 day at 4°C according to the method described by Al-Soufi (2016a).

Effect of recycling immobilized PPO: Immobilized PPO was followed up after each use up to 30 cycles through a method of Al-Soufi (2016c).

RESULTS AND DISCUSSION

Immobilization of PPO: PPO was immobilized by covalent onto activated bentonite by glutaraldehyde, the efficiency of immobilization was 85% from the original enzyme amount, while, it was 70% for immobilization PPO with copper-alginate beads (Kocaturk and Yagar 2010). Previous studies revealed that by immobilization of PPO on various matrixes supports, such as used activated DEAE-cellulose sodium alginate-polyvinyl alcohol-silver nanoparticles (SA-PVA-AgNPs) and amine-functionalized Graphene oxide (GO-NH_2) for immobilization PPO (Lončar and Vujčić 2011, Edalli et al

2016, Pravin et al 2018). All these methods of immobilization aim to an improvement of its catalytic properties such as stability of pH and temperature, storage and reuse ability due the immobilization will provide a type of protection, which might be responsible for the stabilization of enzyme and increase degradation rate though, reaction (Edalli et al 2016).

Properties of immobilized PPO: Effect of pH on the activity of the free and immobilized PPO on activated bentonite by glutaraldehyde was investigated at different pH values varying from 4.0 to 9.0. The free and immobilized PPO exhibits the maximal activity at pH 6.5 and 7.0, respectively (Fig. 1). This result is similar to the result of the optimum pH for the free PPO and immobilized PPO on alginate-SiO_2 hybrid gel that was 6.6 and 7.0, respectively, (Shao et al 2009).The immobilized PPO with Eupergit C250L also showed increase at pH activity than the free enzyme that was then 7-9 and 8-9, respectively, indicating that pH value is one of the most important parameters that effect of the enzyme activity in an aqueous medium. The variance in the optimal pH value of free and immobilized enzyme it happen as a result of a change in the ionic environment of the carrier around the active sites of the enzyme (Lončar et al 2011).

The effects of temperature on the activity (Fig. 2) of the free and immobilized PPO were also studied in the temperature range of 30-75°C. The maximum activity was 30°C for both enzymes. Furthermore, compared with other studies, optimum temperature activity was 25, 30 and 37°C of immobilized PPO with DEAE-cellulose (Lončar and Vujčić 2011), amine-functionalized Graphene oxide (Pravin et al 2018) and SA-PVA-AgNPs, respectively. Immobilization of enzyme will improvement of resistance against increase of temperature at reaction due the reduced of enzyme activity due to thermal inhibition (Al-Soufi 2018).

The immobilized PPO was stored at 4°C for 21 day without decrease in activity, while retain about 89% of its activity after 30 day of storage (Fig. 3). General, Immobilization will increase the storage stability of enzyme (Edalli et al 2016), but it depend on some parameters such as matrices, methods type of immobilization and storage temperature that it's determine the stability of immobilization enzymes during storage. The immobilized PPO on alginate-SiO_2 hybrid gel was retained about 93.3% of its original activity after 30 day of storage at 4°C (Shao et al 2009). Immobilized PPO with amine-functionalized Graphene oxide was retained more than 90% of its initial activity after 15 days of storage at -20°C and 4°C, while it's retained a same activity only up to 10 days of stored at room temperature and 37°C (Pravin et al 2018).

The immobilized PPO retained above 100% of its initial activity after 20 cycles and over than 62% after 30 cycles of continuous uses (Fig. 4). The reusing of immobilized enzyme is one of the most important features affecting of economic aspect it's in various applications (Lončar et al 2011). However, it consists of several parameters such as type of immobilization matrices, number of use and concentration of substrate. The activity of immobilized PPO with copper alginate beads remained nearly unchanged through the first

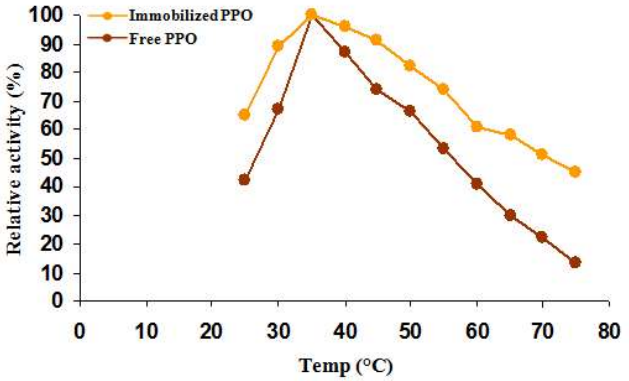


Fig. 2. Effects of temperature on the activity of the free and immobilized PPO

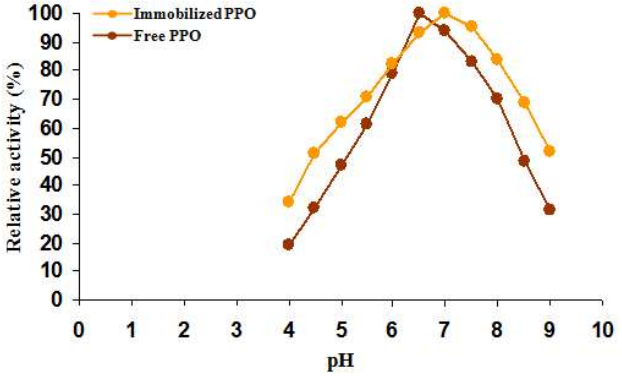


Fig. 1. Effect of pH on the activity of the free and immobilized PPO

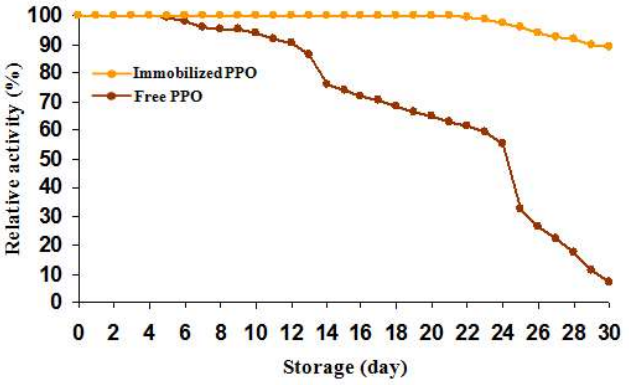


Fig. 3. Effects of storage on the activity of the free and immobilized PPO through 30 day at 4°C

8 cycles, while retained with 40 and 56% of its initial catecholase and cresolase activity, respectively, up to 10 cycles (Kocaturk and Yagar 2010). While, the entrapped PPO in chitosan coated sodium alginate beads were reused for 18 cycles with minimum loss of degrading activity for both the concentrations (10 and 20mM) of phenol and 14 cycles for 4-chlorophenol. However, when initial concentrations of phenol and 4-chlorophenol were increased to 20 mM, it was observed that the rate of degradation of phenol and 4-chlorophenol decreased and the immobilized enzymes were reused with lesser frequency (Edalli and Kamanavalli 2013). The reduction of the removal efficiency of immobilized PPO in latter cycles can be due to accumulation of gradually dark precipitate, that it will increased after each cycle, so these precipitate react with immobilized PPO by hydrophobic interactions which will causes banning its activity and probably inhibition it as in the false substrate (Lončar and Vujčić 2011), or, to the decreasing in the immobilized PPO activity probably due to the denaturation of enzyme and due to the physical loss of enzyme from the carrier (Kocaturk and Yagar 2010).

Removal of phenolic compounds: The immobilized PPO completely removal 10 mM of phenol and 4-chlorophenol after 5 and 7h of incubation, respectively (Fig 5). Immobilized PPO is considered from the better methods in terms of stability, reusability and reduces costs to treat wastewater and removal of aqueous phenolic compounds (Mukherjee et al 2013). Researchers have reported the use of immobilized PPO in this bioremediation. The efficiency of phenol removal by immobilized PPO on alginate-SiO2 hybrid gel was 87.3% after 8 h of treated (Shao et al 2009). Lončar et al (2011) observed that the immobilized PPO with Eupergit C 250L could to remove more than 40, 30 and 20% from 2.5mM aqueous solution of 4-bromophenol, 4-chlorophenol and phenol, respectively after 5 h of incubation. Pravin et al (2018) refer that the immobilized PPO with amine-functionalized Graphene oxide removal more than 99% of phenol within 5 h of aqueous solution treatment.

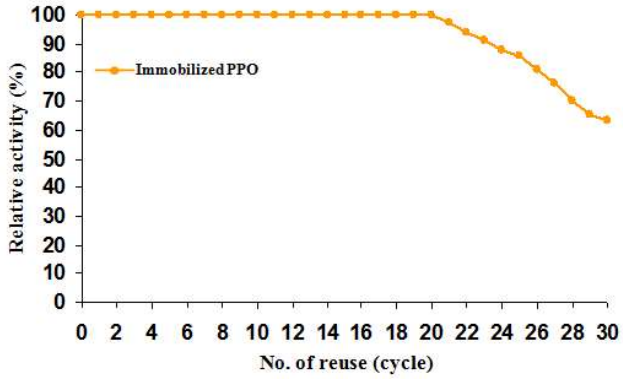


Fig. 4. Effects of reuse (cycle) on the immobilized PPO activity

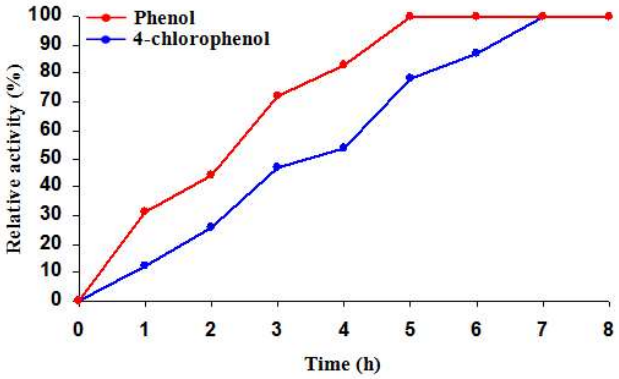


Fig. 5. Effects of immobilized PPO for removal phenol and 4-chlorophenol

CONCLUSIONS

This study showed possibility use of immobilized polyphenol oxidase with bentonite by glutaraldehyde for the removal of phenolic compounds from aqueous solutions by economic and easy method.

REFERENCES

Al-Soufi MA 2010. Purification of polyphenoloxidase from (*Lactuca serriola* L.) prickly lettuce. *Iraqi Journal of Biotechnology* **9**(4): 701-715.

Al-Soufi MA 2011. Characterization of purified polyphenol oxidase (PPO) from (*Lactuca serriola* L.) prickly lettuce. *Journal of Biotechnology Research Center* **5**(1): 40-50.

Al-Soufi MA 2015. Production of high fructose syrup by using invertase that immobilization on Iraqi bentonite. *Thi-Qar University Journal for Agricultural Research* **4**(2): 202-215.

Al-Soufi MA 2016a. Quantitative and qualitative detection of vitamin C in some foods by immobilized ascorbate oxidase. *International Journal of Sciences: Basic and Applied Research* **26**(3): 235-245.

Al-Soufi MA 2018. Use of immobilized laccase in bioremediation of phenolic compounds which causes environmental pollution. *Journal of Biodiversity and Environmental Science* **79**(3): 370-377.

Al-Soufi MA 2016b. Use of purified laccase from Prickly lettuce (*Lactuca serriola* L.) in removal of phenolic compound from some foods. *International Journal of Novel Research in Life Sciences* **3**(3): 7-17.

Al-Soufi MA 2016c. Using of immobilized naringinase and pectinase to improvement properties of the natural juice. *Diyala Journal of Agricultural Sciences* **8**(1): 259-270.

Alsoufi MA 2019. Use of immobilized L-arabinose isomerase for production of tagatose. *Iraqi Journal of Market Research and Consumer Protection* **11**(2): 122-131.

Alsoufi MA and Aziz RA 2019. Production of aspartame by immobilized thermolysin. *Iraqi Journal of Sciences* **60**(6): 1232-1239.

Bradford MM 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Analytical Biochemistry* **72**: 248-254.

Coseteng MY and Lee CY 1987. Changes in apple

polyphenoloxidase and polyphenol concentrations in relation to degree of browning. *Journal of Food Science* **52**: 985-989.

Dincer B, Colak A, Aytin N, Kadioglu A and Guner S 2002. Characterization of polyphenoloxidase from medlar fruits (*Mespilus germanica* L., Rosaceae). *Food Chemistry* **77**: 1-7.

EdalliVA and Kamanavalli CM 2013. Application of immobilized mushroom polyphenoloxidase for the removal of phenol and 4-Chlorophenol. *International Journal of Biochemistry* **108**: 144-150.

Edalli VA, Mulla SI, Eqani SAMAS, Mahadevan GD, Sharma R, Shouche Y and Kamanavalli CM 2016. Evaluation of *p*-cresol degradation with polyphenol oxidase (PPO) immobilized in various matrices. *3 Biotech* **6**: 229.

Erat M, Halis Sakiroglu H and Kufrevioglu OI 2005. Purification and characterization of polyphenol oxidase from Ferula sp. *Food Chemistry* **95**(3): 503-508.

Goulart PDFP, Alves JD, Magalhaes MM, Lima LCDO and Meyer LE 2003. Purification of polyphenoloxidase from coffee fruits. *Food Chemistry* **83**(1): 7-11.

Kocaturk S and Yagar H 2010. Optimization of polyphenol oxidase immobilization in copper alginate beads. *Artificial Cells Blood Substitutes and Biotechnology* **38**: 157-163.

Lončar N and Vujčić Z 2011. Tentacle carrier for immobilization of potato phenoloxidase and its application for halogenophenols removal from aqueous solutions. *Journal of Hazardous Materials* **196**: 73-78.

Lončar N, Božić N, Anđelković I, Milovanović A, Dojnov B, Vujčić M, Roglić G and Vujčić Z 2011. Removal of aqueous phenol and phenol derivatives by immobilized potato polyphenol oxidase. *Journal of the Serbian Chemical Society* **76**(4): 513-522.

Mukherjee S, Basak B, Bhunia B, Dey A and Mondal B 2013. Potential use of polyphenol oxidases (PPO) in the bioremediation of phenolic contaminants containing industrial wastewater.*Reviews in Environmental Science and Biotechnology* **12**: 61-73.

Pravin MD, Chris FS and Gnanamani A 2018. Preparation, characterization and reusability efficacy of amine-functionalized grapheme oxide polyphenol oxidase complex for removal of phenol from aqueous phase. *RSC Advances* **8**: 38416-38424.

Shao J, Huang LL and Yang YM 2009. Immobilization of polyphenol oxidase on alginate-SiO_2 hybrid gel: stability and preliminary applications in the removal of aqueous phenol. *Journal of Chemical Technology and Biotechnology* **84**(4): 633-635.

Sun X, Wang C, Li Y, Wang W and We J 2015. Treatment of phenolic wastewater by combined UF and NF/RO processes. *Desalination* **355**: 68-74.

Villegas LGC, Mashhadi N, Chen M, Mukherjee D, Taylor KE and Biswas N 2016. A short review of techniques for phenol removal from wastewater. *Current Pollution Reports* **2**(3): 157-167.

Wuyts N, DeWaele D and Swennen R 2006. Extraction and partial characterization of polyphenol oxidase from banana (*Musa acuminata* Grande naine) roots. *Plant Physiology Biochemistry* **44**(5-6): 308-314.

Received 03 June, 2020; Accepted 19 August, 2020

Indian Journal of Ecology (2020) 47(3): 668-675

Manuscript Number: 3063
NAAS Rating: 4.96

Effect of Conservation Tillage on Soil Quality of Southern Russia

Kamil' Sh. Kazeev, Tatiana V. Minnikova*, Gregory V. Mokrikov and Sergey I. Kolesnikov

Southern Federal University, Academy of Biology and Biotechnology Named After D.I. Ivanovsky Rostov-on-Don, Russia
**E-mail:tminnikova@sfedu.ru*

Abstract: The effect of No-tillage (NT) versus to Conventional tillage (CT) on chernozems physical properties and winter wheat (*Triticum aestivum* L.) fertility was studied. The chernozems are the most widespread and most fertility soils of the steppe zone of southern Russia. A total 15 fields were investigated on a 5.500 ha farm with NT treatment for 10 years versus to 15 neighboring fields with CT. During the peak plant growth season (in May), soil penetration resistance in 0-50 cm layer did not show any essential difference at NT versus to CT. Due to diminishing soil moisture, the essential increase of soil penetration resistance was observed (above 5.0 MPa) particularly in lower layers both in CT and NT fields. The range of soil aggregates 0.25–10 mm in size with NT was from 21% to 82%. The increase of winter wheat yield when using NT varied from 26% to 114% compared to CT. Technology NT contributed to better soil moisture conservation and physical consistency. In addition, versus to CT, NT resulted in yield growth, motor fuel savings and staple crops cost reduction.

Keywords: No-till, Soil treatment, Land use system, Tillage management, Fertility, Physical properties

The soil physical state is an essential factor of soil fertility and conventional tillage (CT) - moldboard plowing results in soil erosion and soil compaction, as well as deteriorating of soil humification (Belousova and Belousov 2017, Chudanov 2017, Gaevaya 2018, Valkov et al 2008). No-Tillage (NT) being a sustainable agricultural tillage management makes a minimal impact on fertile soil depth leaving straw crop residues in the soil. Left on the surface of the field after NT, straw and other plant residues contribute to improving soil agrophysical properties and produce beneficial conditions for preserving soil fertility (Baibekov 2018, Di Prima et al 2018, Crovetto 2010, He et al 2019, Feiziene et al 2018, Minnikova et al 2017, Zelensky et al 2018). When growth agricultural staple crops with NT and CT management, the key indicators of soil physical state are soil bulk density, soil moisture, soil consistency and penetration resistance. The highest productivity of agricultural crops is achieved with optimal soil bulk density. Soil bulk density depends on numerous factors including particle size distribution, organic matter content, soil consistency, application of organic and mineral fertilizers, soil moisture, etc. (Bayev 2017, Bogunović et al 2019, Daraghmeh et al 2019, Ferreira Nunes et al 2018, Goryanin et al 2017, Trofimova et al 2018, Okada et al 2019, Yáñez*-Díaz et al 2019). Particle size distribution determines chernozems bulk density which ranges between 1.0-1.3 $g \times cm^{-3}$. However, chernozems in the south of the steppe part of the Russian Federation characterized by arid climate, loose soil state results in significant water losses due to evaporation and wind erosion (Korchagin et al 2014). In the present study, for the first time in the conditions of southern European part of Russia, soil physical properties when No-tillage management is applied compared with conventional tillage. The objectives of the study include the following: analyzing seasonal dynamics of soil temperature and moisture; evaluating seasonal change in soil bulk density and soil penetration resistance; assessing the impact of direct sowing on physical state of soils; evaluating winter wheat fertility when No-till or conventional tillage is applied.

MATERIAL AND METHODS

Location, soil and climate: The area of the south of the steppe part of the Russian Federation (Rostov region) is located in hot climate with significant thermal resources. The amount of positive air temperatures (above 10°C) is 3200°C. The summer is hot (temperature in July-24.3°C), and winter is moderately cold (temperature in January-2.5-2.7°C). Aggregate annual precipitation in 2016, 2017 and 2018 was 707, 569 and 722 mm respectively, including rains in the growing season – 374, 294 and 332 mm, respectively (fig.1). The soils are referred to as Voronic Chernozems with a different degree of carbonates leaching and various humus content (Valkov et al 2007, 2008). According to soil particle size distribution they are attributed to heavy clay and silty clay loamy chernozems: the content of physical clay is 48-53%, and the content of silt is 29-32% (Dadenko et al 2014). According to the International reference base of soil

resources (WRB), the soils under study are referred to Voronic Chernozems (IUSS 2007).

Experimental details: Experimental fields with No-Tillage (NT) applied since 2009 and conventional tillage (CT) fields are located in the south of the steppe part of the Russian Federation (Rostov region) (Fig. 1). The study was started at the May in 2016 and was conducted during the 2016–2017 and 2018–2019 crops production period. Sowing of crops with NT was carried out with the following equipment: Buhler Versatile 2375 tractor + Great Plains NTA 3510 (10.7 m) and Case Magnum 315 + Great Plains NTA 3510 (10.7 m). The crops were sown with row spacing of 19.1 cm. Fuel consumption at direct sowing was 26 liter $\times ha^{-1}$, while the conventional technology used 74.1 liter $\times ha^{-1}$. NT fields were located in close proximity to each other in 50-100 m distance from the fields with CT. In the present study 30 fields with NT and conventional tillage: 15 fields with NT and 15 fields with conventional tillage were surveyed. Fields with No-Till were located 50-100 m from the control areas with conventional tillage. Control fields were sown with crops using conventional tillage as depth 20 cm. NT fields were sown with winter wheat (*Triticum aestivum* L.) of «Zustrich» variety, flax plant (*Linum usitatissimum* L.) of «Nebesny» variety, coriander (*Coriandrum sativum* L.) of «Alekseevsky – 190» sort and chickpea (*Cicer arietinum* L.) of «Privo-1» variety. Three soil samples were mixed to produce a composite sample. The collected soil samples were sieved through a 1 mm sieve to remove large particles, plant debris and stones. To evaluate soil physical condition, such parameters as its penetration resistance, bulk density, moisture and temperature were studied in 4 monitoring sites with winter wheat (*Triticum aestivum* L.) with 3-10-fold replication. Soil sampling was made from top layer (0-10 cm) three times during the growing seasons of 2016-2018 in May, July and September.

Measurement procedures: Soil penetration resistance was studied in the field conditions using EIJKELKAMP Agrisearch Equipment (06.01.SA) penetrometer as deep as 45 cm (with 5 cm interval). The maximum soil penetration resistance, registered by penetrometer, was 10 MPa. The area of probe surface was 1-2 cm^2 at angle of 60°. The device accuracy was ±0.01 MPa. The analytical experiment was repeated 10 times. Soil bulk density was determined by volume-weight method using sustainable metal rings of 135 cm^3 volume repeated 3 times, in $g \times cm^{-3}$ (Zhang et al 2013). Analytical repetition of the experiment was 10 times. Soil temperature was identified by electronic pocket thermometer HANNA Checktemp at depth of 0-10 cm. Analytical repetition of the analysis was 3-10 times. Soil consistency was evaluated by dry sieving method in the column of metal sieves with cell diameters of 0.1; 0.25; 0.5; 1.0; 2.0; 3.0; 5.0; 10.0 mm in the soil depth of 0-10 cm. Availability of soil aggregates was estimated by correlation with aggregates in the size range of 0.25-10 mm to the total weight of particles of all fractions. Analytical repetition of the analysis was 3-10 times. Soil moisture was measured by volumetric method in the field conditions with humidity meter of Fieldscout TDR 100 with 10-time repetition in the layer of 0-10 cm deep at each site. Analytical repetition of the experiment was 3-10 times.

Statistical processing of the data obtained was carried out using the software package of STATISTICA 12.0. Variation statistics (mean values, dispersion) was determined, reliability of different samples was established by using dispersion analysis (Student-t) and the correlation analysis (Pearson correlation coefficient) was conducted.

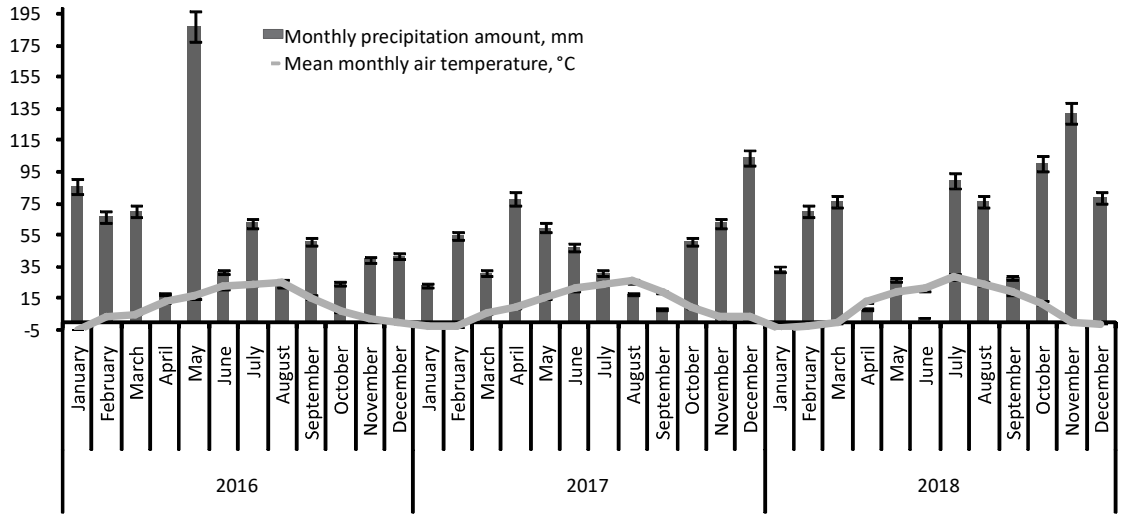


Fig. 1. Mean monthly air temperature (in °C) and monthly precipitation amount (in mm) over 2016-2018

RESULTS AND DISCUSSIONS

Dynamics of precipitations and air temperature: According to meteorological records for 2017 (Fig. 1) the amount of precipitation over the growing season (from April to October) was 295 mm, which was 26% higher than in the same period in 2016 and similar to the season of 2015. According to reference data, mean annual rainfall is 423 mm (Khrustalev et al 2002). However, precipitation index in 2015 and 2017 was at the level of normal moisture – 2.1 and 1.8, respectively. The year of 2016 was abnormally wet, and its precipitation index was 3.2. In general, according to long-term dynamics (from 2015 to 2018) excessive rainfall was recorded only in 2016. The amount of positive temperatures in the season of 2017 was 3200 °C and did not differ significantly from 2015-2016. Mean temperatures in September during those years were in the range of 16-21°C. In fact, winter wheat fertility depends not only on temperatures during the growing season, but also temperatures during the sowing period. In September 2016, during winter crops sowing, soil temperature complied with a monthly norm, but the amount of precipitation 3 times exceeded the norm. However, in 2016 and 2017 winter wheat yields exceeded the yields on adjacent fields by 39 and 26% (54 and 56 $dt \times ha^{-1}$) where moldboard plowing was applied.

Effect of tillage management on soil temperature and moisture dynamics: Regarding the amount of precipitation in 2016 just before the measurements were conducted, soil moisture with NT changed significantly (Fig. 3). Wet spring and early summer resulted in higher moisture values in all the plots, regardless of their tillage method. The second period of observation was generally drier, but relatively wet for that particular season, regardless of tillage methods – 54-55%. In 2016, no difference in soil moisture in May and July were observed. In September, soil moisture reached its minimum values due to insufficient amount of precipitation. In addition, September manifested a significant difference in soil moisture compared to July-9%. September soil dryness considerably reduced soil moisture for all tillage techniques (2 times reduction) compared with the standard soil moisture values. Soil temperature changed slightly depending on the tillage method. In 2017 soil moisture varied during the season: with decreasing by 50% by July and subsequent increasing by 132% by September. Similar moisture drop was observed in 2018: with64% decrease in July compared with May and 59% rise by September. There was no significant difference between the sites.

In 2018, the optimal conditions for the spring period as to soil moisture were recorded. In May soil moisture values with NT exceeded those values at CT plots by 57%. At the same time, the amount of atmospheric precipitation in May 2018 was less than in wet May in 2016 and 2017. In July and September, higher soil moisture 28 and 19% higher values were recorded at NT sites compared with those with CT. The top soil moisture in May was at its highest levels in all the fields under study. This was due to the large amount of precipitation in the period prior to the studies. Earlier studies showed greater moisture retention by top soil in NT fields (Mokrikov et al 2017). This is of particular importance in the period of moisture deficit after a long period of no rainfall. Soil temperature decline and soil moisture rise at NT probably occurred due to the lack of soil mixing and the presence of plant residues that prevented moisture evaporating from the soil.

The study of soil temperature in 2016-2018 proved the pronounced seasonality of this indicator. In 2016, soil temperatures in July were 25% higher than in May). The typical soil temperature pattern with NT was confirmed in the growing season of 2017 in relation to CT. The high soil moisture in May and September was 36 and 41% and low soil moisture in July (18%). Seasonal decrease in soil moisture in hot and dry July 2017 was associated with 34% rain fall drop if compared with June as well as higher air temperatures. Compared to CT, top soil temperatures with NT increased in September 2017 by 83% (). However, in the period of active vegetation there was a slight decrease in soil temperature by 13-20% compared to CT. In 2017-2018, higher moisture retention was recorded in the dry period (July) in NT soils with compared with CT soils.

Effect of tillage management on soil bulk density: In 2016, most soils with NT had soil bulk density values optimal for plants (Fig. 4). In most cases, the same soil bulk density was observed in NT soils as in CT, with no reliable differences between NT and CT. In all soils under study, top soil bulk density did not reach the critical level that could make root and plant growth difficult. This is also the feature of the wet season of 2016, when large rainfall contributed to soil loosening. In the study of soil bulk density, no dependence in winter wheat cultivation technology was found. In September 2016, however, the sites with NT showed an increase in soil bulk density of above 1.3 $g \times cm^{-1}$. This was due to the seasonal drying of top soil in the hot season (April, July) and soil compaction after harvesting (September). In 2017, there was no significant difference in soil bulk density with NT and CT methods. During the season, the average soil bulk density remained the same. In 2018, similar to May and July in 2017, there was no significant difference between NT and CT. In September, however, we observed 12% drop in soil bulk density in the fields with NT compared to CT. During 2016-2018, no significant difference between bulk densities

in soils with different types of tillage was found. However, there was a soil bulk density rise by September. Despite the average bulk density increase in the dry period in the fields under study, it hardly exceeded a high level (higher than 1.3 g×cm^{-3}), which could possibly hinder root and plant growth. In spring, after winter soil freezing and thawing, as well as seasonal moisturizing, soil bulk density reduced to its optimal values (1.0-1.1 g×cm^{-3}) for agricultural crops. The absence of over-compacted soils at NT is explained by improved soil consistency and texture which brings them close to pristine soils, with the latter becoming less dense and compacted after the tillage is over (Ferreira et al 2018, Kazeev et al 2019).

Effect of tillage management on soil penetration resistance: Another vital indicator of NT soil is soil penetration resistance. Soil penetration resistance is the ability of soil to withstand any penetration of agrotechnical appliances or plant roots into it. When NT is applied, plowing occurs only in the upper layer and does not affect the underlying layers. Therefore, it seems to be promising to study soil penetration resistance. Soil penetration resistance is affected by soil moisture, particle size distribution, mineralogical and soil aggregate composition (Gaevaya 2018, Haruna et al 2018, He et al 2019, Kormilitsina, Bondarenko 2016, Mokrikov et al 2017). Soil penetration resistance produces a limiting effect on plants ranging from 2.0 to 5.0 MPa (Kunah 2011, Otto et al 2011). The recent study by American scientists (Comprehensive Assessment of Soil Health 2016), indicate the critical value of soil penetration resistance is 1.13 MPa for top soil (0-15 cm) and 2.07 MPa for subsoil (15-45 cm). Lower soil penetration resistance values are considered to be insignificant for agriculture. Soil compaction at the level depth than 20 cm leads to hardpan formation which is quite time-consuming to get rid of due to its depth location (Gaevaya 2018, Rykov et al 2013). The negative effect of hardpan is expressed in preventing moisture penetration into subsoil and gas exchange failure. In addition, solid soil prevents even a strong root system from growing, for example of such agricultural crops as sunflower, corn and coriander.

In May 2016 no excess critical values of soil penetration resistance in the layer of 0-50 cm were revealed, neither was revealed any difference in soils with different tillage (Fig. 5). In July, however, a significant rise in soil penetration resistance was found in all the plots under study. Soil penetration resistance increased essentially; there was a double rise in soil penetration resistance from as deep as 15 cm compared to the optimal values (1.0 MPa). Critical soil penetration resistance exceeding 5.0 MPa was found in 27 out of 50 fields under study.

In September soil penetration resistance increased significantly) both in CT plot (83%) and NT plots (72%). In most fields, the top soil with conventional tillage became loose due to extensive plowing and cultivation. A significant increase in soil penetration resistance in NT fields was



Fig. 2. Layout of sampling sites in Oktabrskiy district (Rostov region, Russian federation)

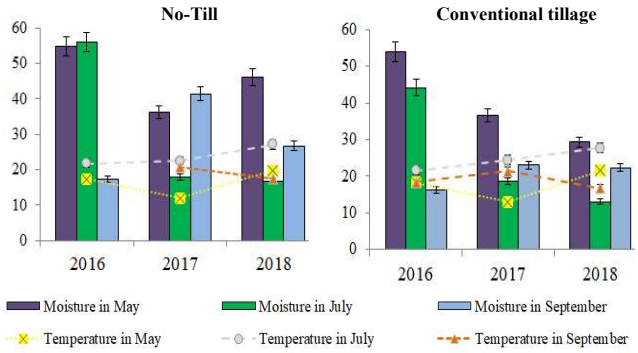


Fig. 3. Variation of soil moisture (in %) and soil temperature (°C) at NT and CT in May, July and September of 2016-2018 (mean values, n=4, p<0,05)

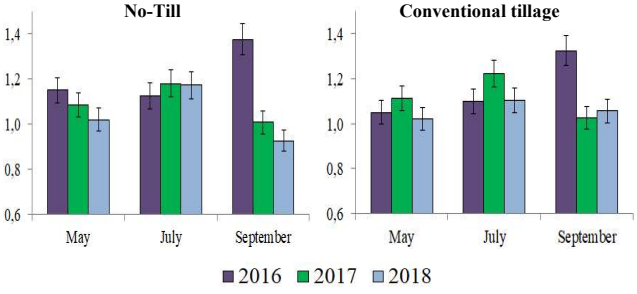


Fig. 4. Soil bulk density variation at NT and CT in May, July and September of 2016-2018 (mean values, n=4, p<0,05), g cm^{-3}

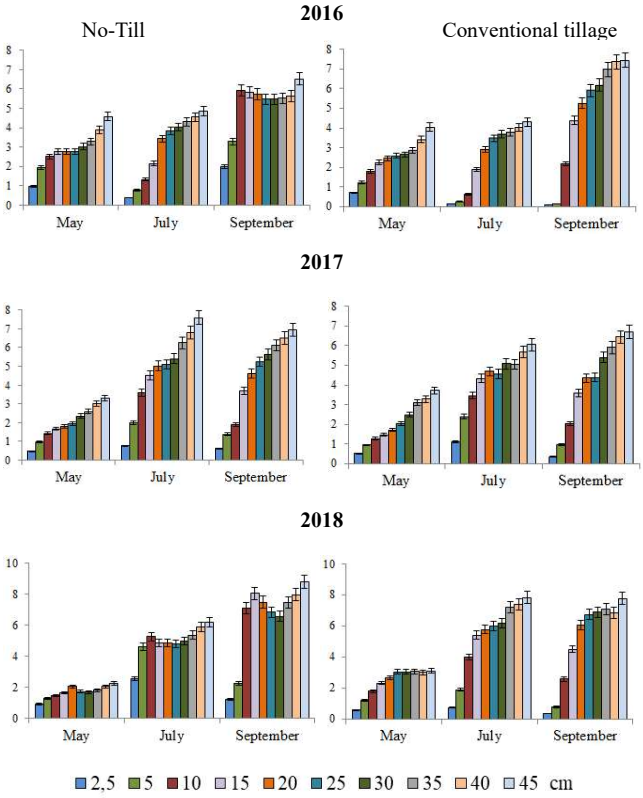


Fig. 5. Soil penetration resistance variation at NT and CT in May, July and September of 2016-2018 (mean values, n=4, p<0,05), MPa

observed even at the top soil layer, which, in addition to no tillage, resulted from low rainfall and high air temperature in September 2016. The increase in soil penetration resistance with NT reached its highest values (over 5.0 MPa) at depth of more than 10 cm. In September, the fields with CT showed excessive critical values of soil penetration resistance at depth of more than 15 cm. During April 2017 d no excessive critical values of soil penetration resistance in NT plots under study. In May 2017, some NT fields revealed increased values - 2.5-3.0 MPa in the lower soil layers from 30 cm deep. In July, most NT fields under study showed soil penetration resistance rising to its supercritical values from 5.0 to 7.6 MPa. In July and September 2017, when soil moisture fell due to high air temperatures and relatively low rainfall, there was a significant rise in soil penetration resistance of 51-60%. The maximum soil hardness of 6.05-7.6 MPa was observed in July and September at 20 cm deep, regardless of the tillage method applied.

In May 2018, soil penetration resistance in the layer of 0-20 cm in NT plots compared to the same period in 2017 was 15% higher, but 49% lower than in May 2016. Such changes in soil penetration resistance were associated with a different amount of precipitation in that month: in 2016 – 187 mm, 2017 – 60 mm, 2018 – 27 mm. However, despite the differences in top soil (0-20 cm), penetration resistance values did not exceed the critical level thus facilitating the active growth of winter wheat roots (Kazeev et al 2017). However, in July 2018, just beginning from 5 cm deep, there was an increase up to 4.6-4.9 MPa in soil penetration resistance at NT. In the same period, in CT plots we recorded ultra-high soil penetration resistance – 5.4-7.8 MPa in the layer of 15 cm deep. In September high soil penetration resistance of 7.1 MPa was observed from depth of 10 cm at NT, while at CT it was 6.05 MPa from depth of 20 cm. Such values of soil penetration resistance are likely to be associated with waterlogged soil in July and August, when the rainfall was 89 and 76 mm, as well as rainfall drop by 65% in September. In September 2016 and 2018, in top soil (0-10 cm) with NT we observed an increase in soil penetration resistance by 3.8 MPa (172%) and 4.5 MPa (175%) compared to CT.

The results of studies revealed a significant dependence of soil penetration resistance on soil moisture (depending on the season) and the depth of soil under study. When soil moisture was high, soil penetration resistance values appeared to be minimal. In May, soil penetration resistance values were found to be at their optimal level for agricultural crops in all the plots. The particular tillage technique proved to affect penetration resistance at depth of 15-20 cm. The same layer in the plots with CT revealed either higher values of soil penetration resistance (in Spring) or its lower values because of the extensive soil tillage management with agricultural tools (in Autumn). Down the profile, the differences between soils at different tillage management become less significant and are determined by differences in soil moisture. The studies conducted in 2017 and 2018 confirmed the regularities observed in 2016 (the first year of observation). Soil moisture seemed to essentially affect soil penetration resistance. Soil moisture impact proved to be much stronger than the tillage management applied, except for cases when the soil was plowed just prior to the measurement. Differences in soil tillage management appeared to be minimal in May of each year of the study (Kazeev et al 2017, 2019, Mokrikov et al 2017). With increasing temperatures and decreasing soil moisture typical for July and September, soil penetration resistance tends to grow.

Effect of tillage management on physical soil consistency: In 2016-2018 years a significant improvement in physical soil consistency was revealed. During the growing season of 2016 good soil consistency was determined in the studied plots in June and July. However, in August and September soil became very dense, and its consistency

deteriorated significantly. In the soils with tilled crops (sunflower, coriander, chickpeas) large structural aggregates began to prevail; however, in the soils with winter wheat these were not observed. Besides, similar to findings of 2016, in 2017 there was an increase of soil valuable aggregates in the range of 10-0.25 mm. Actually, they ensure soil fertility and give the soil its unique appearance - lumps. The consistency analysis showed that with dry sifting the number of valuable aggregates in the soil plough layer of 0-10 cm deep exceeds 60% and varies from 62.7 to 82.8%. The largest amount of soil valuable aggregates was observed from May to September - 26-38%. According to generally accepted estimates and indicative scales, soils of these fields could be described as having perfect consistency and thickness. Regardless of the tillage method applied, the structure coefficient exceeded 1.5, i.e. the aggregate state of soil can be assessed as excellent.

In May 2018, when analyzing the structural composition of soil, large fraction of d > 10 mm (20-63%) was found dominating, with a rare exception of individual plots where smaller fractions of 1-0.5 (23-27%) prevailed. In July, with the exception of some individual fields (19-43%), the prevalence of aggregates with d > 10 mm (21-76%) was identified. Structural analysis showed that the amount of valuable aggregates in the plow layer of 0-10 cm with dry sifting varied from 21 to 82%. When comparing NT with CT, the amount of soil valuable aggregates showed both a rise and a fall in the plow layer of 0-10 cm. Generally, the study period (2016-2018) provided evidence of varying structural composition of chernozem during the growing season regardless of the soil tillage technique applied. Remarkably, there is a decrease of fine fraction with d > 10 mm, but an increase of dust fraction with d < 0.25 mm. This regularity appeared to be typical for all plots under study (Kazeev et al 2017, 2019, Minnikova et al 2018, Mokrikov et al 2017, 2019).

Effect of tillage technique on winter wheat fertility: In recent years, the fertility of agricultural crops has varied significantly in the Russian Federation. For the last five years, gross winter wheat harvests have varied considerably in 2014 and 2015 they made 59.7 and 61.8 million tons respectively; in 2016 and 2017 - 73.3 and 86.0 million tons, and the year of 2018 produced 72.1 million tons. Data for sunflower gross harvest was similar in 2014 and 2015 – 8.5 and 9.2 million tons, in 2016 and 2017 - 11.0 and 10.5 million tons. To analyze the fertility of winter wheat agro-ecosystems in the south of the Russian Federation, statistical reporting data on crop yields for the last 5 years (2014-2018) was studied. With regards to rainfall in 2014 and 2015, soil was evenly moistened in the wheat growing season – 218 and 228 mm in 2014 and 2015, respectively. Considerably less moisture was recorded in the growth season of sunflower: 65 and 25 mm in 2014 and 2015, respectively. In 2016 and 2017, the amount of precipitation during the growing season of winter wheat was 237 and 185 mm respectively, for sunflower growing season - 137 and 58 mm. As to climate conditions of 2016, the excess precipitation of 66% of the standard was registered; in 2017 it made 34%. In terms of amount of precipitation, 2016 was very wet due to big rainfalls in May and July - 187 and 63 mm. In 2016 in the growth season of winter wheat precipitation reached 237 mm, for sunflower - 169 mm. In the growth season of winter wheat in 2017 rainfall reached 185 mm, for sunflower - 105 mm. The largest precipitation fell after the season of sunflower and winter wheat critical vegetation in October, November and December 2017 with the increase of 51, 63, 104 mm, respectively. With the average annual rainfall in the south of the steppe part of the Russian Federation (Rostov region) being rather high (722 mm), the winter wheat growth season of 2018 was extremely dry: the critical period of its growth from April to June received 79-83% less rainfall than in previous years. Lack of precipitation in spring and early summer 2018 led to decrease in winter wheat yields throughout the Russian Federation by 17%, including the south of the steppe part of the Russian Federation with 10% fall.

In 2014 and 2015 with the amount of precipitation of 520-522 mm, NT produced higher yield of winter wheat versus to CT by 51 and 114%, respectively (Table 1). In 2016-2017 the yield of winter wheat in the Rostov region with NT was higher than that with CT by 36 and 26%, with total higher yields of winter wheat in the region. In 2018 the drought occurred from April to June, so winter wheat yield with NT decreased by 16% versus to CT and by 46% compared to the harvest of 2017. The cost of winter wheat in 2015, 2016 and 2017 was lower than the cost of CT by 41, 45 and 10% respectively. In 2014 and 2015, the sunflower yield in the study area at NT was higher versus to CT by 32 and 92%, respectively. Sunflower grown on soils with NT in the south of the European part of the Russian Federation (Rostov region) in 2016 and 2017 also had higher fertility, particularly in 2016: 92% rise versus to CT. Despite the lack of moisture in the growing seasons of 2014, 2015 and 2017, sunflower yield

Table 1. Winter wheat yield at different soil tillage management (2014-2018), dt×ha^{-1}

Tillage	Years				
	2014	2015	2016	2017	2018
No-Till	36,3	50,7	54,2	56,0	29,8
Conventional tillage	24,1	23,7	39,0	44,5	41,0

with NT varied in the range of 27.0 - 27.2 dt×ha^{-1}. Versus to 2017, sunflower yield in 2018 declined by 10%, but exceeded the sunflower yield at CT by 27%. Such features as stubble preservation, straw crop residues, the improvement of soil consistency and soil moisture retention at NT contribute to decreasing soil erosion. Three-fold reduction in fuel consumption at NT saves motor fuel thus cutting down greenhouse gasses emissions. Fewer stages of soil cultivation at NT bring about reducing soil over-compaction caused by agricultural machines, which also has a beneficial effect on physical and biological soil conditions. Considering fuel cost reduction at all stages of sunflower cultivation, cost price at NT appeared to be lower by 35-68% versus to CT.

In previous years, a two-year experiment conducted in the south of the European part of the Russian Federation provided growing evidence that the highest winter wheat fertility was obtained when using NT technology (4.19 tonn×ha^{-1}), which was 18% higher versus to CT. By far the highest economic indicators were obtained when growth winter wheat using NT due to lower grain cost and higher production efficiency. There was also an increase in sunflower yield by 49% (22.5 dt×ha^{-1}) at NT versus to CT. It is associated with increased moisture reserves of NT soil. In early spring, the moisture reserves in the soil layer of 0-150 cm deep with NT were 15.5 mm higher, and by the time of sunflower sowing – by 20.4 mm higher. The major indication of soil restoration at NT is better organic matter accumulation i.e. better soil fertility caused by soil microbiota (Bajbekov 2018, Kudeyarov 2015).

CONCLUSION

The present study indicated that in the south of the European part of the Russian Federation (Rostov region), in addition to cost reduction, NT contributes to increasing fertility of cultivated plants due to better moisture conservation and more favorable physical properties of soils during most of the growing season. Soil consistency in the study period is described as excellent and good, and only in dry and cold months as unsatisfactory. NT retains deposits of moisture during the growth season and improves the physical soil consistency, which increases agricultural crops fertility. During 2014-2018 years NT showed a decrease in the cost of winter wheat of 41-45% to versus to CT. NT application in the south of the steppe part of the Russian Federation can enhance agricultural crops fertility by improving ecological state of soil due to conserving moisture, improving soil consistency and activating microbiota. In order to improve black soils in southern Russia we recommend applying No-tillage management when growth various crops.

ACKNOWLEDGEMENTS

Authors would also like to express acknowledgements to the criticism and constructive comments of the anonymous referees.

REFERENCES

Baeva YI, Kurganova IN, Lopes de Gerenyu VO, Ovsepyan LA, Telesnina VM and Cvetkova YD 2017. Changes in the aggregate composition of various soil types during fallow succession. *Bulletin of the Soil Institute* **88**: 47-74. (In Russian)

Bajbekov RF 2018. Nature-like technologies are the basis for the sustainable development of agriculture. *Agriculture* **2**: 5-8. (In Russian)

Bogunović I, Kovács PG, Đekemati I, Kisić I, Balla I and Birkás M 2019. Long-term effect of soil conservation tillage on soil water content, penetration resistance, crumb ratio and crusted area. *Plant Soil Environment* **65**: 442-448.

Moebius-Clune BN, Moebius-Clune DJ, Gugino BK., Idowu OJ, Schindelbeck RR, Ristow AJ, van Es HM, Thies JE, Shayler HA, McBride MB, Wolfe DW and Abawi GS 2016. *Comprehensive Assessment of Soil Health Third Edition Interim* **22**:140.

Daraghmeh OA, Petersen CT, Munkholm LJ, Znova L, Obour PB, Nielsen SK and Green O 2019. Impact of tillage intensity on clay loam soil structure. *Soil Use and Management* 1-12.

Derpsch R, Friedrich T, Kassam A and Hongwen L 2010. Current status of adoption of no-till farming in the world and some of its main benefits. *International Journal of Agricultural and Biological Engineering* **31**: 1-26.

Di Prima S, Rodrigo-Comino J, Novara A, Iovino M and Cerdà A 2018. Soil physical quality of citrus orchards under tillage, herbicide, and organic managements. *Pedosphere* **28**(3): 463-477.

Feiziene D, Feiza V, Karklins A, Versuliene A and Antanaitis S 2018. After-effects of long-term tillage and residue management on topsoil state in Boreal conditions. *European Journal of Agronomy* **94**: 12-24.

Ferreira A, Carneiro Amado TJ, Rice ChW, Ruiz Diaz DA and Ruiz Potma Gonçalves D 2018. Driving factors of soil carbon accumulation in Oxisols in long-term no-till systems of South Brazil. *Science of The Total Environment* **622-623**: 735-742.

Gaevaya EA 2018. The influence of soil cultivation methods on the water-physical properties and productivity of spring barley when cultivated on the slope lands of the Rostov Region. *Scientific journal of the Russian Research Institute of Land Reclamation Problems* **31**: 132-147. (In Russian).

Haruna SI, Anderson SH, Nkongolo NV, Zaibon S 2018. Soil Hydraulic Properties: Influence of Tillage and Cover Crops. *Pedosphere* **28**(3): 430-442.

He JN, Yu ZW and Shi Y 2019. Effects of strip rotary tillage with subsoiling on soil enzyme activity, soil fertility, and wheat yield. *Plant Soil Environmental* **65**: 449–455.

He Zh, Tazisong IA, Yin X, Watts DB and Torbert HA 2019. Long-term cropping system, tillage, and poultry litter application affect the chemical properties of an Alabama Ultisol. *Pedosphere* **29**(2): 180-194.

IUSS Working Group WRB 2007. *World Reference Base for Soil Resources*, World Soil Resources Reports No. 103. FAO, Rome, 116.

Kazeev KS, Kolesnikov SI, Akimenko YV and Dadenko EV 2016. *Methods of biodiagnostics of terrestrial ecosystems*. Publishing House SFU, Rostov-na-Donu, 356 (In Russian).

Kazeev KS, Minnikova TV, Mokrikov GV, Myasnikova MA, Kolesnikov SI 2019. Assessment of the impact of direct sowing on the physical properties of chernozems of the Rostov region. *Agrophysics* **2**: 15-24 (In Russian).

Kazeev KS, Mokrikov GV, Akimenko YV, Kolesnikov SI 2017. Effect of no-till on the physical properties of south Russia soil. International Multidisciplinary Scientific GeoConference *Surveying Geology and Mining Ecology Management, SGEM* **17**(32): 185-192.

Kravcova NE, Mokrikov GV, Kazeev KS, Minnikova TV and Kolesnikov SI 2019. The dynamics of the content of nutrients in the chernozems of the Rostov region with different soil cultivation technologies. *Agrochemical Bulletin* **1**(1): 33-36. (In Russian)

Krovetto K 2010. Zero processing. The role of plant residues. *Resource-saving agriculture* **1**(5): 7-10. (In Russian).

Kudeyarov VN 2015. The current state of carbon balance and the ultimate ability of soils to absorb carbon in Russia. *Soil science* **9**: 1049-1060 (In Russian).

Minnikova TV, Mokrikov GV, Kazeev KS, Akimenko YV and Kolesnikov SI 2017. The influence of no-till technology on the nitrification activity of chernozems of the Rostov region. *Agrochemistry* **9**: 33-38 (In Russian).

Minnikova TV, Mokrikov GV, Kazeev KS, Akimenko YV and Kolesnikov SI 2018. Estimation of dependencies between hydrothermal indices and enzymatic activity of chernozems of the Rostov region using various agricultural technologies. *Agrophysics* **1**: 9-17 (In Russian).

Mokrikov GV, Minnikova TV, Kazeev KS and Kolesnikov SI 2019. The effect of productive moisture reserves and precipitation on crop yields under direct sowing of crops in the Rostov Region. *Samara Scientific Bulletin* 8 **1**(26): 69-75 (In Russian).

Nunes RM, Mathijs van Es H, Schindelbeck R, James Ristow A and Ryan M 2018. No-till and cropping system diversification improve soil health and crop yield. *Geoderma* **328**: 30-43.

Okada E, Costa JL and Bedmar F 2019. Glyphosate dissipation in different soils under no-till and conventional tillage. *Pedosphere* **29** (6): 773-783.

Otto R, Silva AP, Franco HCJ, Oliveira ECA and Trivelin PCO 2011. High soil penetration resistance reduces sugarcane root system development. *Soil and Tillage Research* **117**: 201-210.

Romanov VN, Ivchenko VK, Il'chenko IO and Luganceva MV 2018. The influence of the main tillage methods in crop rotation on the dynamics of moisture and agrophysical properties of leached chernozem. *Achievements of science and technology of the agro-industrial complex* **32**(5): 32-34 (In Russian).

Trofimova TA, Korzhov SI, Gulevskij VA and Obrazcov VN 2018. Assessing the degree of physical degradation and the suitability of chernozems to minimize the main tillage. *Soil Science* **9**: 1125-1131. (In Russian).

Val'kov VF, Denisova TV, Kazeev KS, Kolesnikov SI and Kuznecov RV 2007. Soil and environmental aspects of crop production. *Rostov-on-Don: Rostizdat*, 391. (In Russian)

Val'kov VF, Denisova TV, Kazeev KS, Kolesnikov SI, Kuznecov RV 2008. *Soil fertility and agricultural plants: Environmental aspects.* Rostov-on-Don: Publishing House of SFU, 416. (In Russian).

Yáñez-Díaz MI, Cantú-Silva I, González-Rodríguez H and Sánchez-Castillo L 2019. *Effects of land use change and seasonal variation in the hydro-physical properties in vertisols in northeastern Mexico.* Soil Use and Management, Available online: https://www.researchgate.net/publication/330891860

Zelenskij NA, Zelenskaya GM, Mokrikov GV and Shurkin AY 2018. Fertility of the soil: The present and future of our agriculture. *Agriculture* **5**: 4-7 (In Russian).

Zhang ZH, Li XY, Jiang ZY, Peng HY, Li L and Zhao GQ 2013. Change in some soil properties induced by re-conversion of cropland into grassland in the semiarid steppe zone of Inner Mongolia, China. *Plant Soil* **373**: 89-106.

Zhao X, Liu Sh, Pu Ch, Zhang X and Zhang H 2017. Crop yields under no-till farming in China: A meta-analysis. *European Journal of Agronomy* **84**: 67-75.

Received 15 July, 2020; Accepted 26 August, 2020

Indian Journal of Ecology (2020) 47(3): 676-680

Manuscript Number: 3064
NAAS Rating: 4.96

Hyper Spectral Imaging Technology for Seed Quality Identification

D. Madhusudhana Rao, B. Naga Sudheer, K. Sarada and A. Ramarao[1]

Department of IT, VFSTR (Deemed to be University), Vadlamudi-522 213, India
[1]Department of Applied Engineering, VFSTR (Deemed to be University), Vadlamudi-522 213, India
E-mail: madhudontha@gmail.com

Abstract: Agriculture is the backbone for any Nation. The quality of agriculture is depends on the amount of production. Seed is an elementary contribution in agriculture which is a supreme and crucial input for best crop production, one of the methods to surge the yield through the plantation of quality seed. It is the high time for reconsideration of the farming processes in the agriculture specifically the development of the seed in a low cost rate and the usage of a reduced amount of fertilizers. Hyperspectral imaging (HSI) technology is a procedure which makes use of different classification models such as Deep convolution Neural network (DCNN), Partial least squares regression (PLSR) and Deep Forest (DF) for the prediction of growth rate of the seed. The HSI system covering the spectral range of 948-2494 nm. The Deep Forest (DF) model to elevate spectral features in the seeds. In this study the hyperspectral images of seeds were used to get the objects. This paper represents a topo spectral view on using the various machine learning algorithms that evades the development of the seed in comparison with various machine learning algorithms.

Keywords: Seed quality, Hyperspectral imaging, Multivariate scatter correction, Deep convolution neural network, Random multi-graph (RMG), Deep forest model

Hyperspectral image can be used to measure the viability of a seed and in that measurement the evaluation of vigorous productivity in the seed can be obtained in the progressive outcomes. This development can be happened by using the progress of image acquisition with the support from the CNN models along with the deep forest algorithm-based measures that retrospect the productivity of the seed and its growth with respect to changes in the environment. The reason behind using these many techniques is the utilization of a design thinking measurement where we can attain a progressive outcome that inculcates the best fit algorithm to measure and analyze the productivity of the seed from evolution to revolutionary change. The primary stage in the evolution of the seed is the seed germination which is done by using hyperspectral image acquisition. The techniques or the methodologies that are chosen in the vigorous extension of the seeds depend on the seed choice that was chosen and the methodology that was used in building a seed into complete crop productivity. It is the task for extracting the variety of the features from the seed to evaluate the vigor growth productivity rate by taking a sample seed. With the use of CNN, the soya bean seed was tested for the germination growth. In order to classify the soya bean varieties, opted Near-infrared hyperspectral Imaging and applied it. Ahilya1 (NRC2), LSB1, CO Soya 2 and Sneh (KB79) are the variety of soya beans available. Using the basic CNN model the extraction of the average spectral values are taken from each soya bean and from which pixel wise spectra was built in order to evaluate the growth rate of the seed in various dimensions and in building a CNN spectra image makes a drastic and domestic growth in measure of the germination rate by evaluating the each sample in a generous way.

When the seed sample that is taken is revamped the attributes that constitute the quality are also revamped simultaneously when there is another consideration of sample seed like muskmelon the resultants change. The reason behind conducting a progressive test is when the results change the predictive analysis of growth rate with regard to identities can be measured and induced new technological support assistance required in attaining various solutions to a particular problem. The reason behind this analysis is that a single problem check regarding the quality of a seed has multiple range of solutions and admitting a best fit model that evaluates the growth rate and quality of a seed is the challenge that is taken to resemble the measurements and building a good farming crop for the farmer. The technologies such as chemo metrics-based and genetic analysis considered dominant sources in identifying the seed varieties in a very accurate manner.

MATERIAL AND METHODS

Image acquisition: Three varieties of soya beans such as Ahilya1 (NRC2), LSB1, CO Soya 2 and Sneh (KB79) were

used. The variation of the variety of a soya bean taken from the sample are checked for quality which deserves the attributes like vigour, generic purity and physical purity the produces a qualitative seed. This result produces a major contribution towards the growth with regard to check sum of a quality.

Image acquisition and correction: In this study, a near-infrared hyperspectral image system casing range of 958-2393 nm was used for acquiring hyper spectral images. The below Figure 2 shows major Components of hyper-spectral image system.

Seeds were positioned in the sampler distinctly. The significant determining aspects which enhance the image class for apprehending vibrant hyper-spectral and non-deformable images. The distance between the lenses of camera to that of sampler, the promptness of mobile stand, the projection angle of light, the reflection intensity from mirror and the contact time respectively. The attained hyperspectral images were with light intensity which has to be amended as the reflectance images. The Figure 3 is a model of seed scanner for acquiring seed samples.

With the help of Teflon white tile, we can obtain white reference image with a reflectance of 96% and by turning off the light source, we can obtain the dark reflectance image by engaging camera lens with a cap. The effects of the white and dark reference images are detached for extracting an IR response. The calibrated image was calculated as follows:

$$I_{Cal} = \frac{I_{raw} - I_{dark}}{I_{ref} - I_{dark}}$$

Data abstraction and preprocessing: The calibrated image was segmented with the help of threshold value. The image still has some dead pixels due to camera and these dead pixels were detached by a 4× 4 median filter. Moreover, ROI step was implemented on the image for extracting statistical and spectral signature information. A Region of Interest comprising about 190 ± 10pixels was designated for seed image accordingly. In total, 180 average spectra demonstrating the 208 scanned seeds were intended and hoarded for future study amongst the effects of the germination and variable selection methods. Spectral data was mined from the hyperspectral images by image amendment. Due tothe restrictions, the reflectance standards cannot be taken into consideration due to captured image noise. Only reliable range of images was used for further analysis. The spectral range of 451-879 nm was nominated for visible hyper spectral images and the spectral range of 95-1887 nm was nominated for near-infrared images. At this point, a third level decomposition was used as a pre-processing stage to attain levelled images. Later pre-processing of the image dimension, the segmentation of images was used on the 3-D dimensions. Mostly, black background reflectance values are noted to be near zero. Then, individual group of associated pixels is observed as a soya bean seed. For each seed, total pixel based images were comprised to single spectrum of image for further study.

Feature extraction: The collective spectral and spatial features are provided for the classification using RMG which is considered to resolve the difficulty in recognition. It



Fig. 1. Soya beans of different varieties

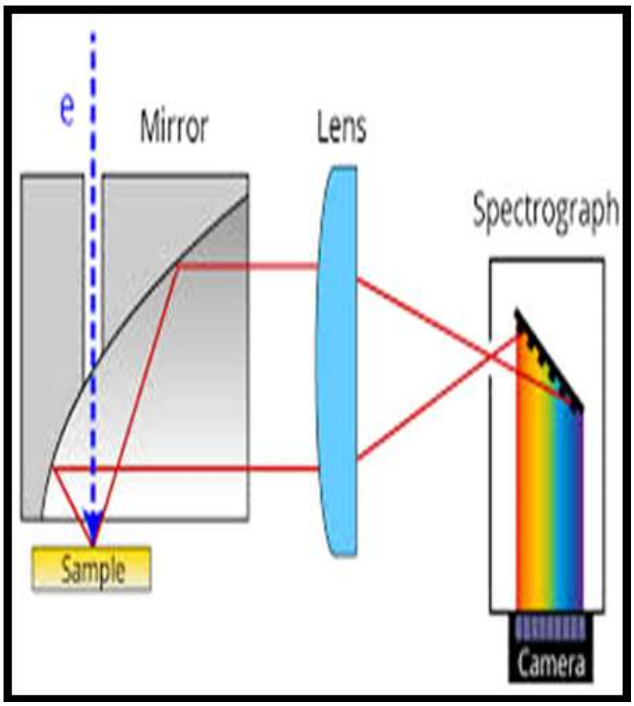


Fig. 2. Major components of hyper-spectral image

attempts to accomplish 2 major goals like: to evade the improper dimensionality and extra fitting by using randomness. The next one is to deliver an innovative framework which can lever higher dimension and larger data difficulties. The Figure 4 represents RMG image features recognition process. Given a dataset comprised of labelled data

X_{lab} = [x1, x2, . . . , xl] and unlabelled data X_{unlab} =xl+1, xl+2, . . . , xl+u], we can obtain a weighted graph. In the graph, the vertices consist of N = l + u data points. The edges in the graph with weights represent the similarity between the affiliated nodes, and these edges can be represented by a weight matrix W 2 RN_N. Once the graph is built, the label information is injected into the graph and propagated throughout the whole graph to obtain the labels for the unlabelled data. Specifically, if the weight w_{ij} is large, then the labels of the adjacent vertices $x_i$and x_j are considered to have the same label. The whole framework of RMG can be described as follows:

Step 1: Randomly select k f features from all the high dimensional features of each sample.

Step 2: Select m anchor points to cover the data manifold denoted by an anchors matrix, and then

Compute the mapping matrix P to represent the rest of the data points via the selected anchors.

Step 3: Run semi-supervised inference on this graph by using graph Laplacian Regularization.

Step 4: Repeat the above steps to get kg graphs.

Step 5: kg graphs are voted to obtain the labels for the unlabelled data points.

In this study, sample average spectra and pixel-wise spectra were both used and wavebands ranging from 975 to 1646 nm of hyperspectral images were studied. Figure shows the procedures of spectral data extraction and pre-processing. Firstly, single soya beans were segmented from the background. Grey-scale images at 1200 nm were used to form binary images (soybean regions as '1' and background regions as '0') to isolate the soybeans from the background of near-infrared hyperspectral images. Then, the binary images were multiplied with the grey-scale images at each wavelength to remove the background. Pixel-wise spectra within each soybean were pre-processed by wavelet transform. Pixel-wise spectra of each soybean were exacted and pre-processed, and the pre-processed spectra were then averaged to represent the soybean. Both pixel-wise spectra and the average spectrum of each soya bean were studied. To specify the difference between pixel-wise spectra and average spectra, models using pixel-wise spectra were defined as pixel-wise models, and models using average spectra were defined as object-wise models. The below Figure 5 represents how required features are extracted from hyper spectral image soya beans.

Apply Various Algorithms

K-nearest neighbour: The KNN algorithm is both a theoretically mature algorithm and one of the simplest algorithms in machine learning. The core idea of the KNN algorithm is that if the majority of the k most neighbouring samples in a feature space belong to certain category. This study used an automatic optimization parameter program to determine the k value of the model.

Support vector machine: SVM is mostly based on a structural risk minimization, finding the basic segmentation hyper plane between the data, maximize the spacing, and

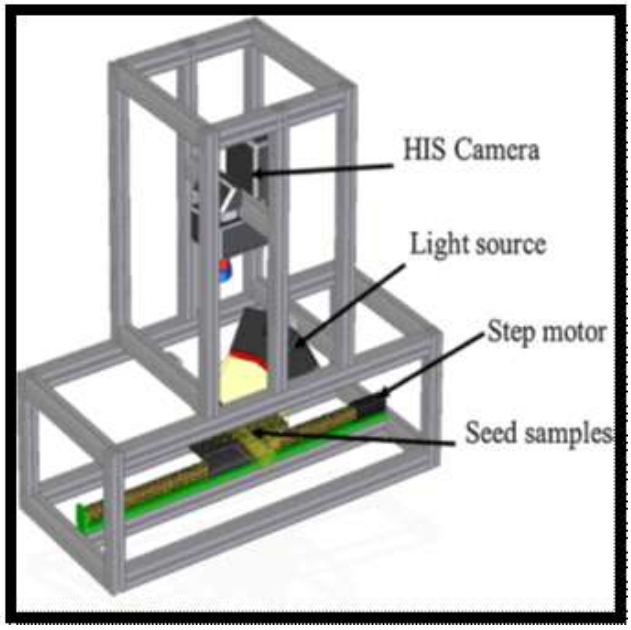


Fig. 3. Seed samples scanner

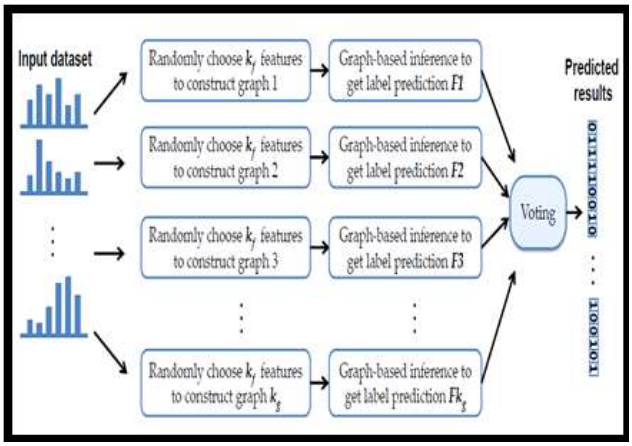


Fig. 4. Feature extraction

achieve data classification. SVM generally has linear kernel function, polynomial kernel function, and radial basis function (RBF) kernel function. This study used the RBF kernel function, which can effectively process linear and nonlinear data.

Deep forest: DF is a deep learning algorithm that is a new tree-based model comparable to deep neural networks. It uses the structure of the cascaded forest for representational learning. The DF consists mainly of two modules: a multigranularity scanning module and a cascaded forest module.

RESULTS AND DISCUSSIONS

In order to predict the feasibility, viability and vitality in seeds, a NIR hyper spectral imaging system was used and a NIR push-broom HSI system is used for acquiring the hyper spectral images of these seeds by casing the spectral range of 958-2393 nm. Moreover, Non- germinated seeds and the seeds of 4-5 germination days were further used for the progress of a cataloging model of Partial Least Squares Discriminated Analysis (PLSDA). Based on these 3 model-based variable selection methods such as variable important in projection (VIP), selectivity ratio (SR), and significance multivariate correlation (SMC) are best active wavelengths were nominated with optimal variables as 24, 18, and 20 from full set of 210 variables. The Figure 6 shows level of accuracy for DF, CNN, KNN and SVM for various classes of seeds given in Table 2.When different algorithms is compared DF shows best accuracy. The various accuracy percentages among SVM, CNN, DF and KNN for various classes of seeds when different algorithms are compared DF shows best precision and accuracy percentage (Table 1). Accuracy

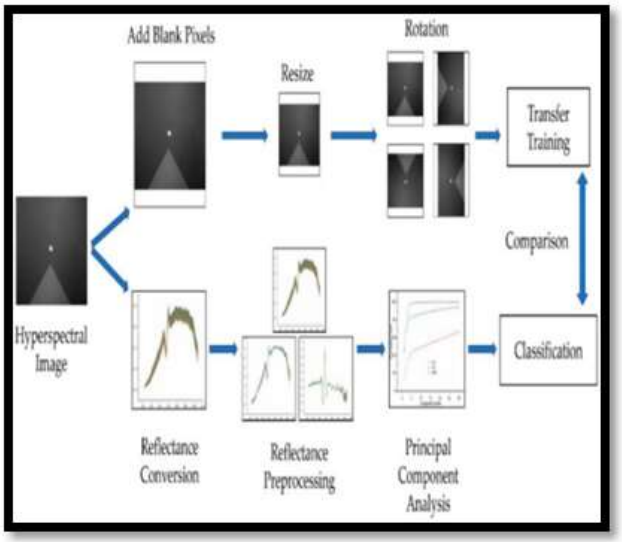


Fig. 5. Feature extraction in Soya bean

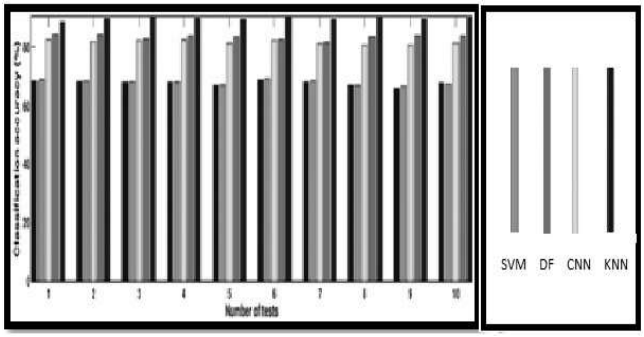


Fig. 6. KNN accuracy

Table 1. Deep forest accuracy

Deep/shallow classification	Machine learning			
	CNN	DF	KNN	SVM
Precision	0.9730	0.9792	0.9625	0.8214
Recall	0.9731	0.9790	0.9626	0.7334
F1-Score	0.9732	0.9791	0.9627	0.6942
Accuracy	0.9738	0.9751	0.9633	0.7444

Table 2. SVM accuracy

Class	Producer accuracy (%)			User accuracy (%)		
	DF	SVM	KNN	DF	SVM	KNN
Wheat	80.0	83.4	89.7	81.1	76.2	77.6
Paddy	82.4	85.2	91.6	85.6	76.5	69.8
Ragi	100	96.4	93.8	100	94.5	92.7
Barley	91.7	86.2	84.9	93.4	86.8	87.8
Maize	98.4	92.6	91.9	99.1	90.2	89.2
Bajra	85.4	83.6	90.3	89.2	72.8	69.5
Jowar	90.9	91.2	98.4	92.3	89.4	86.2

percentages among SVM, DF and KNN for various class with different algorithms are compared DF shows best accuracy percentage (Table 2).

CONCLUSIONS

The above analysis understands the growth and the germination of variety of seeds is by using the Deep Forest algorithm that gives a very good accuracy but the result analysis may vary depends on the variety of seeds used and analysing them with the adaptability and understanding the seed production with the variety of seeds used in the seed productivity.

REFERENCES

Ana Paula BR, Renato G, Luiz AG and Lireny AG 2009. Zero Trans fats from soybean oil and fully hydrogenated soybean oil:Physico-chemical properties and food applications. *Food Research International* **42**(3): 401-410.

Anchal B, Dhirendra K, Priya N and Niraj T 2015. SSR analysis of 38 genotypes of soybean (Glycine mox (l.) merr.) genetic diversity in India. *Journal of Physiology and Molecular Biology of Plants* **21**(1): 109-115.

Anisur R and Byoung-Kwan Ch 2016. Assessment of seed quality using non-destructive measurement techniques: A review. *Journal of Seed Science* **26**(1): 285-305.

Armstrong P, Maghirang E and Ozulu M 2019. Determining damage levels in wheat caused by Sunn pest (Eurygaster integriceps) using visible and near-infrared spectroscopy *Journal Cereal Science* **86**: 102-107.

Bender RR, Haegele JW and Below FE 2015. Nutrient uptake, partitioning, and remobilization in modern soybean varieties. *Agronomy Journal* **107**: 563-573.

Boelt B, Shrestha S, Salimi Z, Jørgensen, JR, Nicolaisen M and Carstensen JM 2018. MultispectralImaging-A new tool in seed quality assessment.*Journal of Seed Science Research* **28**(3): 222-228.

Dell'Aquila A 2007. Towards new computer imaging techniques applied to seed quality testing and sorting. *Journal of Seed Science Technology* **35**(3): 519-538.

Huang M, Tang J, Yang B and Zhu Q 2016. Classification of maize seeds of different years based on hyperspectral imaging and model updating. *Computer Electron Agriculture* **122**: 139-145.

Kandpal LM, Lohumi S, Kim MS, Kang J and Cho B 2016. Near-infrared hyperspectral imaging system coupled with multivariate methods to predict viability and vigor in muskmelon seeds. *Sensors Actuators B Chemistry* **229**: 534-544.

McCarville MT, Marett CC, Mullaney MP, Gebhart GD and Tylka GL 2017. Increase in soybean cyst nematode virulence and reproduction on resistant soybean varieties in Iowa from 2001 to 2015 and the effects on soybean yields. *Plant Health Programme* **18**: 146-155.

Min H, Chujie He, Qibing Zhu and Jianwei Qin 2016. Maize seed variety classification using theintegration of spectral and image features combined with feature transformation based on hyperspectral imaging. *Journal of Applied Science* **6** (1): 1-12.

Qiu Z, Chen J, Zhao Y,Zhu S, He Y and Zhang C 2018. Variety identification of single rice seed using hyperspectral imaging combined with convolutional neural network, *Applied Science* **8**(2): 212.

Teng W, Li W, Zhang Q, Wu A, Zhao X,Li H, Hass Y and Li W 2017. Identification of qu7antitative trait loci underlying seed protein content of Soybean including main, epistatic and QTL x environment effects in different regions of Northeast China. *Journal of Plant Breeding* **60**(8): 649-655.

Received 01 July, 2020; Accepted 26 August, 2020

Indian Journal of Ecology (2020) 47(3): 681-685

Manuscript Number: 3065
NAAS Rating: 4.96

Growth, Yield and Nutrient Uptake of Knol-Khol (*Brassica oleracea Var. gongylodes*) as Influenced by Organic Manures, Inorganic Fertilizers and Biochar

Ashaq Hussain, Manzoor A. Ganai, Mudasir A. Shan, Intikhab Aalum Jehangir*, Shabir H. Wani and Aziz M.A.

Mountain Research Centre for Field Crops
Sher-e-Kashmir University of Agricultural Sciences and Technology, Khudwani, Anantnag-192 102, India
**E-mail: intikhabaalum@gmail.com*

Abstract: An experiment on the effect of organic manures, fertilizers and biochar on knolkhol was conducted during 2014. Highest no. leaves/plant, leaf area/plant, specific leaf weight, fresh and dry leaf and knob weight was recorded ,when enriched FYM was applied in combination with biochar, with an increase of 19.5% in fresh leaf weight and 57% in fresh knob weight over enriched FYM alone. Enriched FYM+ biochar recorded an increase of 194, and 241% over control in respect of fresh and dry root biomass, respectively. Enriched FYM + biochar recorded a significantly increase in N concentration in above ground biomass over all other treatments. However, enriched FYM + biochar was at par with inorganic fertilizer, FYM and Enriched FYM in respect of P concentration. Highest N, P and K uptake was recorded in enriched FYM+ Biochar which was followed by enriched FYM + ash. Addition of biochar resulted in a significant decrease both wet and dry bulk density. Further a significant increase in soil available N was recorded due to the application of enriched FYM + biochar. Soil available K recorded a significant increase in FYM and enriched FYM pots. Enriched FYM +biochar in combination with FYM resulted in a significant increase in soil available K.

Keywords: Knoll khol, FYM, Enriched FYM, Biochar, Ash

Knol-khol (*Brassica oleracea var. gongylodes*) is a popular vegetable in Jammu & Kashmir, West Bengal, Maharashtra, Assam, Uttar Pradesh, Punjab and some parts of South India. Plants require an adequate and proportionate supply of all essential nutrients for optimum growth and productivity. Balanced use of plant nutrients corrects nutrient deficiency, improves soil fertility, increases nutrient and water use efficiency, improves crop and environmental quality, and above all enhances crop yields and farmers' income. Knol-khol responds well to manuring, as it is a heavy feeder. A yield of 20 tonnes/ha removes about 100 kg N, 85 kg P and 170 kg K. Excess of N may cause abundant leafy growth and a delayed crop maturity. Optimum N and K doses are necessary to get good flavoured knobs. Although the organic manures contain major nutrients in small quantities as compared to the chemical fertilizers, but the presence of organic carbon and growth promoting principles like enzymes and hormones, make them a preferential choice for improvement of soil fertility and productivity (Bhuma 2001). For the reuse of organic waste material many approaches are being used and composting is one of them.

Farmers use farmyard manure (FYM) on a large scale in vegetable and cereal crops. However the percent nutrient content of FYM are 0.5 N, 0.1 P and 0.5 K which is very low and release takes still longer time to meet the crop nutrient demands. Strategies to improve the nutrient content of FYM include either the addition of biofertilizers or inorganic fertilizers or both. Nitrogen, phosphorous and potassium fertilizers are added to FYM and the mixtures is incubated to enhance the nutrient content and changes the nutrient dynamics in favour of plant growth. The inorganic nutrients are converted into organic form through microbial processes and improve the nutrient use efficiency. Large quantities of rice and wheat straw are burnt every year that results in not only loss of nutrients but also increases the environmental pollution. A useful technological intervention can be the conversion crop residue into biochar. Pyrolysis of crop residue in limited supply of oxygen enhances the yield of biochar. There are a large number of reports about the use of biochar for enhancing the growth and yield of vegetables. Addition of biochar results in the conversion of organic carbon into inert carbon and has the potential to reduce the atmospheric carbon dioxide concentration and GHG emissions from the agricultural soils. Biochar acts as source of mineral nutrients and alters the soil nutrient dynamics (Sohi et al 2010). Apart from the above amendments use of ash prepared from the crop residue is a potential source of minerals keeping in view the high demand of nutrients. Ash is

rich source of potassium, calcium iron etc. and it favourably alters the soil pH and EC. Using organic sources like farm yard manure, enriched organic manure biochar and ash deserve priority for sustained production and better on farm resource utilization. With this background a pot study on the use of organic manures, inorganic fertilizers and biochar was conducted to assess their effect on growth, yield and nutrient uptake of knol-khol (*Brassica oleracea var. gongylodes*) under Kashmir conditions.

MATERIAL AND METHODS

A pot experiment was conducted on knol-khol (*Brassica oleracea var. gongylodes*) at Mountain Research Centre for Field Crops (MRCFC), SKUAST-K, Khudwani, Anantnag, J&K. The centre is located at an altitude of 1595 m amsl, latiute 34.09' and longitude 74.79'. The experimental soil was clay loam in texture, neutral in reaction, low in soil available nitrogen (206 kg/ha) and phosphorous (10.5 kg/ha) and medium in soil available potassium (262kg/ha soil).

Preparation of the nutrient sources

Enriched farm yard manure: Ten kg fresh farm yard manure was spread on a concrete floor. To this was added 20 g N, 10 g of P_2O_5 and 5 g of K_2O using urea, diammonium phosphate (DAP) and muriate of potash (MOP) as respective nutrients sources. The mixture was incubated in a polyhouse for three months. The mixture was given turnings and maintained at constant moisture (60%) inside a polyhouse for three months. Addition of fertilizers resulted in faster decomposition and a composted material of high quality was thus obtained in 3 months.

Biochar and ash: An iron *bukari* (space heater used for heating in winters in northern India) was used for the preparation of wheat straw based biochar. Locally available field dried wheat straw was chopped and tightly packed in the *bukhari.* The container was heated by external combustion of fuel wood in a locally made brick kiln to obtain a temperature of greater than 400^{0}C. The air circulation vent was closed immediately after white smoke began to emit. This helped in regulation of oxygen supply and fast conversion of wheat straw into biochar. The biochar so obtained was further micronized in wooden pestle and mortar. Ash was prepared by burning of the wheat straw in open till it got turned into a silver coloured material.

Preparation of pots: Upper 15 cm of the soil was collected from a field which was under brown *sarson* (*Brassica campestris var. rapa*) during preceding years. The soil was thoroughly mixed by giving many turnings to make it homogenous. The soil for each pot was prepared as per the treatments details (Table 1). Each pot was filled with 4 kg of soil and planted with one seedling per pot of knolkhol variety White Vienna. The experiment was conducted in completely randomized design with three replications in plastic pots.

Table 1. Description of the treatments imposed on knolkhol

Code	Treatment	Dose
T_1	Control	No nutrient
T_2	FYM	100 g/pot
T_3	Synthetic fertilizer	2 g N+ 1g P_2O_5 + 0.5g K_2O/pot
T_4	Enriched FYM	100 g FYM + 2 g N; 1 g P_2O_5; 0.5 g K_2O /pot)
T_5	Biochar	100 g/pot
T_6	Enriched FYM + biochar	100 g FYM + 2 g N; 1 g P_2O_5; 0.5 g K_2O/pot +100 g biochar/pot
T_7	Enriched FYM +Ash	100 g enriched FYM + 50g ash/pot

Biometric observations: The plants were cut at the ground level and the fresh weight was taken immediately on a digital balance. The leaves along with their stalks were plucked immediately for taking fresh leaf weight. The fresh leaf weight was deducted from the total fresh weight to get the fresh knob weight. All the leaves from one plant were cut and their area was measured using a leaf area meter Systronics 211.The knobs and the leaves were first air dried and then placed in oven at 65^{0}C till constant weight was attained. The roots were recovered from each pot by washing method. The soil along with the roots was placed on the wire mesh under tap. The soil passed through the mesh whereas, the roots were retained. The roots were wrapped in a tissue paper to remove the surface moisture and immediately weighed on a digital balance. The air dried roots were placed in oven at 65^{0}C till constant weight was attained.

Plant analysis: Total N content estimation was carried out using Kjeldahl digestion and distillation procedure. Di-acid ($HClO_4$ + HNO_3) digestion was used for the estimation of total P, K in plant samples. P concentration was estimated through vanadomolybdate yellow colour method (Jackson 1973) and K concentration was measured using flame photometry. The uptake of nutrients was computed by multiplying total yield (knob + leaf) with their respective nutrient concentrations (Jackson 1973). The soil pH and EC were measured using pH meter and electrical conductivity meter respectively.

Nutrient uptake = Nutrient concentration x dry matter yield

Soil analysis: Each pot was irrigated and soil samples were collected after 24 hours. The soil samples were collected using a soil sampler of 4 cm diameter and samples were collected from 0-10 cm depth. The samples were weighed immediately to record the fresh weight. The samples were placed in oven at 105^{0}C till constant weight was attained**.** The soil samples were air-dried, ground and passed through 2 mm mesh sieve and were analysed for available N (Subbiah

and Asija 1956), total N using Kjeldalh method (Jackson 1973), available P (Olsen et al 1954), available K and non exchangeable K, (Jackson, 1973).

RESULTS AND DISCUSSION

Growth parameters: There was a significant effect of the nutrient sources on number of leaves/plant (Table 2). Enriched FYM+ Biochar produced double the number of leaves as compared to control. Enriched FYM+ ash was second best in terms of the no of leaves plant^{-1}. The superiority of enriched FYM+ biochar was proportionately also reflected in leaf area plant^{-1}. Highest specific leaf weight was also recorded in enriched in enriched FYM+ biochar which were followed by enriched FYM alone. All the three growth parameters were reduced not only in control but also in biochar applied pots. Addition of fertilizer not only enhanced the nutrient content of FYM but also prolonged their availability to the plant through increase in residence time. A number of workers have reported a higher efficiency of nutrients when applied along with the organic manures (Blackwell et al 2007, Steiner et al 2007 , Jehangir et al 2012, Zhang et al 2012). Biochar by itself had no effect on rice and sorghum yield (at 11t/ha rate), yet biochar with fertilizer increased yield by 73, 82, 50 and 100% over four harvests, compared with fertilizer alone. Results from semi-arid soils in Australia have shown positive response to biochar in combination with fertilizer in pot trials (Chan et al 2007).

Table 2. Effect of nutrient sources on number of leaves, leaf area and specific leaf weight of knolkhol

Treatment	Number of leaves plant^{-1}	Leaf area (cm^2 plant^{-1})	Specific leaf weight (mg cm^{-2})
Control	9.0	246.8	22.10
FYM	10.0	401.1	22.56
Synthetic fertilizer	10.7	567.8	24.19
Enriched FYM	12.7	590.1	25.08
Biochar	8.0	238.0	21.76
Enriched FYM + biochar	16.0	705.2	27.32
Enriched FYM +ash	14.3	642.6	24.28
CD (p=0.05)	1.48	76.71	0.31
SE m (±)	0.69	35.77	0.41

Fresh leaf and knob yield: The treatment had a significant effect on fresh leaf and knob yield (Table 3). Control pots had the lowest and enriched FYM + biochar had the highest fresh leaf and knob weight with 203 % increase over control. Combined application of FYM and fertilizer after incubation also resulted in a significant increase in the fresh biomass yield. The fresh leaf weight increased significantly in all the nutrient sources over control. However, the increased very sharp with the application enriched FYM +biochar. In enriched FYM + biochar an increase of 19.5% in leaf weight and 57% in knob weight was observed over enriched FYM alone. Application of biochar alone had slightly depressing effect on the total fresh weight. However its combination with the enriched FYM displayed synergistic effect and resulted considerable increase in growth and final biomass. Application of ash in combination with enriched FYM also resulted in significant increase in knob and total fresh weight than the application of enriched FYM alone. A similar trend was reflected in dry leaf + knob weight with enriched FYM + biochar maintaining a consistent superiority over other treatments. The increase in the above ground biomass was also reflected by increased root growth (Plate 1). Enriched FYM+ biochar recorded an increase of 194, and 241% over control in respect of fresh and dry root biomass, respectively. The same trend was reflected in root length (Plate 1). The biochar alone had some stimulatory effect on root biomass and root length and the same was significantly higher than control but at par with FYM and synthetic fertilizer. Application of biochar to the unfertilized soil might have locked the

Table 3. Effect of nutrient sources leaf weight, knob weight, root weight, dry root weight (fresh and dry) and root length of knolkhol

Treatment	Fresh weight			Dry weight			Root weight		Root length (cm)
	Leaf	Knob	Total	Leaf	Knob	Total	Fresh	Dry	
Control	64.4	38.6	103.0	5.74	3.94	8.69	6.14	1.43	7.21
FYM	71.7	60.2	131.9	9.87	8.30	18.17	10.69	2.84	9.24
Synthetic fertilizer	103.3	93.6	197.0	13.98	12.66	26.64	9.19	2.19	10.67
Enriched FYM	119.8	107.6	227.5	16.15	14.50	30.64	15.51	4.18	12.49
Biochar	53.7	47.2	100.0	5.18	4.00	9.18	11.80	3.11	14.74
Enriched FYM + biochar	143.2	169.27	312.5	17.89	21.13	39.02	18.03	4.88	15.64
Enriched FYM +ash	126.8	134.84	271.7	18.49	18.21	36.70	16.03	4.32	13.39
CD (p=0.05)	15.8	14.47	27.0	2.19	1.77	3.57	0.85	0.30	0.91

nutrients already present concurrently leading to their decreased availability to the plant. Researchers in Brazil (Steiner et al 2007) observed that while forest wood biochar with fertilizer had no effect on sorghum yield, biochar with fertilizer and compost increased yield by 250%. Sohi et al (2010) mentioned the potential of biochar to immobilize previously plant available N. Progressive increase in the supply of nutrients and improvement in the soil physical properties might have resulted in favourable improvement in the root rhizospheric environment which might have stimulated the root growth. Addition of biochar to enriched FYM further enhanced the root growth due improvement in the soil physico- chemical properties. Pre-incubation of organic manures and N and P mixtures results in the conversions of inorganic form of nutrients into organic and therefore makes them unavailable for leaching or fixation. It is due to this reason that the response to enriched FYM is higher than the application of the fertilizer alone. The semi-arid soils in Australia have shown positive response to biochar in combination with fertilizer in pot trials (Chan et al 2007), and in Indonesia maize and peanut yields were enhanced where bark charcoal was applied in combination with N fertilizer in the field (Yamato et al 2006).

Plant nutrient concentration and uptake: The enriched FYM + biochar was at par with inorganic fertilizer, FYM and enriched FYM in respect of P concentration. Enriched FYM + biochar and enriched FYM +Ash registered higher K concentration in the above ground biomass (Table 4). Enriched FYM + biochar recorded the highest N, P and K uptake pot^{-1} which were 403, 589 and 403% higher over control. Higher yield and N uptake in pot trials using radish crop was also reported by Chan et al 2007; Chan et al 2008.

Soil properties and fertility status: Addition of biochar resulted in a significant decrease both wet and dry bulk density (Table 5). The wet and dry bulk density decreased from1.76 $g/cm^3$to 1.63 g/cm^3 in control and enriched FYM + biochar, respectively. The corresponding figures in dry bulk density were 1.33 g/cm^3 and 1.20 g/cm^3, respectively. There were significant increases in the moisture content on dry weight in FYM and biochar applied pots. The increase soil available N was significant due to the application of fertilizer N. However, a further increase in soil available N was recorded due to the application of enriched FYM + biochar. Although the increase in soil available P was non-significant

Table 4. Effect of nutrient sources in plant nutrient concentration (mg/kg) and uptake (mg/pot) of knolkhol

Treatment	Nutrient concentration (%)			Nutrient uptake (mg pot^{-1})		
	N	P	K	N	P	K
Control	0.21	0.03	0.21	203	25	195
FYM	0.22	0.03	0.22	405	58	399
Synthetic fertilizer	0.23	0.04	0.23	558	89	552
Enriched FYM	0.24	0.04	0.23	797	124	756
Biochar	0.20	0.03	0.22	377	52	402
Enriched FYM + biochar	0.25	0.04	0.24	1026	170	980
Enriched FYM +Ash	0.23	0.04	0.24	926	152	923
CD (p=0.05)	0.005	0.001	0.008	91.70	14.20	82.86

Table 5. Effect of nutrient sources on soil bulk density, soil moisture content, nutrient status, EC and pH

Treatment	Wet bulk density (g/cm^3)	Dry bulk density (g/cm^3)	Moisture content (%)	N (mg/kg)	P (mg/kg)	K (mg/kg)	pH	EC (ds/m)
Control	1.76	1.33	33.42	83	5.15	112	6.88	0.12
FYM	1.74	1.29	35.41	105	5.41	123	6.87	0.11
Synthetic fertilizer	1.80	1.35	33.21	111	5.57	129	6.81	0.11
Enriched FYM	1.71	1.27	35.13	119	5.62	134	6.79	0.11
Biochar	1.67	1.24	35.41	80	5.35	117	6.98	0.13
Enriched FYM + biochar	1.63	1.20	35.79	125	5.62	140	7.00	0.13
Enriched FYM +Ash	1.70	1.26	35.22	119	5.51	136	6.79	0.13
CD (p=0.05)	0.05	0.04	1.04	7.71	NS	10.67	0.012	0.005



Plate 1. Effect of nutrient sources on root growth of knolkhol

but soil available K recorded a significant increase in FYM and enriched FYM pots. Again the application of biochar resulted in further increase in soil available K when applied in combination with enriched FYM. Biochar resulted in a significant increase in soil pH and electrical conductivity. In a tropical environment topsoil bulk density was approximately 10% lower at old kiln sites due to the presence of aged biochar than in nearby soils (Oguntunde et al 2008). Both the mineral and the organic components of soil influence water holding capacity. Although higher levels of soil organic matter increase water-holding capacity and can be deliberately managed, changes will be temporary unless a regime is maintained. The aforementioned changes in soil properties caused by biochar, increase in soil field capacity and decrease soil compaction, may be less relevant under our experimental conditions (Sohi et al 2010).

CONCLUSION

Application of enriched FYM + biochar resulted in a significant increase in growth parameters, leaf yield, knob yield, N, P and K uptake, improvement in soil physical properties and nutrient availability. Use of FYM enriched with nutrients in combination biochar can be a useful strategy in increasing knol khol yield and soil health.

Received 07 June, 2020; Accepted 26 August, 2020

REFERENCES

Bhuma M 2001. *Studies on the impact of humic acid on sustenance of soil fertility and productivity of greengram*. M.Sc. (Ag) Thesis, TNAU, Coimbatore.

Blackwell P, Shea S, Storer P, Solaiman Z, Kerkmans M and Stanley 2007. Improving wheat production with deep banded oil mallee charcoal in Western Australia. In 'Proceedings of the *International Agrichar Initiative Conference*, 29 April-2 May 2007, Terrigal, New South Wales.'

Chan K, Zwieten Y, Van L, Meszaros Downie A and Joseph S 2008. Using poultry litter biochars as soil amendments *Soil Research* **46**(5): 437-444.

Chan KY, Van Zwieten L, Meszaros I, Downie A and Joseph, S 2007. Agronomic values of green waste biochar as a soil amendment. *Australian Journal of Soil Research* **45**: 629-634.

Oguntunde PG, Abiodun BJ, Ajayi AE and van de Giesen N 2008. Effects of charcoal production on soil physical properties in Ghana**.** *Journal of Plant Nutrition and Soil Science* **171**: 591–596.

Jackson ML 1973. *Soil chemical analysis*. Prentice Hall of India Pvt. Ltd., New Delhi.

Jehangir IA, Wani GA, Rasool-Ur-F, Ali T and Bangroo SA 2012. Influence of row spacing and fertilizer management on growth and yield of field pea (*Pisum sativum* var *arvense*). *Indian Journal of Ecology* **39**(2): 323-324.

Olsen SR, Cole CV, Watanabe FS and Dean LA 1954. *Estimation of available phosphorus in soils by extraction with sodium bicarbonate*. USDA Circ.No.939, Washington.

Sohi SP, Krull E, Lopez-Capel E and Bol R 2010. A Review of Biochar and its Use and Function in Soil. In DONALD L. SPARKS editor Burlington: Academic Press: *Advances in Agronomy* **105**: 47-82.

Steiner C, Teixeira WG, Lehmann J, Nehls T, Vasconcelos de Macedo JL, Blum WEH and Zech W 2007. Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil. *Plant and Soil* **291**: 275-290.

Subbiah BV and Asija GL 1956. A rapid procedure for estimation of available nitrogen in soils. *Current Science* **25**(8): 259-260.

Yamato M, Okimori Y, Wibowo IF, Anshori S and Ogawa M 2006. Effects of the application of charred bark of Acacia mangium on the yield of maize, cowpea and peanut, and soil chemical properties in South Sumatra, Indonesia. *Soil Science Plant Nutrition* **52**: 489-495.

Zhang A Liu Y, Pan G, Hussain Q, Li L, Zheng J and Zhang X 2012. Effect of biochar amendment on maize yield and greenhouse gas emissions from a soil organic carbon poor calcareous loamy soil from Central China Plain. *Plant and Soil* **351**: 263-275.

Indian Journal of Ecology (2020) 47(3): 686-689

Manuscript Number: 3066
NAAS Rating: 4.96

Productivity of Spinach Beet as Influenced by Varieties and Nutrients in Humid Tropical Conditions of South Kerala

Vinod Alur and Sheeba Rebecca Isaac*

Department of Agronomy, College of Agriculture, Kerala Agricultural University
Vellayani, Thiruvananthapuram-695 522, India
**E-mail: sheebarebecca@yahoo.co.in*

Abstract: A field experiment was conducted at College of Agriculture, Vellayani, Thiruvananthapuram to assess the influence of varieties and nutrient levels on the growth and leaf yield of spinach beet (*Beta vulgaris* L. var. *bengalensis*), in split plot design with four replications. The treatments included five varieties (All Green, Punjab Green, Pusa Bharathi, Indam Kolakatta, Trendy) in main plots and three nutrient doses (80:40:80, 60:30:60 and 40:20:40 kg NPK ha^{-1}) in sub plots. The variety All Green was significantly superior in terms of the number of leaves, leaf area index (LAI) and yield. The maximum leaf yield in All Green was followed by Pusa Bharathi. The effect of the nutrient levels was also significant, superior values for growth and yield were recorded with the highest dose of 80:40:80 kg NPK ha^{-1}. Among interactions, the combination of Pusa Bharathi and 80:40:80 kg NPK ha^{-1}, resulted in significantly higher yields at par with All Green + 80:40:80 kg NPK ha^{-1}. The economics of cultivation assessed in terms of B:C ratio were 1.25 and 1.21 for Pusa Bharathi and All Green at 80:40:80 kg NPK ha^{-1}, respectively and can be recommended for cultivation in the humid tropical conditions of Kerala.

Keywords: Leafy, Nutrient levels, Spinach beet, Variety, Yield

Leafy vegetables assume paramount importance in the daily human diet being rich in minerals, protein, vitamins and dietary fibre. Spinach beet (*Beta vulgaris* L. var. *bengalensis*) belonging to the family Chenapodiaceae, is one of the popular leafy vegetables grown in India. It is the only cultivar of *Beta vulgaris*, which is annual in duration and does not produce swollen roots. The short duration, high nutritive value and relative ease in cultivation at a comparatively low cost upholds its importance among leafy greens. Spinach beet is a recent introduction in Kerala and has widespread acceptability among the consumers. Studies in the state have been confined to trials on the varietal suitability of the crop under observation trials (KVK 2014). Research on the scientific management of the crop has not been initiated and in this background, the present paper attempts to assess the performance of the varieties generally recommended for cultivation in the country under open conditions and also to standardize the NPK dose for cultivation in the humid tropics of Kerala.

MATERIAL AND METHODS

The field experiment was conducted at College of Agriculture, Vellayani, located at 8.5^{0}N latitude, 76.9^{0}E longitude at an altitude of 29 m above MSL during August-November 2016. The soil was moderately acidic, low in organic carbon and high in available nitrogen, phosphorus and potassium and the experiment was laid out in split plot design with four replications. The treatments included five varieties (V_1: All Green; V_2: Pusa Bharathi; V_3: Punjab Green; V_4: Indam Kolkatta; V_5: Trendy) in main plots and three nutrient levels (N_1: 40:20:40 kg NPK ha^{-1}, N_2: 60:30:60 kg NPK ha^{-1}, N_3: 80:40:80 kg NPK ha^{-1}) in sub plots.

Seedlings of the five varieties were raised in pro trays in a medium of coir pith: FYM: vermicompost in 1:1:1 ratio. The field was prepared as per the experimental design, basal dose of FYM @ 10 kg m^{-2} was incorporated and a soil drench of *Pseudomonas* @ 2 per cent (20 g L^{-1}) was given as prophylactic measure against pathogens. Thirty day old seedlings were transplanted at a spacing of 20 cm x 10 cm in individual plots of 2.5 m x 1.5 m. Chemical fertilizers (urea, rajphos and muriate of potash) were applied as per the treatments fixed. One fourth, each of N and K, full dose of P were given as basal dose and remaining 75 per cent N and K, in three splits as top dressing, after each harvest of the crop. Irrigation was done daily and weeding regularly. Earthing up was done to encourage more shoot formation after the harvests. The observations on plant height, total leaf number $plant^{-1}$, leaf area index (LAI) and yield were recorded and the data were statistically analysed to assess the influence of varieties and nutrient levels on the growth and yield of spinach beet. Economics of cultivation was computed based on the cost of cultivation and gross returns.

RESULTS AND DISCUSSION

Effect of varieties: Varieties showed significant variations in plant height at the different stages of growth up to final

harvest, except at 60 DAT (Table 1). Pusa Bharathi recorded significantly taller plants in the early stages up to 30 DAT, and All Green at 45 DAT and at final harvest. This variation among varieties could be attributed to the genetic variability in morphological characters. Plants were comparatively taller at 45 and 60 DAT and the height declined towards the later stages of growth.

Being a leafy vegetable, the yield attributes in spinach beet include leaf size, number, LAI and number of harvests. The LAI was significantly influenced by the varieties (Table 2) and Indam Kolkatta recorded the highest LAI (0.66) on par with Pusa Bharathi and All Green. At 45, 60 DAT and at final harvest, the variety All Green recorded the highest LAI while Trendy showed the lowest value. Maximum LAI was observed at 45 and 60 DAT indicating maximum growth during this period. The maximum leaf production was in All Green, significantly superior to the other varieties. This was manifested in the yields also. The highest yield (3.9 kg m^{-2}) was in All Green and significantly superior to all other varieties (Table 3) followed by Pusa Bharathi, and the lowest was in Trendy.

Table 1. Effect of varieties, nutrient doses and interactions on plant height (cm)

Treatments	Plant height			
	30 DAT	45 DAT	60 DAT	At final harvest
Varieties (V)				
V_1(All Green)	22.31	26.42	25.23	24.18
V_2 (Pusa Bharathi)	24.60	25.94	24.85	22.54
V_3 (Punjab Green)	19.18	22.17	25.53	24.01
V_4 (Indam Kolkatta)	17.30	23.18	24.02	22.32
V_5 (Trendy)	17.05	25.48	25.47	23.98
CD (p=0.05)	1.11	1.24	NS	1.40
Nutrient levels (N)				
N_1 (40:20:40)	19.54	24.78	24.69	22.88
N_2 (60:30:60)	18.69	23.56	24.80	23.21
N_3 (80:40:80)	22.04	25.57	25.57	24.13
CD (p=0.05)	1.73	1.12	NS	0.96
Interactions (V x N)				
v_1n_1	21.73	29.40	25.83	23.90
v_1n_2	20.80	23.95	25.25	24.43
v_1n_3	24.41	25.90	25.53	24.20
v_2n_1	26.40	26.55	23.98	20.53
v_2n_2	23.19	25.08	24.50	23.08
v_2n_3	24.21	26.20	26.08	24.03
v_3n_1	16.95	20.46	25.28	24.15
v_3n_2	16.11	18.98	24.93	23.50
v_3n_3	24.48	27.08	25.48	24.38
v_4n_1	16.20	22.08	23.00	21.53
v_4n_2	16.62	23.03	23.45	21.53
v_4n_3	19.09	24.45	25.60	23.90
v_5n_1	16.43	25.44	25.35	24.30
v_5n_2	16.73	26.75	25.88	23.50
v_5n_3	17.99	24.25	25.18	24.15
CD (p=0.05)	NS	2.56	NS	NS

DAT- Days After Transplanting

The differences in leaf number and yield recorded in the varieties might be due the inherent characters of the individual varieties. Earlier reports confirm the variations in vegetative growth parameters among varieties (Abou El-Magd et al 2006) and it is these characters that designate it as variety. Analysis of the economics of cultivation revealed the significant differences in the net returns and benefit cost ratio (B: C ratio) among the varieties (Table 3). All Green recorded the highest net returns and B:C ratio (1.19) followed by Pusa Bharathi. The better growth and yield characters contributed to the higher yields in All Green and Pusa Bharathi and hence the highest net returns. In Indam Kolkatta and Trendy, the yields were lower and this along with the high cost of hybrid seeds, resulted in lower net returns and B:C ratios.

Effect of NPK levels: The different levels of the major nutrients significantly influenced the plant height (Table 1), the higher doses recording taller plants at 30, 45, 75 DAT and at final harvest. Leaf area index and number of leaves $plant^{-1}$ (Table 2) were significantly higher at the highest NPK level (80:40:80 kg ha^{-1}). Higher nutrient doses promoted growth and this was expressed as increased plant height and leaf area. Madhavi (2007) elucidated that the number of leaves $plant^{-1}$, total leaf weight $plant^{-1}$ and total yield were the highest in spinach beet with the application of NPK at 80:40:50 kg ha^{-1}.

The mean data on yield are presented in Table 3. Leaf yield was significantly the highest at the highest level of N, P and K. Positive effects of N (Gairola et al 2009), P (Nemadodz 2015) and K (Dzida et al 2011) in spinach beet cultivation have been documented. Chakraborty et al (2015) reported significantly superior number of leaves, LAI, number of branches and yield in palak with the highest dose of 300 : 200 :300 kg NPK ha^{-1}. Singh et al (2015) also documented the significant effect of the highest dose of N on plant growth and leaf yield in spinach beet var. All green. The plausible reason for this could be that spinach beet being a multi cut crop, requires an adequate supply of nutrients for re-growth and putting forth newer leaves after each harvest and the NPK dose of 80: 40: 80 kg ha^{-1} was found to provide them resulting in the higher yields compared to the lower doses.

Increased green fodder yields with increased N doses were reported by Saina and Tiwana (2013).

All management factors being same, the variation noticed in the cost of cultivation was mainly due to the differences in the cost of fertilizer inputs at the different levels of N, P and K. The gross returns were the highest in the NPK dose of 80:40:80 kg NPK ha^{-1} (Table 3) on account of the higher yields. The net returns and benefit cost ratios increased in the order $N_3 > N_2 > N_1$ and the nutrient dose of 80:40:80 kg NPK ha^{-1} was the most economical. The net returns realized from 10 m^2 were ₹ 318.7 for the highest NPK level and the B: C ratio computed was 1.16.

Interaction effect of varieties and nutrient levels: The yield (4.14 kgm^{-2}) was significantly the highest in the combination of Pusa Bharathi and 80:40:80 kg NPK ha^{-1} and on par with All Green at 80 : 40:80 kg NPK ha^{-1}. Although the total leaf number $plant^{-1}$ and LAI were higher for All Green at 80:40:80 kg NPK ha^{-1}, the interaction effect revealed Pusa Bharathi at the highest NPK level to yield better. Net returns were also higher for this combination but on par with All Green at 80:40:80 kg NPK ha^{-1}. It is interpreted that the higher yields were responsible for the maximum returns realized.

Table 2. Effect of varieties, nutrient doses and interactions on number of leaves $plant^{-1}$ and LAI

Treatments	Number of leaves					LAI			
	30 DAT	45 DAT	60 DAT	At final harvest	Total number	30 DAT	45 DAT	60 DAT	At final harvest
Varieties (V)									
V_1(All Green)	6.11	5.09	5.41	4.98	27.1	0.63	1.06	1.18	0.90
V_2 (Pusa Bharathi)	5.67	5.17	4.93	4.91	25.5	0.64	1.04	0.96	0.81
V_3 (Punjab Green)	5.44	5.01	4.83	4.50	25.0	0.58	0.98	0.92	0.77
V_4 (Indam Kolkatta)	4.89	4.91	5.34	4.50	24.3	0.66	0.99	0.94	0.74
V_5 (Trendy)	4.85	4.64	5.15	4.76	24.0	0.50	0.89	0.80	0.70
CD (p=0.05)	0.69	-	0.33	-	1.27	0.03	0.05	0.04	0.03
Nutrient levels (N)									
N_1 (40:20:40)	5.30	4.77	5.10	4.75	24.6	0.53	0.92	0.83	0.67
N_2 (60:30:60)	5.36	4.84	5.00	4.59	24.8	0.60	0.96	0.91	0.75
N_3 (80:40:80)	5.51	5.29	5.30	4.85	26.2	0.68	1.09	1.14	0.93
CD (p=0.05)	-	0.43	-	-	1.05	0.03	0.06	0.03	0.04
Interactions (V x N)									
v_1n_1	5.49	4.75	5.49	5.26	25.8	0.45	1.05	1.05	0.77
v_1n_2	5.77	5.25	5.00	4.45	26.0	0.66	0.91	1.13	0.85
v_1n_3	7.06	5.26	5.75	5.23	29.6	0.78	1.21	1.35	1.07
v_2n_1	5.04	4.72	5.00	4.99	24.5	0.64	0.92	0.77	0.74
v_2n_2	6.25	5.27	4.76	5.25	26.6	0.56	0.98	0.85	0.80
v_2n_3	5.72	5.51	5.02	4.50	25.5	0.70	1.21	1.28	0.90
v_3n_1	6.00	4.82	4.74	4.75	25.1	0.44	0.91	0.84	0.65
v_3n_2	5.56	4.98	4.74	4.00	24.6	0.63	0.99	0.91	0.64
v_3n_3	4.74	5.24	5.00	4.77	25.2	0.66	1.04	1.02	1.03
v_4n_1	4.99	5.05	5.24	3.99	23.8	0.71	0.92	0.84	0.68
v_4n_2	4.98	4.21	5.28	4.49	23.5	0.64	1.05	0.91	0.76
v_4n_3	4.71	5.49	5.51	5.00	25.7	0.63	1.01	1.06	0.79
v_5n_1	4.97	4.50	5.01	4.74	23.7	0.38	0.80	0.68	0.52
v_5n_2	4.26	4.48	5.20	4.78	23.4	0.48	0.88	0.73	0.69
v_5n_3	5.31	4.94	5.23	4.76	24.8	0.62	0.99	1.00	0.89
CD (p=0.05)	0.94	-	-	-	-	0.07	0.14	0.06	0.10

DAT- Days After Transplanting

Table 3. Effect of varieties, nutrient doses and interactions on leaf yield and economics of cultivation

Treatments	Leaf yield kg m^{-2}	Economics	
		Net income (₹10 m^{-2})	B:C ratio
Varieties (V)			
V_1(All Green)	3.93	371.4	1.19
V_2 (Pusa Bharathi)	3.67	220.0	1.11
V_3 (Punjab Green)	3.46	86.0	1.04
V_4 (Indam Kolkatta)	3.60	146.3	1.07
V_5 (Trendy)	3.42	127.9	1.06
CD (p=0.05)	0.168	37.49	0.019
Nutrient levels (N)			
N_1 (40:20:40)	3.48	101.9	1.05
N_2 (60:30:60)	3.64	150.4	1.08
N_3 (80:40:80)	3.73	318.7	1.16
CD (p=0.05)	0.129	32.57	0.016
Interactions (V x N)			
v_1n_1	3.83	310.6	1.16
v_1n_2	3.96	385.2	1.19
v_1n_3	4.02	418.5	1.21
v_2n_1	3.30	21.7	1.01
v_2n_2	3.55	143.0	1.07
v_2n_3	4.14	495.4	1.25
v_3n_1	3.39	45.9	1.02
v_3n_2	3.43	66.9	1.03
v_3n_3	3.56	145.3	1.07
v_4n_1	3.46	60.5	1.03
v_4n_2	3.79	85.1	1.04
v_4n_3	3.56	293.4	1.15
v_5n_1	3.41	71.3	1.03
v_5n_2	3.47	71.6	1.03
v_5n_3	3.38	240.9	1.12
CD (p=0.05)	0.31	74.64	0.04

CONCLUSION

Among the varieties tried, All Green, and among the nutrient levels, 80:40:80 kg NPK ha^{-1} was superior in terms of the number of leaves, LAI and yield in spinach beet. The interaction effects were also significant, with Pusa Bharathi 80:40:80 kg NPK ha^{-1} recording the maximum leaf yield and returns, on par with All Green at the highest NPK level. Hence for spinach beet cultivation in the humid tropical conditions of southern Kerala, Pusa Bharathi or All Green variety can be recommended with an NPK dose of 80:40:80 kg ha^{-1}.

Received 03 June, 2020; Accepted 19 August, 2020

ACKNOWLEDGEMENT

The authors place on record their gratitude to Kerala Agricultural University for the physical and financial support provided for the successful completion of the M.Sc. thesis work of the first author, of which the paper forms a part.

REFERENCES

Abou El-Magd MM, El-Bassiony AM and Fawazy ZF 2006. Effect of organic manure with or without chemical fertilizers on growth, yield and quality of some varieties of broccoli plants. *Journal of Applied Sciences and Research* **2**(10): 791-798.

Chakraborty S, Mandi A and Panda D 2015. Effect of nutrients and spacing on growth and seed yield of palak (*Beta vulgaris* var. *bengalensis*). *Environment and Ecology* **33**(1B): 410-415.

Dzida K, Jarosz Z and Michaojc Z 2011. The effect of diversified potassium fertilization on the yield and chemical composition of *Beta vulgaris* L. *Acta Scientiarum Poonorum Hortorum Cultus* **10**(4): 263-274.

Gairola S, Umar S and Suryapani S 2009. Nitrate accumulation, growth and leaf quality of spinach beet (*Beta vulgaris* Linn.) as affected by NPK fertilization with special reference to potassium. *Indian Journal of Science and Technology* **2**(2): 237-240.

KVK [Krishi Vigyan Kendra 2014. *Newsletter*. Krishi Vigyan Kendra, Ernakulam, No.13, p5.

Madhavi Y 2007. *Studies on the effect of different levels of vermicompost, castor cake, poultry manure and bio fertilizers on growth yield and quality of Indian spinach (Beta vulgaris var. bengalensis Hort).* M.Sc. (Ag) thesis, Acharya N. G. Ranga Agricultural University, Hyderabad, 137p.

Nemadodz LE 2015. *Growth and development of baby spinach (Spinacea oleracea L.) with reference to mineral nutrition.* M.Sc. (Ag) thesis, University of South Africa, South Africa, 72p.

Saina A and Tiwana US 2013. Effect of irrigation and nitrogen levels on growth, yield and hydrocyanic acid (HCN) content of forage sorghum (*Sorghum bicolor*) under different cutting managements. *Indian Journal of Ecology* **40**(1): 51-53.

Singh GP, Meena ML and Prakash J 2015. Effect of different levels of nitrogen and cuttings on growth, leaf yield and quality of spinach beet *(Beta vulgaris* var*. bengalensis)* cv. All Green. *European Journal of Biotechnology and Biosciences* **3**(6): 38-42.

Indian Journal of Ecology (2020) 47(3): 690-696

Manuscript Number: 3067
NAAS Rating: 4.96

Comparison of CERES-Wheat and InfoCrop Model to Predict the Phenology and Yield of Wheat

Amarinder Singh, Gurbax Singh[1] and Prabhjyot Kaur[2]

Department of Agriculture, Guru Nanak Dev University, Amritsar-143001, India
[1]Department of Agriculture, Khalsa College, Amritsar-143 001, India
[2]Department of Climate Change and Agrometeorology, Punjab Agricultural University, Ludhiana-141 001, India
E-mail: amarinder.agri@gndu.ac.in

Abstract: The DSSAT CERES Wheat model and INFOCROP model were calibrated and validated with field data of two consecutive years *Rabi* 2015-16 and 2016-17 at Khalsa College, Amritsar under variable environmental conditions created by 15 October, 30 October, 15 November, 30 November, 15 December and 30 December. The genetic coefficients for cultivar PBW 621 and HD 3086 of wheat were estimated. In case of CERES wheat model, higher R^2(0.77) was obtained between measured and simulated for days to physiological maturity and D-stat 0.85 whereas higher R^2(0.78) was obtained between measured and simulated for grain yield and D-stat 0.80 for INFOCROP model. The grain yield between measured and observed for all the parameters were below ±10 % error. The both models could be used to predict the seed yield accurately under different management conditions. The CERES model and INFOCROP can be used to simulate the phenology and yield of wheat.

Keywords: CERES, InfoCrop, Model, Wheat, Yield predition

Simulation techniques are easy and time saving for studying the influence of climatic variability on growth, development and yield of the crops. Several crop simulation models have been released and developed in the last two decades. Few of these models are truly predicting growth, development, and yield of a given crop. Simulation models runs with minimum time spending as compared to multi-year and multi-location and are often used to verify the potentiality of crop management. Plants at different growth stages can be simulated and the outputs can be evaluated according to different categories using crop simulation models under different climatic variability. Among production factors, sowing time and wheat varieties are the most crucial factors deciding its productivity. Sowing of wheat generally starts from November and ends in late December depending on the weather; topography and harvesting of the preceding crop. Under late sown conditions, wheat face low temperature in the earlier part and high temperature in the later part of the growing season and require favorable moisture for better growth and development. Decision Support System for Agro-technology Transfer (DSSAT) is a software package integrating the effects of soil, crop phenotype; weather and management options that allow users to ask "what if" type questions and simulate results by conducting, in minutes on a desktop computer, experiments which would consume a significant part of an agronomist's career. It has been in use for more than 15 years by researchers in over 100 countries. The DSSAT simulates growth, development and yield of a crop growing on a uniform area of land under prescribed or simulated management as well as the changes in soil, water, carbon, and nitrogen that take place under the cropping system over time. CERES-Wheat simulates crop growth, development and yield taking into account the effects of weather, management, genetics, soil water, carbon and nitrogen (Eitzinger et al 2016). INFOCROP, a generic crop model, simulates the effects of weather, soils, agronomic management (planting, nitrogen, residues and irrigation) and major pests on crop growth, yield **(**Aggarwal et al 2006) soil carbon, nitrogen and water, and greenhouse gas emissions. The model considers different crop development and growth processes influencing the yield. Total crop growth period in the model is divided into three phases viz. sowing to seedling emergence, seedling emergence to anthesis and the storage organ filling phases. So, keeping in mindthis research has been done to calibrate and validate these models for Amritsar and to compare these models for further studies.

MATERIAL AND METHODS

Climate and location: Amritsar station is located at latitude of 31°38'N and longitude of 74°52'E with an altitude of234 m above mean sea level, in Punjab under Trans-Gangetic agro climatic zone of India. The general climatic condition is classified as semi-arid with mean annual rainfall of about 681 mm out of which 75% rainfall is received during monsoon (June to September). The summer temperature exceeds above 38 °C and reaches upto 49°C with dry summer spell.

Crop data: The data on wheat cultivars (cv PBW 621 and HD 3086) under six date of sowings (D_1: 15 October, D_2: 30 October, D_3: 15 November, D_4: 30 November, D_5: 15 December, D_6: 30 December) was recorded from the research trial conducted at the Research Farm of Khalsa College, Amritsar and used for the calibration and validation of the models. The actual crop, soil and weather data were extracted for 2 years (2015-16 and 2016-17). The inputs have been taken for the CERES-Wheat model and INOCROP model prepared as per the model format.

Model calibration: The calibration of the models were done for wheat during crop year 2015-16. In this context the genotypic coefficients were adjusted/ calibrated in order to get the minimum variation over the actual data. Eight cultivar coefficients (Table 1) were adjusted to match observed growth. First, coefficients P1V and P1D and P5 were adjusted to match the thesis date observed in the field experiments, and P5 was matched to the growing degree day units for the cultivar planted in this study. Grain growth parameters G1, G2, G3 and PHINT were also adjusted to closely match yield. The cultivar specific parameter values were within reasonable limits compared to literature and also within wheat cultivar input files distributed with the DSSAT v4.7 software. Further, the well-adjusted/ calibrated genotypic coefficients for the cultivar PBW 621and HD 3086 were used for the model validation done using the actual crop data of one crop season *rabi* 2016-17. Similarly, InfoCrop model was also calibrated using experimental data of 2015-16. The thermal period required for different growth stages were adjusted in order to match the phenology of the crop for both the cultivar. Thereafter, yield parameters were also adjusted for the matching of yield attributing characters of the cultivars HD 3086 and PBW-621(Table 2).

Model validation: The well calibrated genotypic coefficients of PBW 621 and HD 3086 were compared with the experimental data recorded during *rabi* 2016-17 for the validation of the CERES-Wheat model and Infocrop model.

RESULTS AND DISCUSSION

Phenology of Wheat

CERES-Wheat model: The evaluation of the CERES-Wheat model for simulating the duration from sowing to anthesis during *rabi* 2015-16 experiment revealed similar average values for the wheat between observed and predicted values, e.g., 113 days for observed and 109 days for simulated (Fig. 1 and 3) The coefficient of determination (R^2) between the simulated and observed duration from sowing to anthesis for the wheat was 0.72 and d-stat was 0.82. The coefficient of determination (R^2) between the simulated (150) and observed (146) duration from sowing to maturity for the wheat was 0.77 and d-stat was 0.69. This evaluation was consistent with Zhang et al *(*2012).The model simulated the phenological stages namely anthesis and physiological maturity for all the two cultivars in close agreement with those observed in the field. However, the days taken to anthesis were simulated more realistically by the model. The deviation in the days taken to anthesis and maturity was -8 to +3 and -6 to +1 day, respectively under different sowing dates (Table

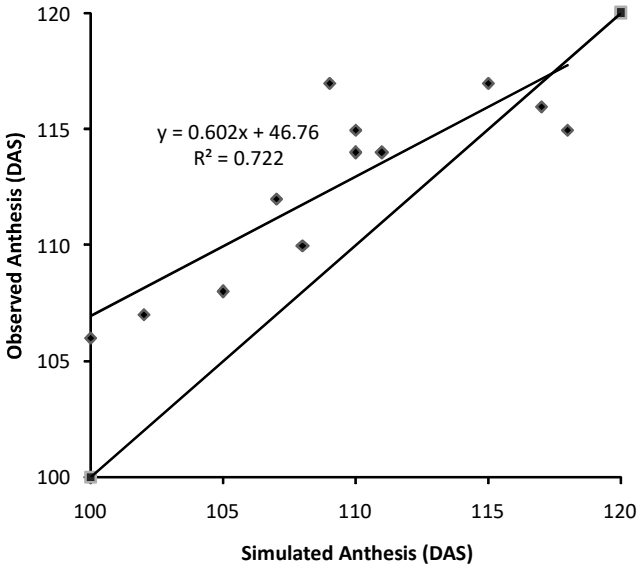


Fig. 1. Comparison of simulated and observed anthesis date (days after sowing) using CERES-Wheatmodel (*Rabi* 2015-16)

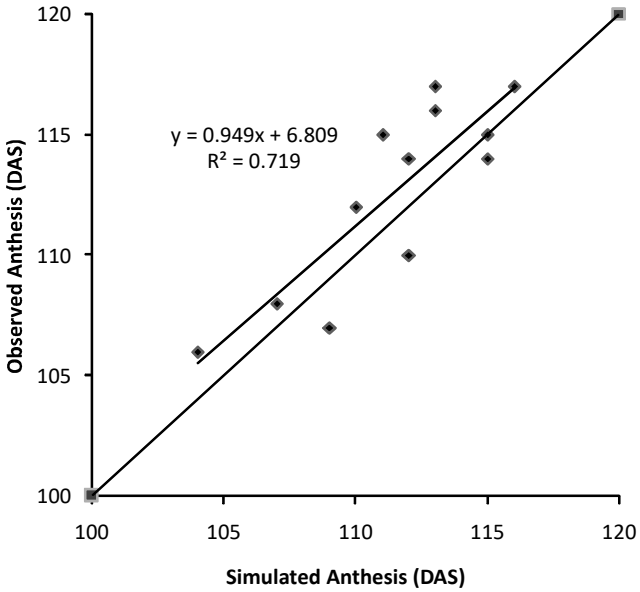


Fig. 2. Comparison of simulated and observed anthesis date (days after sowing) using InfoCrop model for wheat cultivars (*Rabi* 2015-16)

4.6 and 4.7). The linear regression model between observed and simulated anthesis date could account for 66% variations while that for developed for physiological maturity 90%variations. Out of 12 environments, CERES-Wheat model underestimated anthesis for 10 and overestimated for 2 environments and physiological maturity was

Table 1. Characterisation of genotypic coefficients developed for CERES-Wheat model

Parameter	Characterisation	PBW- 621	HD-3086
Coefficients related to development aspects			
Vernalisation coefficients P1V	Relative amount of slowing down the development for each day of unfulfilled vernalisation assuming that 50 days of vernalisation are sufficient for all cultivars.	20.0	22.0
Day length (P1D)	Photoperiod response (% reduction in rate/10 h drop in pp)	100.0	106.0
Grain filling duration coefficient (P5)	P5-Time period in GDD °C from beginning of grain filling (3 to 4 days after flowering) to physiological maturity with a base temperature of 4.5°C.	570	570
Coefficients related to growth aspects			
Kernel number coefficient (G1)	The coefficient controls the kernel number per unit weight of stem (less leaf blades and sheaths) plus spike at anthesis (g^{-1}).	27.0	40.0
Kernel weight coefficient (G2)	Related to kernel filling rate under optimum conditions (mg/day).	40.0	44.0
Tiller weight coefficient (G3)	Accounts for the non-stressed dry weight (g) of a single stem (excluding leaf blades and sheaths) and spike when elongation ceases.	3.60	7.00
Phyllochron interval (PHINT)	Thermal time required between emergence of two successive leaves.	69.0	80.0

Table 2. Characterisation of genotypic coefficients developed for info crop wheat model

Parameter	HD-3086		PBW-621	
	Base temp (°C)	Thermal time (°C)	Base temp (°C)	Thermal time (°C)
A. Phenology				
Sowing to germination	3.6	1	3.6	1
Germination to 50% flowering	4.5	1150	4.5	1200
50% flowering to physiological maturity	7.5	900	7.5	500
Optimal temperature	25		25	
Maximum temperature	40		40	
Sensitivity to photoperiod	1		1	
B. Growth				
Relative growth rate of leaf area (C /day)	0.008		0.008	
Specific leaf area (dm^2mg^{-1})	0.00192		0.0019	
Index of greenness of leaves	1		1	
Extinction coefficient of leaves at flowering	0.6		0.6	
Radiation use efficiency (g/MJ/day)	2.7		2.6	
Root growth rate (mm/day)	30		30	
Sensitivity of crop to flooding scale	1		1	
Index of N fixation	1		1	
C. Source: sink balance				
Slope of storage organ number/m^2 to dry matter during storage organ formation (storage organ/kg/day)	15600		16000	
Potential storage organ weight (mg/grain)	42.7		46.9	
Nitrogen content of storage organ (fraction)	0.02		0.02	
Sensitivity of storage organ setting to low temperature	1		1	
Sensitivity of storage organ setting to high temperature	1		1	

overestimated for 2 and underestimated for 10 environments.

InfoCrop-Wheat model: The evaluation of the InfoCrop-Wheat model for simulating the duration from sowing to anthesis with data from *rabi* 2015-16 experiment revealed similar average values for the wheat between observed and predicted values, e.g.,113 days for observed and 111 days for simulated (Fig. 2 and 4). The coefficient of determination (R^2) between the simulated and observed duration from sowing to anthesis for the wheat was 0.72, d stat was 0.87 and normalized RMSE was 2.66.The coefficient of determination (R^2) between the simulated (146) and observed (150) duration from sowing to maturity for the wheat was 0.69, d stat was 0.81 and RMSE was 5.00 (Table 3).The model simulated the phenological stages namely anthesis and physiological maturity for the two cultivars in close agreement with those observed in the field. However, like CERES-Wheat model, the InfoCrop-Wheat model also simulated the days taken to anthesis more realistically. The deviation in the days taken to anthesis and maturity was -4 to +2 and -9 to +1 days, respectively under different sowing date (Table 4 and 5). The linear regression model between observed and simulated anthesis date could account for 71% variations while that for developed for physiological maturity could account for 69% variations. Out of 12 environments, InfoCrop-Wheat model underestimated anthesis for 8 and overestimated for 4 environments and physiological maturity was overestimated for 3 and underestimated for 9 environments.

Grain Yield of Wheat

CERES-wheat model: The deviation between simulated and observed grain yield of the wheat crop was -0.13 to 15.15% (Fig. 5, Table 6).The coefficient of determination (R^2) 0.78, d stat 0.85 and RMSE between the simulated and observed grain yield for the wheat was 385.2 kg/ha. All these statistical tools indicate that the CERES-Wheat model was validated with a good degree of accuracy and hence can be

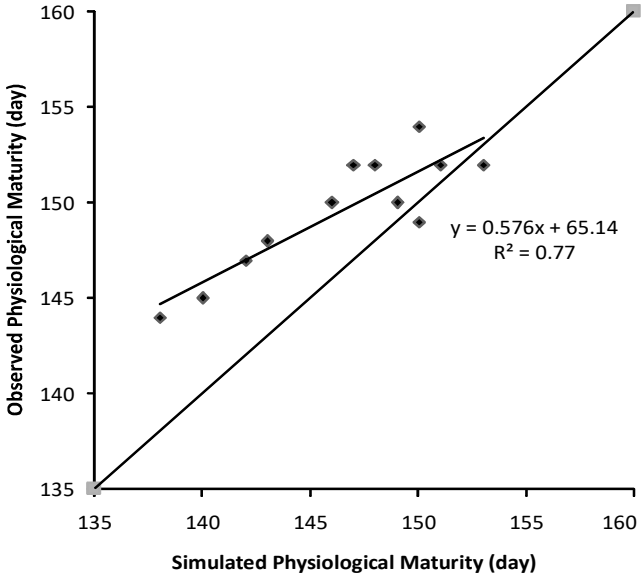


Fig. 3. Comparison of simulated and observed maturity date (days after sowing) using CERES-Wheatmodel for wheat cultivars (*Rabi* 2015-16)

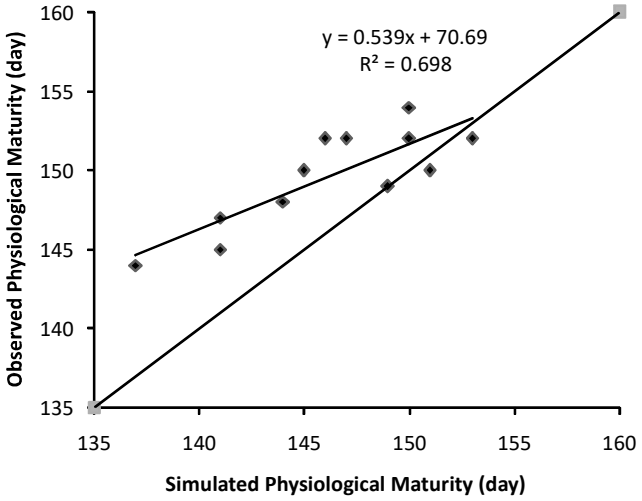


Fig. 4. Comparison of simulated and observed maturity date (days after sowing) using InfoCrop model for wheat cultivars (*Rabi* 2015-16)

Table 3. Statistics of the observed and simulated phenology and yield of wheat (Pooled data of *rabi* 2015-16 and 2016-17)

Variable	Mean			Standard deviation		r-Square	Mean Diff.	Mean Abs. Diff.	RMSE	d-Stat.	Used Obs.	Total Obs.
	Observed	Simulated	Ratio	Observed	Simulated							
CERES-Wheat Model												
Anthesis days	113	109	0.964	3.75	5.29	0.72	-1	3	5.02	0.82	12	12
Maturity days	150	146	0.973	3.08	4.69	0.77	-3	3	4.57	0.60	12	12
Grain Yield (kg ha^{-1})	4544	4825	1.061	305.9	390.1	0.78	466	466	385.2	0.85	12	12
InfoCrop-Wheat Model												
Anthesis days	113	111	0.982	3.75	3.35	0.72	1.42	3.08	2.66	0.87	12	12
Maturity days	150	146	0.973	3.08	4.78	0.69	-6.17	0.82	5.00	0.81	12	12
Grain yield (kg ha^{-1})	4544	4808	1.058	305.9	376.1	0.62	-54.75	286.75	403.5	0.80	12	12

used to work out simulation guided management practices for yield maximization of wheat under climate change conditions(Kaur and Hundal2007). The linear regression model between observed and simulated grain yield could account for 62% variations. Out of 12 environments, CERES-Wheat model overestimated and underestimated for grain yield for 11 and1 environments, respectively.

InfoCrop-wheat model: The deviation between simulated and observed grain yield of the wheat crop was -5.35 to 13.09% (Fig 3, Table 6).The coefficient of determination (R^2)0.62, d stat 0.80 and RMSE of grain yield for the wheat was 403.5 kg/ha. All these statistical tools indicate that the InfoCrop-Wheat model was validated and hence can be used to work out simulation guided management practices for yield maximization of wheat under climate change conditions. The linear regression model between observed and simulated grain yield could account for 62% variations. Out of 12 environments, InfoCrop-wheat model overestimated for 10 and underestimated for 2 environments for grain yield of wheat (Ahmad et al 2014).

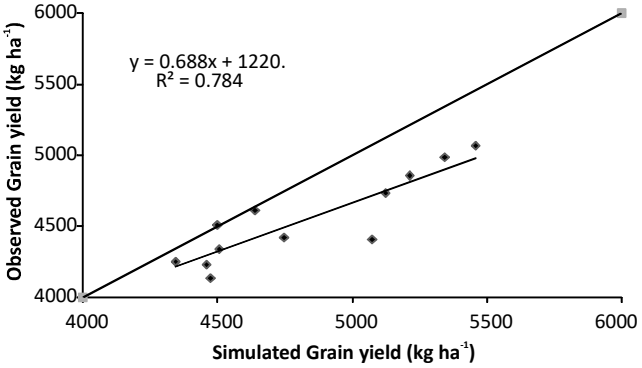


Fig. 5. Comparison of simulated and observed grain yield (kg/ha) for wheat cultivars using CERES-Wheat cultivars (*Rabi* 2015-16)

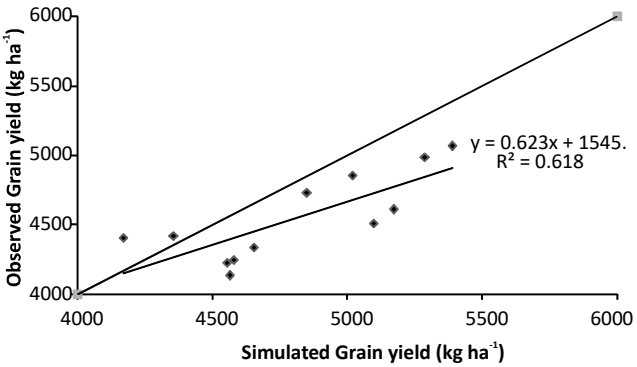


Fig. 6. Comparison of simulated and observed grain yield (kg ha^{-1}) for wheat cutivars using InfoCrop under cultivars (*Rabi* 2015-16)

Table 4. Comparison of CERES-Wheat and InfoCrop model to predict the anthesis (days after sowing) of wheat crop

Sowing date/Cultivar	Observed	CERES-Wheat		InfoCrop-Wheat	
		Simulated	Deviation	Simulated	Deviation
Crop year -2015-16					
15 October					
HD 3086	116	117	+1	113	-3
PBW 621	115	110	-5	111	-4
30 October					
HD 3086	115	118	+3	115	0
PBW 621	117	109	-8	113	-4
15 November					
HD 3086	117	115	-2	116	-1
PBW 621	114	111	-3	112	-2
30 November					
HD 3086	114	110	-4	115	+1
PBW 621	112	107	-5	110	-2
15 December					
HD 3086	110	108	-2	112	+2
PBW 621	108	105	-3	107	-1
30 December					
HD 3086	107	102	-5	109	+2
PBW 621	106	100	-6	104	-2

Table 5. Comparison of CERES-Wheat and InfoCrop model to predict the physiological maturity (days after sowing) of wheat crop

Sowing date/Cultivar	Observed	CERES-Wheat		InfoCrop-Wheat	
		Simulated	Deviation	Simulated	Deviation
Crop year -2015-16					
15 October					
HD 3086	152	151	-1	153	1
PBW 621	149	150	+1	149	0
30 October					
HD 3086	152	153	+1	150	-2
PBW 621	150	149	-1	151	+1
15 November					
HD 3086	154	150	-4	150	-6
PBW 621	152	147	-5	146	-9
30 November					
HD 3086	152	148	-4	147	-5
PBW 621	150	146	-4	145	-5
15 December					
HD 3086	148	143	-5	144	-4
PBW 621	147	142	-5	141	-6
30 December					
HD 3086	145	140	-5	141	-4
PBW 621	144	138	-6	137	-7

Table 6. Comparison of CERES-Wheat and InfoCrop model to predict the grain yield (kg/ha) of wheat crop

Sowing date/Cultivar	Observed	CERES-Wheat		InfoCrop-Wheat	
		Simulated	Deviation	Simulated	Deviation
Crop year -2015-16					
15 October					
HD 3086	4420	4750	7.47	4358	-1.40
PBW 621	4408	5076	15.15	4172	-5.35
30October					
HD 3086	4852	5215	7.48	5020	3.46
PBW 621	4732	5124	8.28	4851	2.51
15 November					
HD 3086	5065	5458	7.76	5390	6.42
PBW 621	4984	5345	7.24	5288	6.10
30 November					
HD 3086	4610	4642	0.69	5172	12.19
PBW 621	4508	4502	-0.13	5098	13.09
15 December					
HD 3086	4338	4508	3.92	4655	7.31
PBW 621	4228	4461	5.51	4554	7.71
30 December					
HD 3086	4250	4345	2.24	4580	7.76
PBW 621	4135	4477	8.27	4566	10.42

CONCLUSION

The both model produced almost overestimated grain yield for wheat cultivars sown under different dates of sowing, thereby indicating that the partitioning of dry matter between grain and straw under sown conditions needs further scrutiny. The results of this study reveal that the calibrated INFOCROP-Wheat model and CERES-Wheat Model can be used for the prediction of wheat growth and yield in the Punjab.

REFERENCES

Aggarwal PK, Banerjee B, Daryaei MG, Bhatia A, Bala A, Rani S, Chander S, Pathak H and Kalra N 2006. A dynamic simulation model forth assessment of crop yields, losses due to pests, and environmental impact of agro-ecosystems in tropical environments. *Agriculture Systems* **89**: 47-67.

Ahmad BG, Rasul W, Iqbal and Bukhari SSA 2014. Regional comparison between global circulation model GCM20 and regional climate model PRECIS. *Pakistan Journal of Meteorology* **11**: 39-51.

Akula B and Shekh AM 2005. Field calibration and evaluation of crop simulation model, Info-crop to estimate wheat yields. *Journal of Agmeteorology* **2**: 199-207.

Eitzinger A, Laderach P, Rodriguez B, Fisher M, Beebe S, Sonder K and Schmidt A 2016. Assessing high-impact spots of climate change: Spatial yield simulations with Decision Support System for Agrotechnology Transfer (DSSAT) model. *Mitigation Adaption Strategies Global Change*.

Kaur P and Hundal SS 2007. Effect of temperature rise on growth and yield of Wheat. *Journal of Research Punjab Agricultural University* **44**: 6-8.

Singh AK, Tripathi P and Adhar S 2008. Heat unit requirements for phenophases of wheat genotypes as influenced by sowing dates. *Journal of Agrometeorology* **10**(2): 209-212.

Zhang Y, Feng L, Wang E, Wang J and Li B 2012. Evaluation of the APSIM-Wheat model in terms of different cultivars, management regimes and environmental conditions. *Canadian Journal Plant Science* **92**: 937-949.

Received 30 June, 2020; Accepted 12 August, 2020

Indian Journal of Ecology (2020) 47(3): 697-702

Manuscript Number: 3068
NAAS Rating: 4.96

Structural Analysis of Shade Nets for Construction of Low-Cost Shade Net Houses in A Semi-Arid Climate of Trichy District, Tamil Nadu, India

G. Gopi, K. Shanmugasundaram[1] and B.S. Madhusudan[2]

Department of Soil and Water Conservation Engineering, AEC&RI, TNAU, Coimbatore- 679573, India
[1]Department of Soil and Water Conservation Engineering, Agricultural Engineering College and Research Institute, Kumulur-679573, India
[2]Vignens Foundation for Science, Technology and Research, Vadlamudi-522 213, India
E-mail: gopi.gudida@gmail.com

Abstract: The dead, live and wind load have been determined as per IS code 875 Part 1, IS code 875 Part 2, IS code 875 Part 3, IS code 875 Part 5 and IS code 14462-1997 for whole structure. Then load on individual member of structure were determined for Trichy condition. Based on loads on the structure and stress analysis, the individual members were tested for its strength and factor of safety. Critical sections with minimum factor of safety were identified. The determination of dead load, live load, wind load, other actions and load combinations are estimated by manual procedure. Analyzed forces on each member and column of shade net house. Determined the nature and magnitude of forces and designed tension and compression members accordingly. Total dead load acting on shade net house was observed 4.326 KN. Similarly, total live load acting on shade net truss was observed 48.00 KN. Wind load has been estimated using IS: 875 Part 3. As per IS code basic wind velocity is 47 m/s, Wind load acting on shade net members have been estimated for whole structure and individual member of shade net truss. The design wind speed was found to be 42.3 m/s and the design wind pressure was found to be 1.0735 KN/m^2. The aim of this study in order to design the shade nets structure to satisfy sufficient margins of safety and to avoid severe damage against various loads.

Keywords: Shade net house, Cost, Strength, Design, Damage

A shade house is a structure enclosed by agro nets or any other woven material to allow required sunlight, moisture and air to pass through the gaps. It creates an appropriate micro climate conducive to the plant growth. It is also referred as shade net house or net house. Shade house can be used in cultivation of flower plants, foliage plants, medicinal plants, vegetables and spices. It is suitable for fruit and vegetable nurseries as well as for raising of forest species. It helps in quality drying of various agro products. It protects the crop from natural weather disturbances such as wind, rain, hail and frost. It can be used in production of graft saplings and reducing its mortality during hot summer days. It is very useful for hardening tissue culture plantlets. The shade house structure should be planned taking into consideration the type of crop to be grown, locally available materials and local climatic conditions. The provision for future expansion should be there. A shade house should be located in such a way that it is well connected with market for input supplies and sale of its produces. This structure should be constructed away from buildings and trees, so also away from industrial or vehicular pollutants. The site should be free from drainage problem. There should be provision of electricity and good quality water. However, wind breakers may be located 30m away from the structure. A shade house structure composed of two basic components i.e. frame and cladding material. The shade house frame provides support for cladding material and designed to protect against wind, rain and crop load. The shade house mild steel (MS) angle frame lasts up to 20 to 25 years, if anti rust treatment is done at regular interval, whereas bamboo structure can last up to 3 years. The agro shade net lasts for 3 to 5 years depending on the climatic condition. Shade nets are available in different colours with wide range of shade percentages.

To design a structure, it is analyzed first for its intended structural configuration and assumed sectional properties against various loads individually and in combination with each other in a way by which the structure may be subjected any time or at all time during the life of the structure for which is to be built. The various primary loads and other secondary effects required to be considered for Indian condition m while computing maximum stresses in a structure. The main loads, which have to be taken into account in the shade net design, are dead load or permanent load, live loads (imposed loads), wind load and snow load. The structures must also be able to withstand against loading due to dead load, live loads and wind loads.

Among all the loads that act on the shade net, wind load is the major one. Wind generates varying pressures on the

shade net cover and corresponding stresses in the frame and foundations, which can cause damage cases of extreme wind speeds. In order to design the shade nets structure to satisfy sufficient margins of safety and to avoid severe damage, the shade net structure should be designed in accordance with relevant Indian standards, which offer guidance for the calculation of various design loads. The various loads acting together on shade net house and their disposition in relation to other loads and severity of stresses or deformations caused by combinations of the various loads is necessary to ensure the required safety. A judicious combination of loads should be used to analyze the structure. Combination of loads produces the most unfavorable effect in the building, foundation or structural member concerned is taken as design load.

MATERIAL AND METHODS

Layout of shade net structure: The experiment was conducted in a shade net with dimensions of shade net area-192 m^2, Length of shade net-16 m, Width of shade net-12 m, Height of column-3 m, total number of columns-31 , Spacing between members-4m.

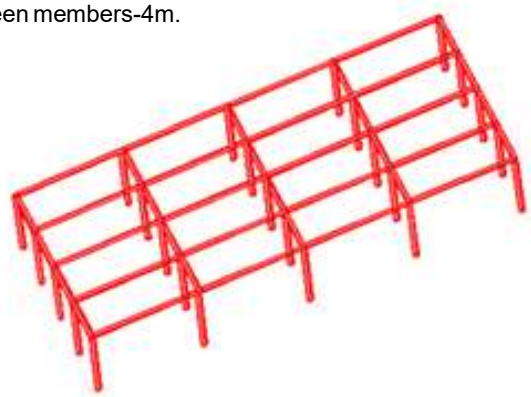


Fig. 1. AutoCAD developed shade net house

Calculation of Load Acting on Shade Net

Dead load calculation (IS 875:1987 Part-I): Dead load is constant in magnitude and fixed in position throughout the lifetime of the structure. Dead load on the roof trusses includes the weight of purlin and total number of columns is 31.

Weight of purlins = Total length of section (m) × Weight per meter of section used (kg m^{-1}) (as per: 1161-1968)

=124 × 3.56

= 441.44 kg

= 441.44 × 9.81

= 4326.1N

Total dead load = weight of purlins = 4326.1N = 4.326KN

Live load on each member = 4326.1/31 = 139.55N = 0.139KN

Live load calculation (IS 875:1987 Part-2): Live loads are the loads that vary in magnitude and position and are also known as imposed load. Live loads include weight of movable equipment and human being for repair work etc. The minimum live loads for greenhouse structure should be taken as 250N/m^2 as per IS 14462-1997.

Total live load = 250 × 192

= 48000 N

Live load on each member = 48000/31

=1548N

=1.548KN

Wind load calculation (IS: 875: 1987 Part-3): The design wind load on the roof was determined as resultant effect of internal air pressure and external air pressure.

Design wind speed: The basic wind speed for any site shall be modified to include the following effect to get design wind velocity at any height for chosen structure:

$$V_z = V_b * k_1 * k_2 * k_3$$

Where, V_z= Design wind speed, m/s, V_b= basic wind speed, m/s, k_1= risk coefficient

k_2= Terrain, height and structure size factor, k_3=Topographic factor

Basic wind speed (v_b)= 47m/s (as per IS:875 (part 3) – 1987)

Risk coefficient (k_1): This factor depends upon the importance of the building and basic wind speed (IS: 875(1987) Part-3) developed an equation to determine risk coefficient k_1 for different types of buildings. The suggested life period to be assumed in design and the corresponding k_1 factor for different class of structures for the purpose of design then K_2 = 0.9

Terrain, height and structure size factor (k_2): This coefficient depends upon the terrain of the building site, height of building and the class of building. The effect of obstruction in the surrounding of structure creates the turbulence and roughness, which also depends on direction of wind.

Category 1: The exposed open terrain with few or no obstruction and in which the average height of any object surrounding the structure is less than 1.5 m above the ground surface.

Category 2: The open terrain with scattered obstruction having height usually in range of 1.5 m to 10 m above ground surface. This category also includes open land adjacent to sea cost due to roughness of large sea waves at high winds.

Category 3: The terrain with numerous large high closely spaced obstructions having the size of building structures up to 10 m in height with or without a few isolated tall structures.

Category 4: The terrain with numerous large high closely spaced obstructions. To incorporate structure size factors the building is classified into the following three different classes.

To incorporate structure size factors the building is classified into the following three different classes

Class A: Building having maximum dimension (greatest horizontal or vertical) less than 20 m.

Class B: Building having maximum dimension between 20 m to 50 m.

Class C: Building having maximum dimension greater than 50 m

Finally, this structure belongs to class A and category 2 then $K_2 = 1$.

Topographic factor (k_3): The effect of topography is significant at a site when the up-wind slope (θ) is greater than about 3 and below this the value of k_3 may be taken to be equal to 1.0. The value of k_3 confined in the range of 1.0 to 1.36 for slopes greater than 3◦. The value of k_3 varies with height above ground level, at a maximum near the ground, and reducing to 1.0 at higher levels. $k_3 = 1$.

Design wind speed =

$$V_z = V_b * k_1 * k_2 * k_3$$
$$= 47 \times 0.9 \times 1 \times 1$$
$$= 42.3 \text{ m/s}$$

Design wind pressure (p_d) = $0.0006V_z^2 = 0.0006(42.3)^2 = 1.0735$ KN/m^2

Wind load on individual members

$F = (C_{pe}-C_{pi}) * A * P_z$

Where, F=Wind load, kN

A=surface area of structural element or cladding unit, m^2, C_{pe} = External pressure coefficient

C_{pi}=Internal pressure coefficient, P_z=Design wind pressure, kNm^{-2}

Internal pressure coefficient (C_{pi}): The internal air pressure depends upon the degree of permeability of structure (cladding) to the flow of air. The values of internal pressure coefficient have been noted briefly according to the categories of structure in (IS 875:1987 Part-3). For shade net large opening (opening > 20 % in wall) = ±0.7 (as per IS 875: Part: 3).

External pressure coefficient (C_{pe}): The average external pressure coefficients for pitched roof for rectangular clad building are noted in Table T1 given in Appendix-I (IS: 875 (1987) Part-3). Height of column is 3m and length of shade net is 16m.

Wind pressure coefficients = H/L= 3/16= 0.187 (H&L defined as per IS 875: Part3)

$C_{pe} = -0.5$

Tributary area (A) = 16m^2

Wind load (F) = $(C_{pe}-C_{pi}) \times A \times P_z = (-0.5 - 0.7) \times 16 \times 1.0735 = -20.611$KN

RESULTS AND DISCUSSION

Design strength of a tension member (as per IS1161:1964): A tension member is defined as a structural member subjected to tensile force in the direction parallel to its longitudinal axis. A tension member is also as a tie member or simply a tie. The term tie is commonly used for tension member to axial tensile force in the roof trusses, and then the distribution of stress over the cross section is uniform.

To check the strength of truss member which are under tension are able to resist the actual load acting on it. Design strength of tension of identified member were obtained as given in Table 1.

Design Procedure: selection of trial section

Axial force (p_d) = 19.10 KN

It is assumed that the steel having yield stress (f_y) = 260 N/mm^2

The allowable stress in axial tension = 0.6× 260 = 156 N/mm^2

Net sectional area = axial force /allowable stress

$$= 19.10 \times 103/156$$
$$= 122.43 \text{mm}^2$$

Gross sectional area = $1.4 \times 122.43 = 171.36$ mm^2

From IS 1161: 1964 hollow circular properties of 20mm steel tube is suitable for every tension member

As per IS1161: 1964 the 20 mm section properties given by

Nominal bore = 20 mm

Outside diameter = 26.9 mm

Thickness = 2.60 mm

Weight = 1.38 kg/m

Area of cross sectional (A) = 1.78 cm^2 = 178 mm^2

Moment of inertia = 1.36 cm^4

Radius of gyration (r_{min}) = 0.87cm = 8.7 mm

As per recommendation gross sectional area is equal to obtained area of cross section.

Design of compression member (as per IS:800-1984): A column is defined as a structural member subjected to compression force in a direction parallel to its longitudinal axis. The terms stanchions and posts are also used for columns. The strength of a compression member is defined as its safe load carrying capacity. The strength of a centrally loaded straight steel column depends on the effective cross-sectional area, radius of gyration, the effective length, the magnitude and distribution residual stress, annealing, out of straightness and cold straightening. The effective cross-sectional area and the slenderness ratio of the compression member are the main features, which influence its strength.

Selection of trial section: properties of hollow circular tube (IS:1161-1998)

Nominal bore = 15mm, Outside diameter = 21.3mm,Thickness = 2mm

Weight = 0.95kg/m,Area of cross sectional(A) =

Table 1. Loads on member forces (tension (-) negative)

Member No	Dead load (Kn)	Live load (Kn)	Wind load (Kn)	Dl +Ll (Kn)	Dl + Wl	Dl+Ll+Wl	Maximum Force (Kn)	-Ve (Tension)
1	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
2	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
3	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
4	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
5	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
6	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
7	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
8	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
9	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
10	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
11	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
12	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
13	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
14	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
15	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
16	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
17	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
18	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
19	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
20	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
21	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
22	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
23	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
24	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
25	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
26	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
27	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
28	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
29	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
30	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension
31	0.139	1.548	-20.61	1.687	-19.062	-18.923	-19.062	Tension

Table 2. Design strength of a compression member

Nominal diameter (mm)	OD (mm)	Length (m)	Radius of gyration (cm^2)	Slenderness ratio (λ)	Ft (KN)	P_d (KN)	Remark
15	21.3	3	0.69	282.6	19.06	12.88	fail
20	26.9	3	0.87	224.1	19.06	17.23	fail
25	33.7	3	1.10	177.2	19.06	21.38	pass
32	42.4	3	1.41	138.2	19.06	23.17	pass
40	48.3	3	1.61	121.1	19.06	26.61	pass
50	60.3	3	2.03	96.05	19.06	28.25	pass
65	76.1	3	2.58	75.58	19.06	32.89	pass
80	88.9	3	3.03	64.35	19.06	33.243	pass
100	114.3	3	3.92	49.7	19.06	38.84	pass
125	139.7	3	4.78	40.65	19.06	48.65	Not sui
150	165.1	3	5.68	-	-	-	-
200	219.1	3	7.58	-	-	-	-

Table 3. Loads on member forces (Tension (-) negative, Compression (+) positive)

Column no	Dead load in KN	Live load in KN	Wind load in KN	DL +LL, KN	DL + WL, KN	DL +LL+WL, KN	Maximum force (kn)	-ve tension and +ve compression
1	0.139	1.548	20.61	1.687	20.749	22.297	22.297	Compression
2	0.209	2.322	30.91	2.531	31.119	33.441	33.441	Compression
3	0.209	2.322	30.91	2.531	31.119	33.441	33.441	Compression
4	0.209	2.322	30.91	2.531	31.119	33.441	33.441	Compression
5	0.139	1.548	20.61	1.687	20.749	22.297	22.297	Compression
6	0.209	2.322	30.91	2.531	31.119	33.441	33.441	Compression
7	0.279	3.096	41.22	3.375	41.499	44.595	44.595	Compression
8	0.279	3.096	41.22	3.375	41.499	44.595	44.595	Compression
9	0.279	3.096	41.22	3.375	41.499	44.595	44.595	Compression
10	0.209	2.322	30.91	2.531	31.119	33.441	33.441	Compression
11	0.209	2.322	30.91	2.531	31.119	33.441	33.441	Compression
12	0.279	3.096	41.22	3.375	41.499	44.595	44.595	Compression
13	0.279	3.096	41.22	3.375	41.499	44.595	44.595	Compression
14	0.279	3.096	41.22	3.375	41.499	44.595	44.595	Compression
15	0.209	2.322	30.91	2.531	31.119	33.441	33.441	Compression
16	0.139	1.548	20.61	1.687	20.749	22.297	22.297	Compression
17	0.279	2.322	30.91	2.531	31.119	33.441	33.441	Compression
18	0.279	2.322	30.91	2.531	31.119	33.441	33.441	Compression
19	0.279	2.322	30.91	2.531	31.119	33.441	33.441	Compression
20	0.139	1.548	20.61	1.687	20.749	22.297	22.297	Compression

Table 4. Design strength of a compression member

Column no	Length (m)	Nominal diameter (mm)	OD (mm)	Radius of gyration	Slenderness ratio (λ)	F_t	P_d	Remark
1	3	32	42.4	1.41	138.2	22.29	23.17	pass
2	3	80	88.9	3.03	64.35	33.14	33.24	pass
3	3	80	88.9	3.03	64.35	33.14	33.24	pass
4	3	80	88.9	3.03	64.35	33.14	33.24	pass
5	3	32	42.4	1.41	138.2	22.29	23.17	pass
6	3	80	88.9	3.03	64.35	33.14	33.24	pass
7	3	125	139.7	4.78	40.65	44.59	48.65	pass
8	3	125	139.7	4.78	40.65	44.59	48.65	pass
9	3	125	139.7	4.78	40.65	44.59	48.65	pass
10	3	80	88.9	3.03	64.35	33.14	33.24	pass
11	3	80	88.9	3.03	64.35	33.14	33.24	Pass
12	3	125	139.7	4.78	40.65	44.59	48.65	pass
13	3	125	139.7	4.78	40.65	44.59	48.65	pass
14	3	125	139.7	4.78	40.65	44.59	48.65	pass
15	3	80	88.9	3.03	64.35	33.14	33.24	pass
16	3	32	42.4	1.41	138.2	22.29	23.17	pass
17	3	80	88.9	3.03	64.35	33.14	33.24	pass
18	3	80	88.9	3.03	64.35	33.14	33.24	Pass
19	3	80	88.9	3.03	64.35	33.14	33.24	pass
20	3	32	42.4	1.41	138.2	22.29	23.17	pass

1.21cm^2, Moment of inertia = 0.57 cm^4

Radius of gyration(r_{min}) = 0.69cm = 6.9mm

Effective length of compression member (l) = 0.65 × actual length of column

$= 0.65 \times 3$

$= 1.95$m

$= 1.95 \times 10^3$ mm

To check the strength of truss member which are under compression or in tension are able to resist the actual load acting on it. Actual strength of truss members isgiven in calculation procedure.

CONCLUSION

During study of structural design of shade net house, the loads acting on shade net house has been divided in three components i.e. dead loads, live load and wind loads for determination of loads acting on individual component of shade net. Total dead load acting on shade net house was observed 4.326 KN. Similarly, total live load acting on shade net truss was observed 48.00 KN. Wind load has been estimated using IS: 875 Part 3. As per IS code basic wind velocity is 47 m/s. Wind load acting on shade net members have been estimated for whole structure and individual member of shade net truss. The design wind speed was found to be 42.3 m/s and the design wind pressure was found to be 1.0735 KN/m^2. During structural analysis of shade net members of existing structure for calculated loads following load combination were used as per IS:875 (Part 5). For each member maximum design force was to be found (taking tension as negative) in which some of member were found to be under tension and some are in compression for all load combination. Design strength of tension and compression of identified member were obtained. While checking the strength of truss member which are under tension or compression are able to resist the actual load acting on it. It were found that member number 1 and 2 which are under tension not able to resist loads acting on it. Similarly, it were found that all columns which are under compression able to resist loads acting on it. Appropriate section has been suggested for this estimated load for this region.

Received 28 May, 2020; Accepted 31 July, 2020

REFERENCES

IS: 14462: (1997). Indian standard recommendation for layout, design and construction of greenhouse structure.

IS: 875 (Part 1)-(1987). Indian standard code of practice for design loads other than earthquake for buildings and structures, Part-1 Dead Load.

IS: 875 (Part 2)-(1987). Indian standard code of practice for design loads other than earthquake for buildings and structures, Part-2 Imposed Load.

IS: 875 (Part 3)-(1987). Indian standard code of practice for design loads other than earthquake for buildings and structures, Part-3 Wind Load.

IS: 875 (Part 4)-(1987). Indian standard code of practice for design loads other than earthquake for buildings and structures, Part-4 Snow Load.

IS: 875 (Part 5)-(1987). Indian standard code of practice for design loads other than earthquake for buildings and structures, Part-5 Special Loads and combination.

IS: 1446: (1997). Indian standard code for surface covered cultivation structure, glossary terms.

IS: 14485: (1997). Indian standard recommendation for heating, ventilating and cooling of greenhouse.

Indian Journal of Ecology (2020) 47(3): 703-707

Manuscript Number: 3069
NAAS Rating: 4.96

Impact of Drip Irrigation on Soil Biological Activity, Symbiotic Traits and Yield in Summer Mungbean

Harpinder Singh*, Mukesh Siag, Nilesh Biwalkar, Poonam Sharma[1] and Rakesh Sharda

Department of Soil and Water Engineering, [1]Department of Plant Breeding and Genetics
Punjab Agricultural University, Ludhiana-141 004, India
E-mail: harpinder.manshahiaa@gmail.com

Abstract: A field experiment was conducted in the summer seasons to assess the impact of drip irrigation on soil biological activity, symbiotic traits and yield in summer mungbean. Recommended variety of summer mungbean "SML-832" was sown with three drip irrigation treatments *viz.* $1.0ET_c(I_1)$, $0.80ET_c(I_2)$, $0.60ET_c(I_3)$ along with one controlled flood irrigation treatment (C). Significant difference for number of nodules, nodule dry weight and leghemoglobin content of nodules was observed at flowering stage between drip irrigation and controlled flood irrigation treatments which also had a positive impact on yield. The maximum number of nodules (35.1 plant^{-1}) nodule dry weight (78.7 mg plant^{-1}) and grain yield (1154 kg ha^{-1}) was under drip irrigation at $0.80ET_c$. Viable population of soil microbes increased from sowing to flowering stage but decreased at maturity of summer mungbean during both the years. Soil dehydrogenase activity was also maximum under drip irrigation at $0.80ET_c$at flowering stage. The overall viable count for bacteria (6.45 log cfu/g), actinomycetes (5.31 log cfu/g) and fungi (4.54 log cfu/g) were higher in drip irrigation at $0.80ET_c$ while minimum under flood irrigation treatment. The total microbial population and nodulation was higher in 2016 as compared with 2015 due to better initial soil microbial population. Grain yield was positively correlated with dry weight of nodules as well as with soil microbial population. From the study it was concluded that drip irrigation at 0.80 ET_c results in high soil microbial activity with enhancement in symbiotic traits and better crop yield in summer mungbean crop.

Keywords: Summer mungbean, Symbiotic traits, Soil biological activity, Drip irrigation

Mungbean (*Vigna radiata* L. Wilzeck), is an important leguminous pulse in Asia which is currently being promoted in arid areas. Mungbean seeds are rich in protein (22-24%) and serve as a valuable cereal supplement for human consumption. Mungbean, like most legumes is able to fix atmospheric nitrogen through symbiotic association with compatible *Rhizobium* which results in improving soil fertility through biological nitrogen fixation (BNF) (Malik et al 2006). Fluctuations in pH, nutrient availability, temperature and water status among other factors greatly influence the growth, survival, and metabolic activity of nitrogen fixation bacteria and plants, and their ability to enter into symbiotic interactions. Water scarcity is a major agricultural and developmental challenge for the dryland tropics. Many of these regions are faced with growing food insecurity associated with water shortage and erratic rainfall patterns, high population growth and dwindling land productivity (Montazar 2009). According to Geerts and Raes (2009), in areas where the available water supply limits agricultural production, deficit irrigation will gain importance over time as farmers strive to increase the productivity of their limited land and water resources. Deficit irrigation can play an important role as farm-level water management strategy with consequent increase in the output generated per unit of water used in agriculture provided that crops suitable for deficit irrigation application is used. Precise application of water through drip irrigation can save a lot of water as compared to high water losses and low irrigation efficiencies by conventional flood irrigation. With drip irrigation systems, water and nutrients can be applied directly to the crop at the root level, having positive effects on growth and yield of crop. Many studies have reported that yield of crops and water use efficiency was higher under drip irrigation over flooded irrigation (Sezen et al 2005, Sharda et al 2012 and Lodhi et al 2014).

Successful nodulation and biological N_2 fixation depend not only on the genetic background of both symbiotic partners but also on environmental factors such as soil water content, aeration, temperature, salinity and mechanical impedance. High soil temperatures strongly affect bacterial infection and N_2 fixation in several legume species, including soybean, guar (*Cyamopsis tetragonoloba*), peanut, cowpea and beans. Nodule functioning in common beans is optimal between 25 and 30°C and is hampered by root temperatures above 30°C. Increasing salt concentrations may have a detrimental effect on soil microbial populations as a result of direct toxicity as well as through osmotic stress.

Soil water influences the growth of soil micro-organisms through processes of diffusion, mass flow and nutrient concentration. Soil water is related to soil pore space, soils containing larger pores and pore spaces retain less water.

Soil moisture directly affects the physiological status of bacteria. Water availability affects the osmotic status of bacterial cells and can indirectly regulate substrate availability, diffusion of gases, soil pH, and temperature. Further, moisture deficit resulted stress in plants and affect bacterial communities through changes in rhizo deposition and nutrient allocation below ground.

Since drip irrigation can maintain optimum moisture content in the soil and help in stabilizing the soil temperature, it is likely to have a positive impact on the microbial population which in turn should positively impact the yield of the legume. This study intended to establish any correlation between microbial population and symbiotic traits in summer mungbean under drip irrigation and its impact on yield of the crop.

MATERIAL AND METHODS

The field experiment was conducted at Punjab Agricultural University, Ludhiana, Punjab, India in the summer season of the years 2015 and 2016. Ludhiana is situated at latitude of 30º 54'N and longitude of 75º 48' E and at the mean height of 247 meters above sea level. The minimum temperature may go down to 0°C or even less in winter while the maximum temperature may go as high as 46-47ºC during the summer season. Soil texture at the experimental site was sandy loam. The mungbean variety 'SML-832' which is a short duration (65-70 days) with medium shining seeds crop was grown in the dry summer months from April to June.

Experimental design and treatments: The experiment was designed as Randomized Block Design with four treatments, three drip irrigation treatments at different levels of water application i.e. water applied at 1.0 ET_c (I_1) , 0.80 ET_c (I_2) and 0.60 ET_c (I_3) under drip (applied at two days interval) and one conventional flood irrigation treatment was taken as controlled. One drip line was provided between two rows of crops. Each treatment was replicated thrice. Whole plot was divided into 12 sub-plot and every plot had fourteen rows. The two outer rows on each side were treated as buffers in each sub plot. Mungbean variety 'SML-832' was planted with 22.5 cm row to rows spacing on a 3.15 m × 10 m sub plot. Crop was raised as per recommended packages of practices. In the first year (2015) the crop was sown on fallow land, whereas in the second year (2016) the crop was sown in the same area but followed green manuring and tomato crop. Crop was sown after a pre sowing irrigation of 10 cm and irrigation started 10 days after sowing and stopped about 10 days before crop harvesting. The daily evapotranspiration values for the crop season were calculated using Modified Penman Method (Allen et al 1998) based upon daily meteorological data collected from the School of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana.

Data collection and analyses: Symbiotic traits, soil quality parameters and grain yield were recorded in different irrigation treatments. Data were recorded for number of nodules and dry weight of nodules (mg), leghemoglobin content of nodules by using Wilson and Reisenauer (1963) method and dehydrogenase activity in soil as per method of Tabatabai (1982) at flowering stage (35-40 days after sowing (DAS). The viable count of soil microbes like bacteria, actinomycetes and fungi was recorded at 0, 25, 40, 65 DAS according to standard pour plate method. The viable count for bacteria, actinomycetes and fungi was done on Nutrient agar (NA), Keenknight's and Potato dextrose agar (PDA) media respectively. After incubation (28±2°C for 2-4 days), colonies developed and the viable count of soil microbes was enumerated by following formula.

$$\text{Colony forming unit (Cfu) per g of sample} = \frac{\text{Number of colonies x Dilution factor}}{\text{Quantity of soil sample}}$$

Colony forming unit (Cfu) per gm sample was converted in log value using following formula.

$\text{Log}(a \times b^n) = \log a + n \log b$

Where a = Mean number of bacterial colonies

b^n = Dilution factor

Grains from whole of the plot (excluding buffer zone) was harvested and expressed in kg per hectare.

RESULTS AND DISCUSSION

Grain yield: The maximum yield for year 2015 and 2016 was obtained in I_2 (0.8 ET_c) i.e. 1107 kg ha^{-1} and 1202 kg ha^{-1}, respectively which was followed by I_1 (1.0 ET_c) and I_3 (0.6 ET_c), respectively (Table 1). Earlier finding also documented that sufficient moisture content in soil led to higher yields but under constrained moisture regime or water stressed conditions tended to decrease the grain yields in mungbean (Kulathunga et al 2008 and Manoj et al 2014) in the year 2015 for yield as compared to controlled. However, difference in yield between varied drip irrigation levels was non-significant.

Table 1. Effect of different irrigation regimes on the grain yield of summer mungbean

Treatments	Grain yield (kg ha^{-1})			Percentage increase over flood irrigation
	2015	2016	Mean	
I_1 (1.0 ET_c)	1081	1148	1114	38.4
I_2 (0.80 ET_c)	1107	1202	1154	43.3
I_3 (0.60 ET_c)	1037	1057	1047	30.0
C	778	833	805	-
CD (p=0.05)	83.0	124.5	-	-

During the year 2016 yield was significantly higher in 0.8 ET_c as compared with drip irrigation at 0.6 ET_c. In both years there was significant difference in yield between drip irrigation and flood irrigation treatment. The increase in yield in year 2016 might be due to cultivation of mungbean, green manuring and tomato on same land which may have contributed in improvement of soil fertility. In 2015, munbean was sown on fallow land. Thomas et al (2004) also reported drip irrigation stabilizes the optimum moisture content in soil rhizosphere with improvement in grain yield of mungbean. On the basis of pooled data of two years highest percent increase in grain yield with 0.80 ET_c treatment (43.3%) followed by 1.0 ET_c and 0.60 ET_c over flood irrigation.

Enumeration of soil Microflora: On the basis of two year data, soil bacteria were dominant group followed by actinomycetes and fungi. Results are also well in line with findings of Zhang et al (2000) and Li et al (2006) who reported different ratio of soil microflora in safflower. Dominance of soil bacteria in all the water regimes indicated efficient utilization of soil substrate and are also biologically active. Actinomycetes and fungi might have decomposed organic matter added in the soil through green manuring in the present experiment. Further low bacterial/fungi ratio also indicated high level of organic matter using efficiency and high quality environment conditions. During both years viable count of soil microbes increased upto 40 DAS (flowering stage) (Table 2) and decreased at maturity of crop which may be due to increasing temperature of soil at crop maturity stage and drying up of soil as irrigation was stopped at 55 DAS as per recommended package of practices. Moreover at maturity, due to diminishing amount of root exudates also resulted in reduction of microbial population in rhizosphere of summer mungbean crop. The viable count of bacteria, actinomycetes and fungi were higher in the year 2016 over the year 2015.

This enhancement in viable population of soil organisms could be due to sowing of mungbean followed by green manuring of land in 2015 which contributed into increased viable count of soil microbes in the year 2016. Maximum viable count of soil microbes were under drip irrigation 0.80 ET_c (I_2) followed by 1.0 ET_c (I_1) and 0.60 ET_c (I_3) but minimum under controlled flood irrigation treatment for both years. On the basis of pooled data for two years, overall mean values for soil microbes also observed under 0.80 ET_c and minimum for controlled flood irrigation (Table 2). Further it has been observed as soil becomes dry, water potential decreases and microbial activity becomes weak. During excessive moisture or flooding due to water logging anoxia in plant roots might have resulted in lower population of soil microbes as compared to other water regime treatments. Yan et al (2015) also documented excess water content limited the O_2 diffusion as O_2 diffusion in water is much lower (about 10^4

Table 2. Population dynamics of bacteria, actinomycetes and fungi at different time intervals under varied irrigation regimes in summer mungbean

Treatments	Viable population density (log cfu/g of soil) at DAS*												
	Before sowing			25			40			65			Overall mean
	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean	
Bacteria**													
I_1 (1.0 ET_c)	6.18	6.32	6.25	6.34	6.48	6.41	6.55	6.78	6.66	6.22	6.28	6.25	6.39
I_2 (0.80 ET_c)				6.39	6.53	6.46	6.57	6.83	6.70	6.24	6.35	6.30	6.45
I_3 (0.60 ET_c)				6.32	6.44	6.38	6.51	6.74	6.62	6.15	6.23	6.19	6.36
C				6.28	6.42	6.35	6.48	6.60	6.54	6.13	6.22	6.17	6.33
Actinomycetes**													
I_1 (1.0 ET_c)	5.09	5.19	5.14	5.26	5.42	5.34	5.43	5.66	5.54	4.96	5.15	5.05	5.27
I_2 (0.80 ET_c)				5.27	5.43	5.35	5.52	5.69	5.60	5.11	5.18	5.14	5.31
I_3 (0.60 ET_c)				5.23	5.35	5.29	5.38	5.57	5.47	4.81	5.06	4.93	5.21
C				5.15	5.27	5.21	5.30	5.53	5.41	4.76	5.03	4.89	5.16
Fungi**													
I_1 (1.0 ET_c)	4.00	4.71	4.35	4.49	4.79	4.64	4.72	4.93	4.82	4.12	4.33	4.22	4.51
I_2 (0.80 ET_c)				4.58	4.81	4.69	4.87	4.95	4.91	4.12	4.35	4.23	4.54
I_3 (0.60 ET_c)				4.33	4.67	4.50	4.44	4.80	4.62	4.09	4.22	4.15	4.40
C				4.14	4.63	4.38	4.35	4.75	4.54	4.0	4.12	4.06	4.33

* DAS= Days after sowing
**Non-significant at 5% level of significant

times) than in air which further reduced the viable population of aerobic organisms. The study indicates increase in soil microbes under drip irrigation treatment as compared to flood irrigation which may be attributed due to maintenance of better soil moisture regime. Variation in microbial count under different treatments was correlated to the yield. The highly positive correlation was observed for grain yield with peak total microbial population at 40 DAS (Fig. 1). Regression line analysis revealed that during 2015, the slope of linear correlation line is steeper than in year 2016 which indicating yield is more sensitive to change in microbial population at lower levels.

Dehydrogenase activity of soil: Maximum dehydrogenase activity of soil was under 0.80 ET_c in both years (Table 3). The dehydrogenase activity of soil was higher in year 2016, which might be due to increase in the viable count of soil microbes like bacteria, actinomycetes and fungi in year 2016. In 2015, there was non-significant difference between different drip irrigation treatments but differed significantly from controlled flood irrigation. During the year 2016 there was significant difference between drip irrigation of I_2 and I_3 apart from the significant difference between drip and flood irrigation (Fig. 2). The significant difference in grain yield between I_2 and I_3 were observed in 2016 thereby establishing a good correlation between dehydrogenase activity and grain yield. The drip irrigation probably enhanced dehydrogenase activity of soil as compared to flood irrigation which positively correlates with crop yield due to intense microbial activity. The abundance of microbial community in soil rhizospheres of different irrigation regimes greatly influenced the soil dehydrogenase activity as compared to control treatment. Excess and less water treatment reduced the soil dehydrogenase activity (Gianfreda 2015). Reduced level of dehydrogenase activity in 0.6 ET_c (I_3) could be due to constrained moisture conditions which might have influenced the activity of soil enzymes.

Effect of different irrigation regimes on symbiotic traits: In both years there was non-significant difference between I_1 and I_2 treatment, but was significantly higher than I_3 treatment and controlled flood irrigation for nodulation (Table 4). Significantly low leghemoglobin content in the nodules of

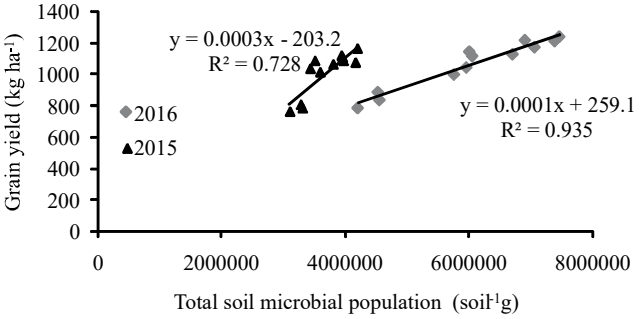


Fig. 1. Correlation between total soil microbial population (40 DAS) and grain yield

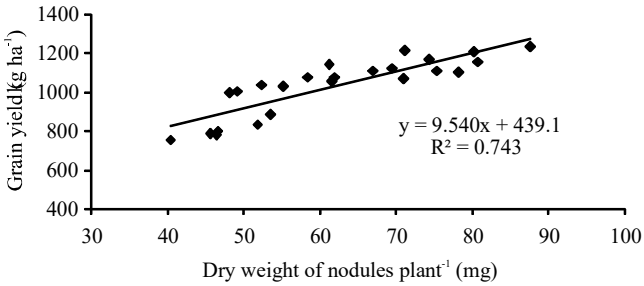


Fig. 2. Correlation between dry weight of nodules and grain yield in summer mungbean

Table 3. Effect of different irrigation regimes on soil dehydrogenase activity in summer mungbean

Treatments	Dehydrogenase activity (µg TPF g^{-1} soil hr^{-1})			Percentage increase over flood irrigation
	2015	2016	Mean	
I_1 (1.0 ET_c)	22.36	31.79	27.07	59.4
I_2 (0.80 ET_c)	23.75	37.76	30.75	81.1
I_3 (0.60 ET_c)	21.3	26.82	24.06	41.7
C	14.87	19.1	16.98	-
CD (p=0.05)	5.02	6.12	-	-

Table 4. Effect of different irrigation regimes on symbiotic parameters in summer mungbean

Treatments	Symbiotic parameters								
	Number of nodule $plant^{-1}$			Dry weight of nodules $plant^{-1}$ (mg)			Leghemoglobin content (mg/g fresh weight of nodules)		
	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean
I_1 (1.0 ET_c)	32.3	32.5	32.4	66.3	69.2	67.8	3.2	4.1	3.6
I_2 (0.80 ET_c)	34.5	35.7	35.1	76.7	80.7	78.7	3.4	4.8	4.1
I_3 (0.60 ET_c)	28.1	27.5	27.8	54.3	53.9	54.1	2.7	3.7	3.2
C	14.0	20.8	17.4	44.5	50.3	47.4	2.5	3.1	2.8
CD (p=0.05)	5.6	6.0	-	9.1	12.1	-	0.51	0.77	-

Table 5. Effect of different irrigation regimes on water saving in summer mungbean

Irrigation treatments*	Total depth of irrigation water applied (mm)			Percentage saving over flood irrigation (100%)
	2015**	2016***	Mean	
I_1 (1.0 ET_c)	334.0	368.0	356.0	15.7
I_2 (0.8 ET_c)	267.2	294.5	280.8	33.5
I_3 (0.6 ET_c)	200.4	220.8	210.6	50.2
C	395.0	450.0	422.5	-

*Pre sowing irrigation of 100 mm applied in all treatment
**Effective rainfall in the year 2015= 38.9 mm
***Effective rainfall in the year 2016= 24.3mm

irrigation in 0.6 ET_c may be due to limited moisture content of soil. Number of nodules and nodule dry weight per plant remained similar in both the years except for a substantial increase under flood irrigation treatment. The leghemoglobin content increased in 2016 indicating bold, effective nodules with pink colour. Further from the two year data of all experimental plots, a positive linear correlation between the dry weight of nodules and grain yield was recorded in summer mungbean (Fig. 3). The better nodule formation under drip irrigation treatment had a direct impact on crop yield. Nodule typology greatly influenced the effective N_2 fixation. Summer mungbean nodules are determinate type as they are superficially attached to roots and more adversely affected by low levels of irrigation treatment (0.60 ET_c). Daryanto et al (2015) documented that indeterminate nodules (nodules formed by endoderms) are able to resist water stress better than determinate nodules. Moreover determinate nodules are short lived and that might have limit the efficiency of N_2 fixation in I_3 (0.60 ET_c). Fening et al (2009) documented change in soil moisture stress from 100 to 25% field capacity (FC) reduced nodulation by 37, 19 and 9% in lalab, stylosanthes and cenrtosema, respectively. Increasing water intensity i.e., flood irrigation treatment reduced the symbiotic parameters in summer mungbean. This reduction in symbiotic traits could be due to anaerobic conditions created by flooding as it is well known *Rhizobium* forming nodules are aerobic in nature.

Irrigation water requirement: The maximum percentage saving in irrigation water over flood irrigation was in I_3 (50.15%) followed by I_2 (33.53%) and I_1 (15.73%) in 2015 and 2016 (Table 5).

CONCLUSIONS

The drip irrigation resulted in significantly high soil microbial population. Improvement in population dynamics with soil enzymes along with symbiotic parameters contributed positively in the enhancement of grain yield of summer mungbean in drip irrigation regime at 0.80 ET_c (I_2). Grain yield was positively correlated with total soil microbe population as well as with dry weight of nodules. On the basis of pooled data of two years, drip irrigation treatment at 0.8 ET_c level can be recommended as it improves summer mungbean yield by 43% with saving of 33% of water over flood irrigation treatment.

Received 31 May, 2020; Accepted 12 August, 2020

REFERENCES

Allen RG, Pereira, LS, Raes D and Smith M 1998. Crop evapotranspiration-Guidelines for computing crop water requirements. *FAO irrigation and drainage paper no: **56***, Rome.

Daryanto S, Wang L and Jacinthe PA 2015. Global synthesis of drought effects on food legume production. *Plos One* 10(**6**): 1-16.

Geerts S and Raes D 2009. Deficit irrigation as an on-farm strategy to maximize crop water productivity in dry areas. *Agricultural Water Management* **96:** 1275-1284.

Gianfreda L 2015. Enzymes of importance in rhizosphere. *Journal of Soil Science and Plant Nutrition* **15**(2): 283-306.

Kulathunga MRDL, De Silva SHSA and Sangakkara UR 2008. Impact of soil moisture on growth, yields and nodulation of mungbean (*Vigna radiata*) growing in the yala season on non-calcic brown soils. *Tropical Agriculture Research* **20:** 395-399.

Li N, Li HX and Zhu FJ 2006. Relationship between soil microbial ecological characteristics and physical-chemical properties of vegetable garden soil. *Chinese Journal of Applied Ecology* **17:** 285-290.

Lodhi AS, Kaushal A and Singh KG 2014. Impact of irrigation regimes on growth, yield and water use efficiency of sweet pepper. *Indian Journal of Science and Technology* 7(**6**): 790-794.

Malik MA, Saleem MF, Ali A and Ishaq RAF 2006. Effect of sowing dates and planting patterns on growth and yield of mungbean. *Journal of Agriculture Research* **44:** 139-148.

Manoj Singh RK, Singh AN, Ram H and Prasad SR 2014. Growth, yield attributes and quality of summer green gram (*Vigna radiata* L.) as influenced by nitrogen and irrigation levels. *Annals of Agricultural Research* **35**(1): 47-53.

Montazar A 2009. Assessing the global water productivity of some irrigation command areas in Iran. *World Academy of Science Engineering and Technology* **150:** 18-29.

Sezen SM, Yazar A, Canbolat M, Eker S and Celikel G 2005. Effect of drip irrigation management on yield and quality of field grown green beans. *Agricultural Water Management* **71**: 243-255.

Sharda R, Siag M, Kaur K, Biwalkar N, Singh K, Chawla AK, Thaman S and Singh C 2012. Maximizing production and profitability under drip irrigated and fertigated potato (*Solanum tuberosum* L.). *Indian Journal of Ecology* **39**(2): 222-225.

Tabatabai MA 1982. *Soil enzymes*. In methods of analysis, part 2, 2nd Ed. A L page et al (eds). Agro **9:** 903-947.

Thomas Robertson MJ, Fukai S and Peoples MB 2004. The effect of timing and severity of water deficit on growth, development, yield accumulation and nitrogen fixation of mungbean. *Field Crop Research* **86:** 67-80.

Wilson D and Reisenauer O 1963. Determination of leghaemoglobin in legume nodules. *Analytical Biochemistry* **6:** 27-30.

Yan N, Marschner P, Cao W, Zuo C and Qin W 2015. Influence of salinity and water content on soil microorganisms. *International Journal of Soil Water Conservation Research* **3:** 316-323.

Zhang YB, Wang WQ and Zhuang TC 2000. Microbial amounts variation in mudflat soil at southwest in west Xiamen Harbour. *Journal of Oceanography* **19:** 54-59.

Indian Journal of Ecology (2020) 47(3): 708-711

Manuscript Number: 3070
NAAS Rating: 4.96

Assessment of Changes in Observed Rainfall and Prediction of Future Conditions Using Quantile Delta Mapping Bias Correction Technique over Cauvery River Basin, India

Parthiban Loganathan and Amit Baburao Mahindrakar*

School of Civil Engineering, Vellore Institute of Technology (VIT), Vellore-632014, India
**E-mail: amahindrakar@gmail.com*

Abstract: The assessment of changes in rainfall over a regional scale has become essential to manage future planning and policy development. The changes in precipitation over the Cauvery river basin are studied using the general circulation models output and observed datasets. Future scenarios and historical model outputs from the CNRM-CM5 model are used in this study .The historical observed precipitation data is used to project future precipitation by comparing historical and future model simulation. The change assessment shows significant increase in rainfall throughout the basin with an increase in future time scale. The quantile delta mapping handles the bias in the general circulation models better than the traditional quantile mapping bias correction technique. The quantile delta method is simple, easy to apply and requires less computational power. The increase in future precipitation compared to observed statistics ranges from 20 to 100 % especially during the monsoon seasons. The Representative Concentration Pathways (RCP) 2.6 and RCP 8.5 scenarios show very high changes in precipitation with an increase in future time scale and the RCP 4.5 scenario shows moderate changes compared to other scenarios. Tracking the precipitation rate and forecasting future conditions will help the planning of actions and development at a regional scale.

***Keywords*:** Bias correction, Climate change, Cauvery river basin, Global warming, Precipitation

Over the past few decades, a large number of studies have been conducted to assess the impacts of climate change on hydrological structures(Alexander et al 2006, Tiwari et al 2014, Alexander and Arblaster 2017). Rainfall is one of the important factors that determines the changes in the hydrological regime (Bardossy et al 2005, Asong et al 2016, Zilefac et al 2016). General circulation models (GCMs) are numerical models that simulate the earth atmospheric conditions based on different boundary conditions. The GCMs are very skilled models that represent climate variability on a large scale. However, regional-scale climate studies are required for developing local strategies and actions. Yet, the maximum number of studies focused on large-scale forecasts using the Coupled Model Intercomparison Project Phase 3 (CMIP3) GCMs. These models had altered future scenarios and significantly old matched to the present CMIP5 models. In recent times, studies that applied CMIP5 GCM (Shashikanth et al 2014, Sun et al 2014) proposed improved decisions than that of CMIP3. The GCMs cannot be used directly for regional level studies and it requires a process of downscaling (Bardossy et al 2005, Wilby and Dawson 2013). In recent periods many climate institutes established several GCMs based on the boundary conditions and generated different future scenarios. Since every GCM has its own limitations it is important to choose a suitable model for the study site (Srinivasa Raju et al 2017). Numerous techniques were developed to handle the variability between observed and simulated data but each technique has various limitations. The bias in GCM historical simulated data can be better handled by the bias correction technique with the help of observed data (Ahmed et al 2013). The bias correction technique is computationally efficient yet effective in adjusting the variability in GCM simulations. In this study, the Cauvery river basin located in India is considered because of its history of frequent flood and drought events. The historical observed precipitation data is employed to bias correct the historical GCM simulation. Further, the bias correction pattern is applied over the future scenarios simulated from GCMs to predict the future precipitation amounts. The primary objectives of the present study are to handle the bias in CMIP5 GCMs historical precipitation simulations with the help of historically observed precipitation and to evaluate the changes in future precipitation using future scenarios projected by bias correction.

MATERIAL AND METHODS

Study area: Cauvery River basin falls in peninsular India and lies between 75°27'E to 79°54'E and 10°9'N to 13°30'N and spread over states of Tamil Nadu, Karnataka, Kerala and

Union Territory of Puducherry with draining an area of around 85,000 sq km. It is confined by the Western Ghats on the west, by the Eastern Ghats on the east and south (Fig. 1). The key regions of the basin are covered with agricultural land up to 67% of the total area and 20 % of the basin is covered by forest area (CWC and NRSC 2014). The Cauvery river basin has four seasons namely winter (December to February), summer (March to June), south-west monsoon (July to September) and north-east monsoon (October to November). The basin remains dry in the majority of the area except for the monsoon duration. The basin has both tropical and sub-tropical climate zones whereas the temperature variation in upper reaches of the basin is less compared to the lower reaches. April is the hottest and January turns out to be the coldest month in the basin whereas the average monthly temperature ranges from 18°C to 33°C. Northern parts of the basin are comparatively colder than the southern parts of the basin. The study area is further classified into the upper, middle and lower river basin for a better understanding of changes within the basin (Fig. 2).

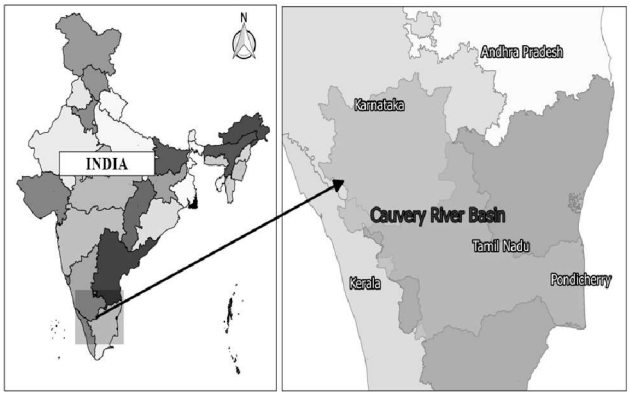


Fig. 1. Cauvery river basin extent and boundary

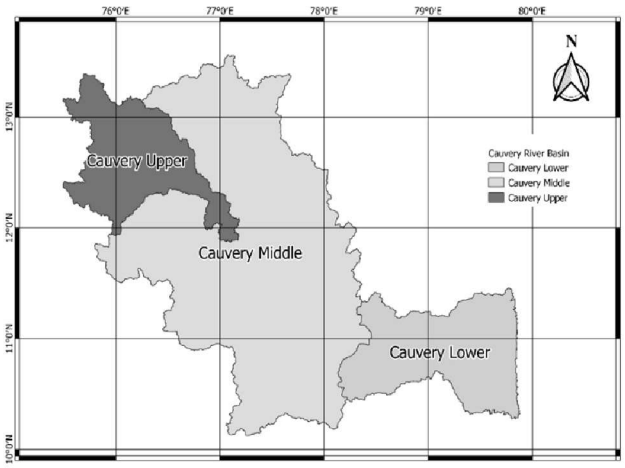


Fig. 2.Classification of the Cauvery river basin

Data Description

Observed data*:* The daily observed average surface temperature is obtained from the Indian Metrological Department (IMD) gridded data (0.5° x 0.5° or 55 km x 55 km) for the Cauvery river basin for the period of 1976-2005. The river basin is further classified into upper, middle and lower Cauvery river basin based on its weather pattern and discharge statistics. Further, the historical GCM dataset is regridded to a 0.5° x 0.5° scale and trimmed to the observed data length.

GCM data*:* The CMIP5 GCM used in this study is CNRM-CM5 due to its best performance in projecting temperature scenario at grid points falling over the Cauvery river basin (Srinivasa Raju et al 2017). The CNRM-CM5 is developed at Météo-France and Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique (CERFACS, France). The time scale of 1976-2005 for historical simulation and 2006-2095 for all future projected scenarios are considered in this study. The grid size of the GCM is 1.4° x 1.4° or 155 km x 155 km. The future scenarios available are Representative Concentration Pathway (RCP) – RCP2.6, RCP4.5, and RCP8.5. The daily ensemble realization run used was r1i1p1 (ensemble member-1, initialization state-1, and physical parameterization-1).

The biases in the GCM need to be corrected for improvising the future climate projection at a regional scale. The quantile mapping (QM) technique is widely used in bias correction of precipitation because of its performance in preserving the trends. The time scale of future projected data is split into three-time slices i.e. 1) near future (2006-2035), 2) mid future (2036-2065), and 3) far future (2066-2095). The QM based bias correction technique can be expressed in the following equation.

$$BC_{Fut}(i) = CDF_{Obs}^{-1}[CDF_{Fut}[His(i)]] \quad (1)$$

Where BC_{Fut} (i) is *i*th bias corrected data, CDF_{Obs}^{-1} is inverse CDF of observed data, CDF_{Fut} is CDF of model simulated future, and His (i) is Historical model simulation data.

In QM the probability distribution function of the future is assumed to be the same as the observed data. Thus, the long term future projection can be biased while using QM. The quantile delta mapping (QDM) technique is designed to preserve long term changes in quantiles projected and also reported to minimize the trends and bias in GCMs. The QDM is expressed in the following equations.

$$\Delta_{Fut}(i) = \frac{Q_{Fut}(i)}{CDF_{His}^{-1}[CDF_{Fut}[Q_{Fut}(i)]]} \quad (2)$$

$$BC_{Fut}(i) = CDF_{Obs}^{-1}[CDF_{Fut}[Q_{Fut}(i)]]\, x\Delta_{Fut}(i) \quad (3)$$

Where, Δ_{Fut} (i) is relative changes in *i*th quantiles between historical and future GCM simulation, and Q_{Fut}(i) is the *i*th quantile of future simulated data. The QDM is divided into two steps i.e. i) Calculating relative changes Δ_{Fut}(i) as in equation (2), and ii) Calculating bias-corrected future projection BC_{Fut} *(i)* by multiplying Δ_{Fut}(i) with historical bis corrected values as directed in equation (3). The quantile delta mapping bias correction methodology is briefly described in Figure 3.

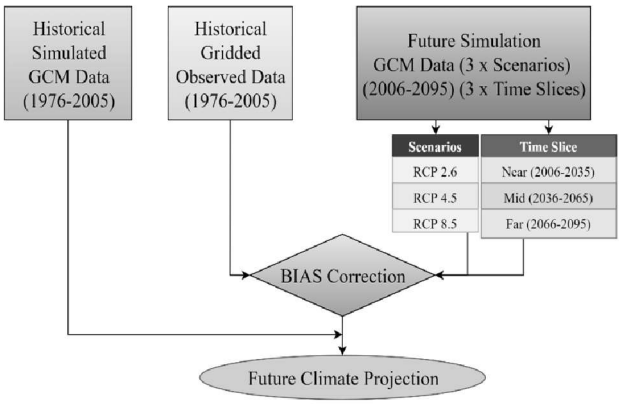


Fig. 3. Quantile mapping bias correction methodology

RESULTS AND DISCUSSION

The projections precipitation over different future scenarios is compared with observed precipitation data to understand the possible changes in future climate. Seasonal changes are mentioned for winter (WIN), summer (SUM), South-West monsoon (SWM), and North-East monsoon (NEM).The historical observed precipitation statistics infers that the upper basin receives more rainfall during SWM whereas middle and lower basins receive their maximum spell during NEM. Upper basin records the least precipitation during winter and the lower basin sets the scale of higher precipitation during NEM (Table 1).

The precipitation data projected for future scenarios generated by applying the QDM on GCM future data is compared with historical observed data (Table 2). The projections show significant changes throughout future time slices during each scenario. The projected data states that during the near future time slice the increase in precipitation trends ranges from 20 to 70 % especially in the upper and middle Cauvery river basin during monsoon seasons. The trend drops a little during the mid future and hikes again for the far future period. However, the comparison between the scenarios shows moderate changes with RCP 4.5 and significant changes considering RCP 2.6 and RCP 8.5.

Table 1. Sub-basin wise observed precipitation

Season	Precipitation (mm)		
	Upper	Middle	Lower
WIN	5.6	15.5	104
SUM	76.4	62.9	35.7
SWM	128.1	119.3	89.4
NEM	116.7	139.9	325.1

CONCLUSION

Forecasting the changes in rainfall has become very essential for water management and planning at a regional scale. An efficient and simple bias correction technique is discussed in this study for handling GCM errors at a local scale. The quantile delta mapping handles bias in climate models better than traditional quantile mapping techniques. The quantile delta mapping technique is a computationally efficient and effective technique for regional precipitation change assessments. The projected precipitation using quantile delta mapping over the Cauvery river basin clearly explains the rapid changes in precipitation over the region. The monsoon rainfall being major contribution throughout the basin tends to increase over the future decades ranges between 20 to 100 %.The increasing trend peaks for RCP 2.6 and RCP 8.5 whereas it's moderate for RCP 4.5 Scenario.

Table 2. Sub-basin wise percentage change in precipitation for future projected scenarios

Time slice	Season	RCP 2.6			RCH 4.5			RCP 8.5		
		Upper	Middle	Lower	Upper	Middle	Lower	Upper	Middle	Lower
Near future	SWM	30	30	20	20	20	20	20	20	20
	NEM	60	60	30	40	40	20	70	70	30
Mid future	SWM	40	30	30	30	30	20	40	40	30
	NEM	50	60	40	40	50	20	70	70	40
Far future	SWM	40	30	30	30	30	30	50	50	40
	NEM	80	100	50	60	60	30	90	90	60

REFERENCES

Ahmed KF, Wang G, Silander J, Wilson AM, Allen JM, Horton R and Anyah R 2013. Statistical downscaling and bias correction of climate model outputs for climate change impact assessment in the U.S. northeast. *Global and Planetary Change* **100**: 320-332.

Alexander LV and Arblaster JM 2017. Historical and projected trends in temperature and precipitation extremes in Australia in observations and CMIP5. *Weather and Climate Extremes* **15**: 34-56.

AlexanderLV, Zhang X, Peterson TC, Caesar J, Gleason B, Klein Tank AMG, Haylock M, Collins D, Trewin B, Rahimzadeh F, Tagipour A, Rupa Kumar K, Revadekar J, Griffiths G, Vincent L, Stephenson DB, Burn J, Aguilar E, Brunet M, Taylor M, New M, Zhai P, Rusticucci M and Vazquez-Aguirre JL 2006. Global observed changes in daily climate extremes of temperature and precipitation. *Journal of Geophysical Research: Atmospheres* **111**: 1-22.

Asong ZE, Khaliq MN and Wheater HS 2016. Projected changes in precipitation and temperature over the Canadian Prairie Provinces using the Generalized Linear Model statistical downscaling approach. *Journal of Hydrology* **539**: 429-446.

Asong ZE, Khaliq MN and Wheater HS 2016. Multisite multivariate modeling of daily precipitation and temperature in the Canadian Prairie Provinces using generalized linear models. *Climate Dynamics* **47**: 2901-2921.

Bardossy A, Bogardi I and Matyasovszky I 2005. Fuzzy rule-based downscaling of precipitation. *Theoretical and Applied Climatology* **82**: 119-129.

Legendre P and Birks HJ 2012. From classical to canonical ordination. Chapter 8 in tracking environmental change using lake sediments, data handling and numerical techniques. *Change* **5**: 716.

CWC and NRSC 2014. *Cauvery Basin Report*. Central Water Commission and National Remote Sensing Centre.

Shashikanth K, Madhusoodhanan CG, Ghosh S, Eldho TI, Rajendran K and Murtugudde R 2014. Comparing statistically downscaled simulations of Indian monsoon at different spatial resolutions. *Journal of Hydrology* **519**: 3163-3177.

Srinivasa Raju K, Sonali P and Nagesh Kumar D 2017. Ranking of CMIP5-based global climate models for India using compromise programming. *Theoretical and Applied Climatology* **128**: 563-574.

Sun X, Thyer M, Renard B and Lang M 2014. A general regional frequency analysis framework for quantifying local-scale climate effects: A case study of ENSO effects on Southeast Queensland rainfall. *Journal of Hydrology* **512**: 53-68.

Tiwari PR, Kar SC, Mohanty UC, Kumari S, Sinha P, Nair A and Dey S 2014. Skill of precipitation prediction with GCMs over north India during winter season. *International Journal of Climatology* **34**: 3440-3455.

Wilby RL and Dawson CW 2013. The statistical downscaling model: Insights from one decade of application. *International Journal of Climatology* **33**: 1707-1719.

Received 25 May, 2020; Accepted 19 August, 2020

Indian Journal of Ecology (2020) 47(3): 712-715

Manuscript Number: 3071
NAAS Rating: 4.96

Nutrient Management of Garlic (*Allium Sativum* L.) cv. Bhima Purple in an Integrated Way

K. Singh, S. Maji, D.H. Dwivedi and M. Prasad

Department of Horticulture, Babasaheb Bhimrao Ambedkar University, Lucknow-226 025, India
E-mail: majisutanu@gmail.com

Abstract: Treatments combination of NPK, sulphur, vermicompost, phosphate solubilizing bacteria, PSB), Farm Yard Manure (FYM, poultry manure and kitchen waste compost were attempted to assess the effect of NPK, organic manure and bio fertilizers on growth, yield and quality of garlic. The application of recommended dose of chemical fertilizers (NPK 100:50:50 kg/ha) had good response to increase the bulb yield. However, most of vegetative growth, morphs-chemical qualities of bulb were better with NPK 75:30:30 kg/ha + S 50kg/ha + Kitchen waste compost 10 t/ha which was better than the recommended dose of chemical fertilizers viz. maximum plant height (52.92 cm), number of leaves/plant (8.74cm), average bulb weight (20.33g), yield/plot (813.2 g), yield/ha (112.94 q). Thus, application of kitchen waste compost may be used in integrated way with chemical NPK and Sulphur to improve the production and quality of garlic.

Keywords: Fertilizers, Garlic, Growth, Manuring, Nutrition, Quality, Yield

Garlic (*Allium sativum* L.) is the second most important bulb crop after onion and India is one of the leading producers after china followed by South Korea, Egypt and Russia. The area and production in India has increased in recent times due to very good export potential having rupees 2097.88 lakh foreign exchange (Anonymous 2017). Like majority of the vegetable crops garlic is vigorously growing, high yield potential and thus, is highly responsive to application of manures and fertilizers. Chemical fertilizers are widely used but, due to soil health and environmental sustainability use of chemical fertilizers should be minimized (Maji 2013). However, organic manures are least to meet the requirement for all agricultural land and also the entire amount of certain nutrient cannot be supplied through organic manures only. Therefore, integrated nutrient management involving judicious application of manures and fertilizers is desirable to maximize the agricultural production as well as to improve soil health and fertility (Lambrecht et al 2015). The role of farm yard manure in enhancing efficient use of chemical fertilizers is well documented. Despite this, the balance use of all the nutrients along with sulphur is necessary for good yield and quality in garlic. Integrated nutrient management practice involving recommended doses of fertilizer along with FYM, vermicompost, PSB and *Trichoderma* would be effective in increasing the plant growth and productivity of garlic besides improving the physico-chemical properties of soil (Mankar 2005, Verma 2013). Kitchen waste is a hazard for rural and urban residential areas, but it can be converted to potential manure which can be utilized for crop production provided there are no toxic materials (Tiwari et al 2016, Kiran et al 2017, Tiwari et al 2017, Nayak and Maji 2018). Therefore, a study on integrated application of organic and inorganic nutrients has been aimed to see the response on growth, yield and quality of garlic cv. Bhima Purple.

MATERIAL AND METHODS

The experiment was conducted during 2017-2018 at Babasaheb Bhimrao Ambedkar University, Lucknow, located at 26°56' North latitude, 80°5' East longitude and an altitude of 111 m above mean sea level (MSL) in sub-tropical tract of Central Uttar Pradesh. It has hot scorch winds during summers with temperature ranging from 22°C to 45°C in summer and 3.5°C to 15°C in winter and related humidity ranging from 60-80% with 750 mm annual rainfall. The soil of experimental plot is sandy loam with more than 7.5 pH. Garlic bulbs cv. Bhima Purple was collected from the Directorate of Onion and Garlic Research, Rajgurunagar, Pune. Nine treatments i.e. recommended dose of chemical fertilizers and integrated nutrient application with combination of sulfur, PSB, vermicompost, kitchen waste manure, FYM, poultry manure, cycocel and paclobutrazol were experimented with three replications under randomized block design. Vegetative characters (plant height, diameter, leaves etc.), yield, bulb and clove quality characters were studied as per standard AOAC (2000) method.

RESULTS AND DISCUSSION

Plant height of garlic was higher with application of recommended dose of fertilizers (RDF) at initial growth stage, however at later stage of growth plant height

increased with application of integrated dose of NPK (75:30:30) + S (50 kg ha^{-1}) and kitchen waste compost (10 t ha^{-1}) followed by application of vermicompost and RDF, although, treatments effect was non-significant. Similarly, number of leaves increased with integrated nutrient management as compared to control and RDF. The treatment 75:30:30 kg ha^{-1} NPK+S 50 kg ha^{-1} +10 t ha^{-1} kitchen waste manure produced the highest number of leaves at all stages of growth (30, 60, 90, 120 DAT) followed by RDF and 75:30:30 kg/ha NPK+S 50 kg/ha+ 7 t/ha vermicompost (Table 1). Basal diameter of stem was d maximum with RDF at 30 DAT, while T_7 showed maximum diameter of stem at 60 DAT and similar trend followed at 90 and 120 DAT. The increase in basal diameter was statistically very close between T_7 and T_2 while control plants exhibited minimum diameter at all stages of growth. Integrated application of nutrients also showed a significant effect or morphological characters of garlic bulb and clove (Table 2). Average of weight of bulb was maximum when the plants were treated with NPK (75: 30: 30) + S (50 kg/ha) + kitchen waste compost (10 t/ha) i.e. T_7 followed by T_2 (RDF), however, they are statistically at par. Similar result was also found in case of number of cloves/bulb but the difference is statistically non-significant. Very close difference was found in average weight of clove due to various treatments. However T_7, T_8 and T_2 showed a same clove weight of 1.17 g. Maximum bulb weight in T_7 resulted in highest bulb yield (813 g/plot and 112.94 q/ha) followed by T_2. Among the various integrated approach, T_7 (i.e. application of 75: 30: 30 NPK (kg/ha) + S (50 kg/ha) and (10 t/ha) caused maximum diameter (polar and equatorial) of bulb followed by recommended dose of fertilizers. The 100 clove weight was maximum in T_7 and T_2

Table 1. Effect of integrated nutrient management on plant height of growth Cv. Bhima Purple

Treatments	Plant height (cm)				Number of leaves/plant				Basal diameter of stem (mm)			
	30 DAT	60 DAT	90 DAT	120 DAT	30 DAT	60 DAT	90 DAT	120 DAT	30 DAT	60 DAT	90 DAT	120 DAT
T_1	14.11	26.14	41.14	47.74	3.11	5.11	5.85	7.92	3.77	5.83	7.17	8.96
T_2	16.11	28.11	44.40	52.33	3.44	5.44	6.55	8.70	5.93	8.00	9.35	12.30
T_3	14.48	27.18	42.85	51.29	3.33	5.33	6.33	8.37	4.31	6.79	8.91	10.14
T_4	14.77	27.66	44.55	52.59	3.40	5.44	6.44	8.70	4.60	7.71	9.35	10.68
T_5	14.24	27.00	44.33	51.88	3.33	5.33	6.66	8.29	4.09	7.09	8.87	10.18
T_6	14.14	26.81	42.96	51.36	3.10	5.14	6.44	8.40	4.13	6.00	8.81	9.96
T_7	15.33	28.36	45.59	52.92	3.48	5.55	6.96	8.74	5.87	9.00	11.4	13.41
T_8	14.74	27.52	44.03	51.40	3.40	5.40	6.66	8.59	4.52	7.60	8.95	10.49
T_9	14.44	27.28	41.62	48.62	3.40	5.40	6.51	8.62	4.32	7.29	8.92	10.43
CD (p= 0.05)	1.18	1.18	NS	NS	NS	NS	0.49	NS	1.789	1.72	1.52	1.89

T_1- Control (no nutrient application); T_2- Recommended dose of fertilizers (NPK 100:50:50; T_3- 75:50:50 KG/ha NPK + S 50 kg/ha; T_4- 75:30:30 kg/ha NPK + S 50 kg/ha +7.5 t/ha Vermicompost; T_5- 75:30:30 kg/ha NPK + S 50 kg/ha + 5 kg/ha PSB; T_6- 75:30:30 kg/ha NPK + S 50 kg/ha + 10 t/ha FYM; T_7- 75:30:30 kg/ha NPK + S 50kg/ha + 10 t/ha; T_8- 75:30:30 kg/ha NPK + S 50 kg/ha + 7.5 t/ha Poultry manure; T_9- 75:30:30 kg/ha NPK + S 50 kg/ha + Paclobuterazol @ 500 ppm + Cycocel @ 1000 ppm

Table 2. Influence of various fertilization on yield and bulb characters

Treatments	Average weight of bulb (g)	Number of cloves /bulb	Average weight of clove (g)	Weight of 100 cloves	Yield/plot (g)	Yield ha^{-1} (q)	Equatorial diameter of bulb (mm)	Polar diameter of bulb (mm)	TSS (°Brix)	pH	Moisture content (%)
T_1	17.38	22.11	0.99	99.00	695.2	96.56	34.71	34.58	29.2	5.15	93.42
T_2	19.29	24.89	1.17	117.00	771.6	107.17	38.87	38.61	39.5	6.40	95.00
T_3	18.14	23.44	1.03	103.00	725.6	100.78	35.47	37.07	34.6	5.35	88.63
T_4	18.96	24.44	1.08	116.00	758.4	105.33	38.43	34.58	38.7	6.25	80.68
T_5	15.92	22.33	1.03	103.00	636.8	88.44	35.84	36.07	37.8	5.70	94.44
T_6	17.11	22.56	1.08	108.00	684.4	95.06	35.38	36.20	39.4	5.50	92.75
T_7	20.33	24.89	1.17	117.00	813.2	112.94	39.27	39.00	39.6	6.80	94.44
T_8	17.07	24.22	1.17	116.00	682.8	94.83	37.83	37.27	38.4	6.00	92.40
T_9	17.37	24.22	1.16	108.00	694.8	96.50	37.30	36.65	37.9	5.55	92.20
CD (p=0.05)	6.01	1.69	3.28	3.28	26.75	3.72	2.91	2.18	4.30	NS	1.86

(117.00 g). All the treatments showed a significant increase of TSS as compared to control plants. The T_7 showed increase in TSS (35.6°B) which was very close to RDF and T_6. Although, pH of garlic was influenced by different treatments but the variation was very close and statistically at par. Dry matter content is an important parameter for any product and maximum dry matter content was found T_7 followed by T_2.

The integrated use of various source of nutrient with organic sources significantly improves the growth characters of the garlic plant in compression to chemical fertilizer alone. Combined application of 75:30:30 kg/ha NPK + S 50 kg/ha + 10t/ha Kitchen waste manure showed the maximum plant height, number of leaves per plant and basal diameter of stem at different stages of growth i.e. 30, 60, 90 and 120 days after planting (DAP). The integrated use of nutrient actually resulted in rapid cell division, multiplication and cell elongation in meristematic region of the plant which promoted vegetative growth of plant. Quick availability of chemical fertilizers (N, P, K) might increase vegetative growth i.e. plant height at initial stage of growth but, other organic manures slowly released elements and caused better vegetative growth at later stage of growth. Similar kind of results were also observed by Kore et al (2006) and Gaiki et al (2006) due to different levels of organic manure, inorganic fertilizers as well as combination of organic and inorganic fertilizers in respect of growth and yield of garlic.

Better vegetative growth might be related to the positive effect of kitchen waste compost and microorganisms in increasing the root surface per unit of soil volume, water-use efficiency and photosynthetic activity, which directly affects the physiological processes and utilization of carbohydrates. These suggestions are confirmed by analysis of bio-compost which illustrates the higher levels nutrients and organic matter was in compost. Similar results were obtained by Zaied et al (2003) on wheat and by Assefa et al (2015) in garlic.

The maximum yield per plot, yield per hectare, average bulb weight, number of cloves per bulb, average weight of clove, weight of 100 cloves, equatorial diameter of bulb and polar diameter of bulb were observed in treatment T_7. This is might be due to organic manures and compost which activate many species of living organisms which release phyto-hormones and might stimulate plant growth and yield (Choudhary et al 2010, 2011). The results obtained in the present investigations confirm with the earlier findings of Chattopadhyay et al (2006) and Gowda et al (2007) who reported better growth of garlic and onion crops with application of organic and inorganic sources of nutrients.

Maximum TSS was estimated under treatment T_7 along with high dry matter content. RDF increased moisture content of the bulb. The result is accordance with the findings of Singh (2016) and Govind et al (2015) in garlic and Waghachavare (2004) in onion. Combined application of organic and inorganic fertilizers are capable of supplying adequate macro and micro plant nutrients which play major role in quality improvement through desirable enzymatic changes taking place during growth. Organic nutrients enhanced synthesis and translocation of photosynthates to the bulbs and the storage organs of the garlic which in turn might be caused by increased uptake of N, P, K and S by roots of crop as revealed by Tripathy et al (2013) in onion and Losak and Kielian (2006) in garlic and Fatima et al (2012) in onion.

CONCLUSION

The application of recommended dose of chemical fertilizers (NPK 100:50:50 kg/ha) had good response for garlic production. However, integrated application of manures (NPK 75:30:30 kg/ha + S 50kg/ha + Kitchen waste compost 10 t/ha) showed better yield and quality of garlic as compared to only chemical fertilizer application. Thus, it is suggested to apply kitchen waste compost in integrated way with chemical NPK and Sulphur to improve the production and quality of garlic.

REFERENCES

Anonymous 2017. *NHRDF Nasik Database.*

AOAC 2000. Association of Official Agricultural Chemists. *Official Methods of Analysis.*

Arora SD and Kaur J 1999. Antimicrobial activity of spices. *Journal of Antimicrob Agents* **12:** 257-262.

Assefa AG, Misgina SH and Abrha YW 2015. Effect of inorganic and organic fertilizers on the growth and yield of garlic crop (*Allium sativum* L.) in Northern Ethiopia. *Journal of Agricultural Science* **7**(4): 80.

Chattopadhyay PK, Hasan MA, Mandal KK and Chand S 2006. Dynamics of growth and yield of garlic (*Allium sativum* L.) in variable planting time and applied nutrients. *Indian Journal of Horticulture* **63**(3): 298-301.

Choudhary SP, Bhardwaj R, Gupta BD, Dutt P, Gupta RK, Biondi S and Kanwar M 2010. Epibrassinolide induces changes in indole-3-acetic acid, abscisic acid and polyamine concentrations and enhances anti-oxidant potential of radish seedlings under copper stress. *Plant Physiology* **140**: 280-296.

Choudhary SP, Kanwar M, Bhardwaj R, Gupta BD and Gupta RK 2011. Epibrassinolide ameliorates Cr (VI) stress via influencing the levels of indole-3-acetic acid, abscisic acid, polyamines and anti-oxidant system of radish seedlings. *Chemosphere* **84**: 5592-5600.

Fatima A, Rizk AM, Shaheen EH, Abd El-Samad, Omaima MS 2012. Effect of different nitrogen plus phosphorus and sulphur fertilizer levels on growth, yield and quality of onion (*Allium cepa* L.). *Journal of Applied and Scientific Research* **8**(7): 3353-3361.

Gaiki UR, Jogdande ND, Dalal SR and Ghawade SM 2006. Effect of biofertilizer under reduced doses of inorganic fertilizers on growth and yield of garlic. *Plant-Archives* **6**(1): 367-368.

Govind, Maji S, Kumawat R, Pal A, Kumar S and Saha, S 2015. Improvement of growth, yield and quality of garlic (*Allium*

sativum L.) cv. G-282 through a novel approach. *The Bioscan* **10**(1): 23-27.

Gowda MC, Vijayakumar M and Gowda APM 2007. Influence of integrated nutrient management on growth, yield and quality of garlic (*Allium sativum* L.) cv. G-282. *Crop Research (Hisar)* **33**(1/3): 144.

Harris JC, Cottrell SL, Plummer S and Lloyd D 2001. Antimicrobial properties of *Allium sativum* L (garlic). *Applied Microbiology and Biotechnology* **57:** 282-286.

Hughes BG and Lawson LD 1991. Antimicrobial effect of *Allium sativum* L (garlic), *Allium ampeloprasum* (elephant garlic) and *Allium cepa* L (onion), garlic compound and commercial garlic supplement products. *Phytotherapy Research* **5:** 154-158.

Kiran R, Maji S and Mishra A 2017. Effect of fish waste, fish guano and compost on growth, yield and quality of broccoli (*Brassica oleracea* var. *Italika*). *Indian Journal of Ecology* **44**(1): 120-123.

Kore MS, Shembekar RZ, Chopde NK, Kuchanwar OD, Pillewan SS and Godse SB 2006. Nutrient management in garlic (*Allium sativum* L.). *Journal of Soils and Crops* **16**(2): 465-468.

Lambrecht I, Vanlauwe B and Maertens M 2015. Integrated soil fertility management: From concept to practices in Eastern DR Congo. *International Journal of Agricultural Sustainability* http://dx.doi.org/10.1080/14735903.2015.1026047

Losak T and Kielian BW 2006. Fertilisation of garlic (*Allium sativum* L.) with nitrogen and sulphur. *Annales Univresities Mariae Curie-Sklodowske* **61**:45-50.

Maji S 2013. Different farming options to reduce pesticide load in crop and environment. In: *Green Chemistry and Sustainable Agriculture Practices: A Step towards a Better Future*, Eds.- T. Chattopadhyay and B. Bhowmik. Council for MS Academic Pub . pp. 45-65.

Mankar 2005. *Effect of combined use of organic and inorganic fertilizers on growth, quality and yield of garlic var. Yamuna Safed-3.* M.Sc. (Ag.) Thesis, Marathwada Agricultural University, Parbhani (India)

Memane PG, Tomar RS, Kakade DK, Kulkarni GU and Chovatia RS 2018. Effect of clove weight and plant growth regulators on growth and yield of garlic (*Allium sativum* Linn) cv. GG 3. *The Asian Journal of Horticulture* **3**(1): 82-86.

Meng YLD, Guo N, Zhang L, Zhou G 1993. Anti-HCMV effect of garlic components. *Virologica Sinica* **8**:147-150.

Nainwal K and Verma O 2013. Resource conserving technologies (RCT) in rice-wheat cropping system. *Indian Farmer's Digest* **46**(10): 7-9

Nayak PK and Maji S 2018. Response of nutrient and cutting management for quality and green yield of Palak (*Beta vulgaris* var. *bengalensis*). *Journal of Crop and Weed* **14**(1): 126-129.

Reuter HD, Koch HP and Lawson LD 1996. Therapeutic effects and applications of garlic and its preparations. pp.135-213. In: *Garlic: the science and therapeutic applications of Allium sativum L. and related species.* Koch HP and Lawson LD (ed). Baltimore: Williams and Wilkins.

Singh I 2016. *Response of integrated nutrient management on growth, yield and nutrient uptake of garlic (Allium sativum L.) cv. G-323*. (Doctoral dissertation, JNKVV).

Tiwari SK, Maji S, Kumar S, Govind, Meena KR, Yadav R and Kumar R 2017. Effect of liquid manure and fish oil emulsion on the growth, yield and quality of broccoli (*Brassica oleracea* var. *Italika*) cv KTS-1. *Environment and Ecology* **35**(1B): 484-489.

Tiwari V, Maji S, Kumar S, Govind and Yadav R 2016. Kitchen waste management and its effect on strawberry (*Fragaria x ananassa* Duch) cv. Sweet Charlie production. *African Journal of Agricultural Research* **11**(4): 259-265.

Tripathy P, Sahoo BB, Patel D and Dash DK 2013. Weed management studies in onion. *Journal of Crop and Weed* **9**(2): 210-212.

Waghachavare DD 2004. *Effect of integrated nutrient management on growth, yield and quality of onion cv PHULE SUVARNA.* M.Sc. (Ag.) Thesis Marathwada Agricultural University, Parbhani (India).

Zaied KA, El-Hady A, Afify AH and Nassef MA 2003.Yield and nitrogen assimilation of winter wheat inoculated with new recombinant inoculants of rhizobacteria. *Pakistan Journal of Biological Sciences (Pakistan)* **6**(4): 344-358.

Received 31 May, 2020; Accepted 12 August, 2020

Indian Journal of Ecology (2020) 47(3): 716-719

Manuscript Number: 3072
NAAS Rating: 4.96

Evaluation of Strawberry Cultivars Under Sub-Mountane Zone of Punjab

Bikramjit Singh

Krishi Vigyan Kendra, Gho, Pathankot-145 023, India
E-mail: bikrampau@pau.edu

Abstract: Three different strawberry cultivars, Chandler, Camarosa and Winter Dawn were evaluated for flowering, quality and fruit yield related parameters. Winter Dawn variety performed better among other two varieties. Number of fruits/plant, marketable yield/plant, TSS, TSS/acid ratio, vitamin C and anthocyanins content among different cultivars varied from 14.2 to 16.0, 220.10 to 299.27 g, 8.73 to 9.10°Brix, 10.55 to 11.14, 55.56 to 59.9 mg/100 g and 57.6 to 61.8 mg/100 g, respectively. Above all, these varieties can be cultivated in sub mountainous zone of Punjab to cater the demand for nutrition security and to improve the economical status of the farmers.

Keywords: Strawberry, Cultivars, Yield, Quality, Anthocyanins

Strawberry (*Fragaria* × *ananassa* Duch) widely cultivated across temperate and sub-tropical regions of the world belong to family Rosaceae and genus *Fragaria*. Ripe fruits are widely relished for their excellent quality; pleasant flavour and attractive colour. Strawberries are widely consumed as fresh table fruits. Besides, the fruits are also available in processed products like jam, jelly, juices, nectar, ice-cream, pies, beverages, wine, soft drinks, RTS and confectioneries (Bhamini et al 2017). It is a rich source of multiple nutritive and non-nutritive bioactive compounds with putative health promoting benefits. Fruits contain good amount of vitamin C, minerals, folates, anthocyanins, flavonoids, fibre and sugars (Perez et al 1997). Being a short day plant, the strawberry cultivation was initially limited to temperate regions with a mean day and night temperature requirement of 22-25°C and 7-13°C, respectively. However, with the advent of day neutral cultivars, its cultivation has extended in sub-tropical regions. It grows as perennial plant in temperate regions but, behaves as annual in sub-tropics. Strawberry gives early and high returns per unit area due to its relatively short crop cycle of five months (Singh et al 2020).

Globally, China leads in the area and production of the crop. But, strawberry cultivation is also popular among other countries like Spain, Poland, Germany, Italy, Turkey, Israel, Egypt, Mexico, Japan, New Zealand and Australia. In India, strawberry is grown on acreage of about 650 ha with an annual production of 5360 MT (NHB, 2018). Haryana is the leading state with maximum area (190 ha) and with the production of 3110 MT strawberries. Other important strawberry producing states are Mizoram, Meghalaya, Kerala, Himachal Pradesh, Madhya Pradesh and Maharashtra. A large number of strawberry germplasm is available for the cultivation in different agro-climatic conditions. Some of the popularly grown varieties are Chandler, Tioga, Torrey, Selva, Belrubi, Fern, Pajaro, Premier, Red cost, Local Jeolikot, Dilpas and, Bangalore, Florida 90, Katrain Sweet, Pusa Early Dwarf, Blakemore and Winter Dawn. Although, strawberry has extensive potential in other regions but, the photo sensitive nature of crop limits its recommendation for commercial cultivation. Evaluation of cultivars for adaptability, yield and quality is necessary to adjudge suitable cultivars for particular agro-climatic conditions. Keeping this in view, the present evaluation was conducted to assess the performance of different strawberry cultivars in the sub-mountainous regions of Punjab.

MATERIAL AND METHODS

The present study was conducted at PAU-Krishi Vigyan Kendra, Pathankot during 2019-20 to evaluate the performance of three different strawberry cultivars viz. Chandler, Camarosa and Winter Dawn. The study site is situated at an altitude of 332m above mean sea level. During the study, runners of each variety were planted on raised beds of 5m length and 1.2m width. Two row planting system was followed on each raised bed. The planting was done at a spacing of 30cm × 30cm, during first fortnight of October. During the entire course of experiment, all the plants received uniform cultural operations i.e. irrigation, fertilization, disease and insect pest management. The experiment was laid out in Randomized Block Design with five replications and 20 plants per replication.

The data on flowering, fruiting, yield, physical and bio-chemical quality attributes of different strawberry cultivars was estimated. Number of fruits per plant was determined by counting marketable fruits at the time of maturity. The marketable yield plant^{-1} was obtained by multiplying the

average fruit weight with the mean number of fruits plant^{-1} while, the total yield/acre was determined by multiplying the yield/plant with the total number of plants/acre. Fully ripened fruits were harvested for quality analysis. Fruit weight was determined with the help of digital measuring balance and the fruit size (L x B) was obtained using digital vernier calliper.

Among the bio-chemical attributes, total soluble solids (TSS) were determined using Erma hand Refractometer of 0-32 °Brix. Titratable acidity was obtained by titrating the fruit juice with N/10 NaOH using phenolphthalein as an indicator. Total sugars in fruit juice were obtained by Lane and Eynon method as described by Ranganna (1986). The vitamin C content was estimated using the chemical method based on the reduction of 2,6-dichlorophenol indophenols dye by ascorbic acid (AOAC 2005). The anthocyanin content in fruit was determined with Spectroscopy method as suggested by Ranganna (1986), anthocyanin content using ethanolic HCl and measurement of colour at 535 nm wave length against ethanolic HCl (used as blank). The descriptive statistics like mean was determined for the entire data obtained. The mean difference of yield and quality attributes among the cultivars was compared using least significant difference test ($p \leq 0.05$) using SPSS computer software program.

RESULTS AND DISCUSSION

The results related to flowering and fruiting attributes are mentioned in Table 1 and Figure 1. Flower initiation was significantly earlier in Winter Dawn (70.33 days after transplanting) i.e. 3rd January followed by Camarosa and Chandler on 77 and 84 days after transplanting, respectively. Bloom was recorded up to 6th March in Winter Dawn 12th March in Camarosa and 21st March in Chandler cultivar. Overall, it was found that the duration of flowering period was slightly higher in Winter Dawn than Camarosa and Chandler cultivars (Fig. 1). Days taken to fruit set also varied among the cultivars being 2.6 days in Winter Dawn and 2.7 days in Chandler, which was significantly earlier than Camarosa (3 days). Fruit harvesting was initiated earlier in Winter Dawn (20th January) followed by Camarosa (4th February) and Chandler (6th February) (Fig. 1). Overall, the study showed

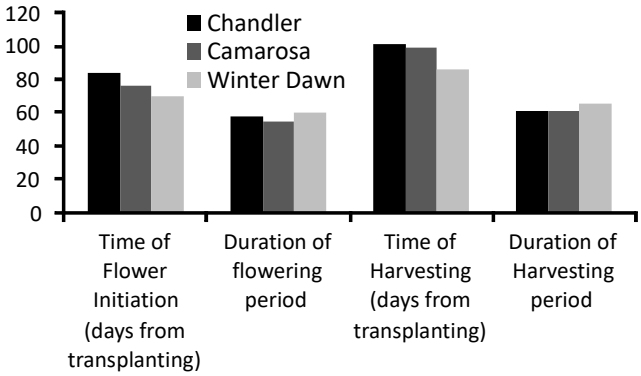


Fig. 1. Comparative assessment of flowering and harvesting period among different strawberry cultivars

that Winter Dawn was classified as earlier maturing, Chandler and Camarosa strawberries as mid-late season cultivars. Similar results were also reported by Ramandeep et al (2016) who revealed the harvesting period in 'Chandler' varied from 8th February to 6th April.

The data pertaining to yield related attributes are mentioned in Table 2. Perusal of the data describes significant differences among strawberry cultivars for fruit yield and allied traits. In cultivar Winter Dawn, it was found to be significantly the most superior in terms of yield performance and depicts maximum number of fruits plant^{-1} (16) followed by Chandler (15.1) and Camarosa (14.2). During the study, the marketable yield plant^{-1} varied from 299.27 to 220.10 g plant^{-1} being maximum in 'Winter Dawn' and minimum in Chandler cultivar. Fruit yield was calculated on the basis of 22,000 plants acre^{-1} and recorded maximum in Winter Dawn (6.58 Mt acre^{-1}) followed by Camarosa (5.06 MT acre^{-1}) and Chandler (4.80 MT acre^{-1}). Such variations in yield might be ascribed to the genotypic potential of the varieties. Moreover, higher yields in Winter Dawn could be due to the development of higher number of fruits with more fruit weight (Gaikwad et al 2018). These findings were in agreement with Recupero et al (1989) and Ramandeep et al (2016) who also reported similar yields among the varieties Chandler and Camarosa under different agro climatic conditions.

Table 1. Flowering and fruiting attributes of different strawberry cultivars under study

Cultivars	Flower initiation	Time of flowering (days from transplanting)	End of flowering	Days taken to fruit set (days)	Harvesting period
Chandler	19th January	84.00± 0.57^{a}	21st March	2.7± 0.03^{a}	6 Feb-9 April
Camarosa	13th January	77.00± 0.57^{b}	12th March	3.0± 0.05^{b}	4 Feb-7April
Winter Dawn	3rd January	70.33± 0.33^{c}	6th March	2.6± 0.03^{a}	20 Jan-28 March

*Data is expressed as mean value ± standard error
**All of the mean values vary at significant level ($p \leq 0.05$).
***Letters in superscript indicate about the statistical differences among the strawberry genotypes

The comparative analysis of physical quality attributes also revealed significant variations for fruit weight and size parameters. Fruit weight was ranged from 18.7 g to 14.5 g being maximum in Winter Dawn (18.7 g) which, was implicated statistically superior over Camarosa (16.2 g) and Chandler (14.5 g). In terms of fruit length, the variety Camarosa was adjudged as the most superior. It exhibited maximum fruit length (3.88 cm) but, was statistically at par with Winter Dawn (3.81 cm). On the other hand, the minimum fruit length was obtained in variety Chandler (3.63 cm). In the present study, all the varieties were found statistically at par with each other for fruit breadth. However numerically, maximum fruit breadth was found in Camarosa (3.25 cm) followed by Winter Dawn (3.24 cm) and 'Chandler' (3.17 cm). The fruit size in strawberry depends upon the extent of pollination and fertilization during blooming (Gaikwad et al 2018). The variations in fruit weight and length might be attributed to the genetic potential of varieties. Similar variations were also reported by Sharma et al (2014) and Recurpo et al (1989).

The results for evaluation of different varieties for bio-chemical attributes are mentioned in Table 3. Bio-chemical characteristics like TSS, acidity, total sugars, anthocyanin content etc. are important criteria for determining the sensory quality and market acceptability of fruits. TSS is a varietal specific character which may vary from genotype to genotype (Macit et al 2007). But, the present findings revealed that all the varieties were statistically at par with each other for TSS and acid content. However, highest T.S.S was obtained in 'Winter Dawn' (9.10°B) followed by 'Camarosa' (9.06°B) and Chandler (8.73°B). Similar results in 'Camarosa' were also emphasized by Mancy and Zurawicz (2010).

Juice acid content ranged from 0.826 to 0.813% among different strawberry cultivars. Numerically, the variety Chandler exhibited highest acidity per cent (0.826) while, lowest acidity per cent was found in Camarosa (0.813%).TSS/acid ratio varied from 11.14 to 10.55 and is important for development of fruit flavour (Antunes et al 2010). In terms of total sugar per cent, significant differences were observed among the varieties. The highest total sugar percentage was found in 'Camarosa' (6.53%) which, was statistically at par with 'Winter Dawn' (6.40%) and the lowest (6.23%) was registered in Chandler. The total soluble solids are a suitable indicator of total sugar in fruits (Haffner and Vestrheim, 1996). Higher total sugars in 'Winter Dawn and 'Camarosa' cultivars might be responsible for high per cent of total sugars in both the varieties. The present findings were in agreement with Dhaliwal and Singh (1983) who revealed that sugar per cent in strawberry fruits varies from 4.1 to 10.5 per cent.

Juice vitamin C content was ranged from 59.90 to 55.56 mg/100g (Table 3). The variety Chandler was found as significantly superior over other varieties for highest vitamin C content i.e. 59.9 mg per 100 g. The other varieties *viz.* Camarosa (55.56 mg per 100 g) and Winter Dawn (56.50 mg per 100 g) were found to be statistically at par with each other. Similar results were also witnessed by Haffner and Vestrheim (1996), Ramandeep et al (2016) and Jami et al (2015). Significant variations were observed for the presence of colour pigments i.e. anthocyanins (an important class of natural antioxidants). The study revealed maximum anthocyanin content in 'Camarosa' (61.8 mg/100 g), which was followed by 'Winter Dawn' (59.56 mg/100g). 'Chandler' cultivar has significantly lower values for the anthocyanin content (57.60 mg/100 g). Such differences in anthocyanin content may be ascribed to the genotypic variability (Crespo et al 2010). These findings were in line with Ramandeep et al (2016).

Table 2. Fruit yield and physical attributes of strawberry cultivars

Cultivars	Total number of fruits	Marketable yield plant^{-1} (g)	Total yield acre^{-1} (MT)*	Fruit weight (g)	Fruit length (cm)	Fruit breadth (cm)
Chandler	15.1± 0.20^{a}	220.10± 8.30^{a}	4.80± 0.05^{a}	14.5± 0.34^{a}	3.63±0.06^{a}	3.17± 0.08^{a}
Camarosa	14.2± 0.15^{b}	230.19± 9.78^{a}	5.06± 0.03^{a}	16.2± 0.51^{b}	3.88± 0.05^{b}	3.25± 0.01^{a}
Winter Dawn	16.0± 0.26^{c}	299.27± 9.01^{b}	6.58± 0.18^{b}	18.7± 0.26^{c}	3.81± 0.03^{b}	3.24± 0.02^{a}

Data is expressed as mean value ± standard error and letters in superscript indicate about the statistical differences among the strawberry genotypes

Table 3. Biochemical attributes of different strawberry cultivars

Cultivars	TSS	Acidity (%)	TSS/acid ratio	Total sugars (%)	Vitamin C (mg/100 g)	Anthocyanin (mg/100 g)
Chandler	8.73± 0.08^{a}	0.826± 0.008^{a}	10.55± 0.22^{a}	6.23± 0.06^{a}	59.9± 0.26^{a}	57.60± 0.52^{a}
Camarosa	9.06± 0.14^{a}	0.813± 0.003^{a}	11.14± 0.22^{a}	6.53± 0.06^{b}	55.56± 0.69^{b}	61.8± 0.55^{b}
Winter Dawn	9.10± 0.11^{a}	0.816± 0.008^{a}	11.14± 0.21^{a}	6.40± 0.00^{b}	56.50± 0.51^{b}	59.56± 0.49^{c}

Data is expressed as mean value ± standard error and letters in superscript indicate about the statistical differences among the strawberry genotypes

CONCLUSION

Winter Dawn followed by Camarosa and Chandler strawberry cultivars can be successfully cultivated in sub mountainous zone of Punjab. But, more investigations encompassing new cultivars must be introduced to study their performance in the particular agro climatic region of the north India.

REFERENCES

AOAC 1990. *Official Methods of Analysis.*14th ed. Association of Official Agril. Chemists, Washington D.C. U.S.A.

Antunes LEC, Ristow NC, Krolow ACR, Carpenedo S and Reisser Junior C 2010. Yield and quality of strawberry cultivars. *Horticultura Brasileira* **28**(2): 222-226.

Basu A, Nguyen A, Betts NM and Lyons TJ 2014. Strawberry as a functional food: an evidence-based review. *Critical Reviews in Food Science and Nutrition* **54**(6): 790-806.

Bhamini Kanchan, Rani Ruby, Nayyer Md Abu, Ahmad Md Feza and Ahmed Afzel 2017. Influence of planting dates and temperature on plant growth, flowering and fruiting of strawberry in agroclimatic condition of Bihar, India. *International Journal of Current Microbiology and Applied* **6**(9): 3184-3191.

Crespo P, Bordonaba JG, Terry LA and Carlen C 2010. Characterization of major taste and health related compounds of four strawberry genotypes grown at different Swiss production sites. *Food Chemistry* **122**: 16-24.

Dhaliwal GS and Singh k 1983. Evaluation of strawberry cultivars under Ludhiana conditions. *Haryana Journal of Horticultural Science* **12:** 36-40.

Gaikwad SP, Sali VM and Chalak SU 2018. Performance of strawberry cultivars under Mahabaleshwar conditions. *Journal of Pharmacognosy and Phytochemistry* **7**(4): 1850-1852.

Received 11 July, 2020; Accepted 12 August, 2020

Haffner K and Vestrheim S 1996. Fruit quality of strawberry cultivars. In *III International Strawberry Symposium* **439:** 325-332.

Jami YY, Sarkar A and Maiti CS 2015. Evaluation of strawberry cultivars in the foothills of Nagaland. *Journal of Crop Weed* **11:** 198-200.

Macit I, Koç A, Guler S and Deligoz I 2007. Yield, quality and nutritional status of organically and conventionally-grown strawberry cultivars. *Asian Journal of Plant Sciences* **6**(7): 1131-1136.

Masny A, and Zurawicz E 2010. Productive value of new foreign strawberry cultivars evaluated in 2007–2010. *Journal of Fruit and Ornamental Plant Research* **18**(2): 273-282.

NHB (2018). *Horticultural statistics at a glance 2018*. National Horticulture Board, 490P.

Perez AG, Olias R, Espada J, Olias JM and Sanz C 1997. Rapid determination of sugars, non-volatile acids, and ascorbic acid in strawberry and other fruits. *Journal of Agricultural and Food Chemistry* **45:** 3545-3549.

Ranganna S 1986. *Handbook of analysis and quality control for fruit and vegetable products*. Tata McGraw-Hill Education.

Ramandeep S, Sangwan AK, Navprem S and Sarvpriya S 2016. Evaluation of strawberry (Fragaria× ananassa Duch.) cultivars for fruit quality and biochemical characters under North-Western plains of India. *HortFlora Research Spectrum* **5**(4): 295-300.

Recupero S, Arcuti P, Margrini M and Damiano C 1989. Field performance of several strawberry cultivars and selections in southern Italy. *Acta Hort* **265:** 105-112.

Sharma G, Yadav A and Thakur M 2014. Studies on growth and flowering attributes of different strawberry cultivars (*Fragaria ananassa* Duch.) in Himachal Pradesh. *Asian Journal of Advanced Basic Sciences* **3**(1): 1-4.

Singh S, Singh NP, Sharda R and Sangwan AK 2020. Effect of drip irrigation, fertigation and mulching on fruit quality of strawberry (*Fragaria × ananassa*). *Indian Journal of Agricultural Sciences* **90**(3): 541-545.

Indian Journal of Ecology (2020) 47(3): 720-725

Manuscript Number: 3073
NAAS Rating: 4.96

Growth Performance and Health Status of Pangas catfish (*Pangasianodon hypophthalmus* Sauvage, 1878*)* Fingerlings Fed on Fish Silage and Linseed Oil Supplemented Diets

Injeela Khan, Vaneet Inder Kaur* and Surjya Narayan Datta[1]

Department of Aquaculture, College of Fisheries
[1]Department of Fisheries Resource Management, College of Fisheries
Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana-141 004, India
**E-mail: vinnygulati@gmail.com*

Abstract: The study (150 days) was conducted to evaluate the efficacy of fish silage as potential animal protein source in grow out diet (120 days) along with linseed oil (@ 5% in all diets) in finishing diet (30 days) for Pangas catfish (*Pangasianodon hypophthalmus*) in outdoor cemented tanks (80 m^3). Five experimental diets were prepared; out of which, in two diets fishmeal was replaced with fish (formic acid fermented) silage @ 50% and 100%; in two diets plant protein ingredients (soybean and groundnut meal) were replaced with fish silage @ 25% and 50%; one diet was prepared with mixture of only plant protein ingredients and having no animal protein source. To compare the efficiency of fish silage in experimental diets, control diet was prepared without fish silage but having fish meal. The growth performance and feed efficiency of pangas enhanced in fish silage supplemented diets with significantly higher values for NWG, SGR and PER fish silage @ 50% (217.14, 1.00 and 3.08) and minimum value of FCR (2.37). Improved health status of fish in terms of haematological (Hb and Ht) and biochemical (blood serum protein, albumin and globulin) parameters also indicated significant improvement in diet having 50% of fish silage as replacement to plant protein sources. Antioxidant status in terms of SOD (0.54 U mgl^{-1} Hb) and LPO (0.78 nmol MDAg Hb^{-1}) also showed significant increase and decrease in this diet. The overall results of present study revealed fish silage as a potential alternative protein ingredient mixed with linseed oil for Pangas catfish in terms of improved growth, feed efficiency and health status.

Keywords**:** Pangasius, Fish silage, Linseed oil, Fish growth, Fish meal

Over the last ten years, pangas catfish has emerged as a new aquaculture whitefish product in the world market. In India, it was introduced in West Bengal from Bangladesh during 1997 and eventually to other states viz. Andhra Pradesh, Kerala, Odisha, where it is now well established and cultured under monoculture system, with a production range of 15-20 t/ha/yr (Singh and Lakra 2012). In the recent past, along with coastal states, pangas catfish culture is also expanding in non-coastal states of Punjab and Haryana and has emerged as one of the potential candidate species for diversification in these states, due to huge demand of fish having less intramuscular spines. In commercial Pangas catfish culture, floating pellet feed is used, accounting > 60 % (Ovie and Ovie 2007) of input cost. Pangas catfish is carnivorous and cannibalistic during early stages and becomes omnivorous in later stages of development (fingerling onwards) and readily accepts artificial feed under confined conditions. Most of the commercial feeds (crude protein 28-32 %) or farm made feeds are prepared with protein rich plant (soybean meal, ground nut meal) and/or animal (fish meal) sources. Fish meal is the conventional source of animal protein in fish diet and it has been valued for its balanced amino acids, vitamin content, palatability and growth factors (Badillo et al 2014). However, due to variations in supply and cost of fish meal, urgent need is there to search for alternative animal and plant protein sources for fish feeds (Sogbesan and Ugwumba 2008, Uran et al 2008). These alternatives must be able to supply adequate indispensable and dispensable amino acid requirements of the fish or sufficient amino nitrogen to enable their synthesis along with dietary energy requirements because its excessive intake may restrict protein consumption and subsequent growth of the fish fed.

The use of plant protein in diets for aquaculture species has been very successful, but several studies have shown that high levels of plant protein in fish diets or complete substitution of animal proteins has resulted in poor growth and feed efficiency (Poor growth in such studies have been attributed to anti nutritional factors or toxic substances; improper balance of essential nutrients such as amino acids, energy and minerals, high amount of fibre and carbohydrate, reduced palatability of the feed; and reduction of pellet quality especially water stability). Hence, focus is now towards use of animal protein resources having nutritional similarity to fish meal and appear to be more suitable as a dietary replacement. There are several reports regarding usage of fish silage as sole ingredient or as one of the ingredients in formulated feeds at different levels for different fish species

(Haider et al 2016). Moreover, using fish silage as an animal protein source can help in solving the environmental problems associated with disposal of waste and formulating cost-effective livestock feed, including fish. Further, feed composition not only effects growth, health and reproductive potential of fish, but is also responsible for quality of fish meat. Food fish of high value like pangas need to be fed with specially formulated finishing diets, which can maintain long chain (LC) n-3 PUFA of fish and human as well. In addition to fish oil, vegetable oil like linseed oil (richest source of PUFAsamong crop plants) holds importance due to its worldwide accepted health benefits (Goyal et al 2014).

With this background, the experimental study was conducted to evaluate the possibility of replacing traditional feed ingredients including animal (fish meal) and plant (groundnut and soybean meal) proteins with acid fermented fish silage along with linseed oil as finishing diets on water quality parameters, survival, growth and health status (haematological, biochemical and antioxidant parameters) of Pangas (*P. hypophthalmus*) catfish under semi-intensive culture conditions.

MATERIAL AND METHODS

Fish stocking: Pangas (*P. hypophthalmus*) catfish procured from West Bengal and reared for one year at Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana was used for experiment. For experimental study, 40 uniformly sized fishes (average body weight 55g, average total length 18 cm) were stocked in each cemented experimental tanks (80 m^2) having 1-2 inch thick soil at the bottom. Experiment was carried out in triplicate. Borewell water was used for initial filling and exchange of water during the experimental period.

Feed preparation, composition and fish feeding: Five experimental floating pelleted diets were prepared by replacing fish meal @ 50 and 100% (D2 and D3) and a mixture of groundnut and soybean meal @ 25 and 50% (D4 and D5) in control diet (D1) with fish silage. One more experimental diet (D6) was prepared without any animal protein source (Table 1). For preparation of fish silage, fish waste (including viscera, scales, head, fins etc.) was procured from local fish market of Ludhiana. Waste was finely chopped and 4% formic acid (weight by volume) was added to lower the pH up to 3.5 along with butylated hydroxyl toluene (BHT) as antioxidant @ 250 mgl^{-1}. The mixture was stored at room temperature for a period of 30 days (30-35°C), with daily thorough mixing along with maintaining pH at 3.5 to avoid putrification (Oetterer 2002). The silage (after neutralization with 8% NaOH to pH 7.0) was added to finely grounded ingredients as per feed formulation (Table 1) and floating feed pellets were prepared with extruder machine. The proximate composition of feed ingredients and experimental diets (Table 2) was analysed by following the methods of AOAC (1995). Fish was fed with experimental floating pelleted feed @ 5-3% (5% for 1st month, 4% for 2nd and 3rd month and 3% for 4th month) fish body weight twice a day. After feeding for 4 months, finishing diets were prepared by adding linseed oil to all the experimental and control diets @ 5% and fish was fed @ 3% for one month. Amount of feed was adjusted at every monthly sampling according to increase in fish weight throughout experimental period of 5 months (150 days).

Water quality parameters: Water quality parameters in terms of water temperature, pH, dissolved oxygen (DO), total alkalinity (TA), ammonical nitrogen (NH_3-N), nitrate nitrogen (NO_3^--N), nitrite nitrogen (NO_2^--N) and orthophosphate (O-PO_4^{3-}), were measured at fortnightly intervals (APHA 2012).

Survival and growth parameters: Fish survival was estimated by counting fish at the end of experiment and comparing it with number of fish stocked. Fish growth in terms of total body length and body weight was recorded at monthly intervals. At the end of experiment, net weight gain (NWG), specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio (PER) and condition factor (K) were calculated as follows:

NWG =average final body weight − average initial body weight

$$\text{SGR (\% increase in weight/day)} = \frac{(\text{ln final body weight} - \text{ln initial body weight})}{\text{Culture days}} \times 100$$

ln = Natural Logarithm

FCR = Feed given (g) / Weight gain (g)

PER = Weight gain (g) / Protein intake (g)

$K = \text{Body weight} / (\text{Body length})^3 \times 100$

Haematological parameters: Hematological parameters

Table 1. Percent composition of experimental diets

Ingredients	Experimental diets					
	D1	D2	D3	D4	D5	D6
Rice bran	28	28	28	28	28	28
Groundnut meal	30	30	30	26.25	17.5	35
Soybean meal	30	30	30	26.25	17.5	35
Fish meal	10	5	-	-	-	-
Fish silage	-	5	10	17.5	35	-
Vitamin-mineral mixture	1.5	1.5	1.5	1.5	1.5	1.5
Salt	0.5	0.5	0.5	0.5	0.5	0.5

After feeding for 120 days with above formulated diets, fish was fed with finishing diets, in which all the 6 diets (D1-D6) were supplemented with linseed oil @ 5 % (95% formulated diet + 5 % linseed oil) – feeding for one month (30 days)

were analysed at the completion of experiment for haemoglobin (Hb) and haematocrit (Ht) by following the methods of Sahli (1962) and Mukherjee (1988).

Biochemical parameters: Biochemical parameters (gdl^{-1}), including total proteins (Gornall et al 1949), and albumin were analysed from blood serum by using Erba Manhelm Kit, whereas globulin and albumin/globulin ratio were calculated as

Globulin = Total Protein – Albumin

Albumin/Globulin ratio =Albumin/Globulin

Antioxidant parameter: Blood hemolysate (RBC lysate) was used to analyse antioxidant parameters i.e Superoxide dismutase (SOD) and lipid peroxidation (LPO) by following the methods of Nishikimi et al (1972) and Placer et al (1966) respectively, at the completion of experiment.

RESULTS AND DISCUSSION

Water quality: The water quality parameters viz. temperature, pH, DO, TA, NH_3-N, NO_2^--N, NO_3^--N and O-PO_4^{3-} varied from 30.26-34.86°C, 7.26-7.95, 10.00-12.80 mgl^{-1}, 126-188 $CaCO_3$ mgl^{-1}, 0.01-0.09 mgl^{-1}, 0.014-0.099 mgl^{-1}, 0.13-0.89 mgl^{-1} and 0.01-0.09 mgl^{-1}, respectively in all the diets (D1-D6) and did not vary significantly among experimental diets and control and were well within the desirable range required for normal growth and physiological activities of warm water fish (Santhosh and Singh 2007). Consistency and uniformity of water quality parameters revealed that silage supplemented diets had no detrimental effect on water quality, which remained in optimum range for pangas catfish culture (Abedin et al 2017).

Survival and growth of fish: Fish survival was 100% in control and all the experimental diets at the completion of experiment, which revealed omnivorous nature of pangas during grow out stage. Both internal (body physiology) and external factors (feed quality and the environmental variations) affect the survival of fish (Amanlia 2013) and 100% survival during present study clearly indicated that both the factors were in optimum range for pangas. Datta et al (2018) observed that, multiple protein feed ingredients including poultry waste, fish meal, fish silage and soybean meal were equally effective in terms of pangas survival (100%) after 120 days of experiment. Similar observations were also recorded by Bekibele et al (2010), who reported 100% survival in tilapia (*O. niloticus*), when fed with animal based feed ingredients (fish and blood meal) @10% level.

At the end of experimental period, final total body length and TBLG (cm) was significantly higher in D2 and D5 and minimum in D1. Likewise, significantly higher (fish growth in terms of final body weight (FBW), NWG and SGR was also observed in D5, while minimum FBW and NWG in D1 and

Table 2. Proximate composition (% DM basis) of different feed ingredients and experimental diets

Ingredient/Diet	Crude Protein	Ether extract	Ash	Crude fiber	NFE	Gross energy (Kcal g^{-1})
Rice bran	14.67	2.47	11.00	8.56	63.30	365.75
Groundnut meal	35.62	1.76	8.40	19.26	34.96	361.22
Soybean meal	41.67	2.18	4.53	6.77	44.85	439.92
Fish meal	51.33	5.56	24.33	3.44	15.34	405.45
Fish silage	36.45	15.23	10.89	4.50	32.93	484.87
Grow out diets						
D1	32.41	2.45	9.36	10.57	45.21	391.63
D2	31.67	2.91	8.71	10.61	46.1	395.44
D3	30.93	3.39	8.05	10.69	46.94	399.24
D4	30.81	4.38	8.39	10.01	46.41	405.74
D5	30.32	6.71	9.15	8.51	45.31	420.48
D6	31.16	2.07	7.61	11.4	47.68	391.10
Finishing diets						
D1	32.42	7.37	9.47	10.56	40.18	417.55
D2	31.65	8.11	8.72	10.62	40.90	423.15
D3	30.91	8.39	8.07	10.65	41.98	426.04
D4	30.83	8.65	8.41	10.05	42.06	428.37
D5	30.35	9.23	9.14	8.52	42.76	434.01
D6	31.18	5.50	7.61	11.45	44.26	409.60

SGR in D6. The differences for condition factor were insignificant for all the experimental diets and control. Significantly lower value for FCR was in D4 and D5 and maximum in D1 (Table 3). Likewise, PER was also significantly higher in D5 and minimum in D1 and D2. The overall results revealed that fish growth improved in all silage fed groups as compared to control with significantly higher values for all growth parameters in D5 (without fish meal, but with fish silage and plant ingredients).

The higher growth performance in D5 can be explained by the synergistic effect of combining plant proteins with animal protein in the form of fish silage. These findings are in agreement with the results of number of studies conducted with combined protein sources showing better results in terms of fish growth as compared to single protein source (Ugwumba et al 2001, Sogbesan et al 2005, Sogbesan and Ugwumba 2008). Ability of fish to convert nutrient especially protein can positively influence growth performance. This is justified in terms of best PER and overall improved growth performance of fish in D5 along with lowest FCR indicates better utilization of feed by the fish along with fulfilment of amino acid requirement of fish from mixed protein sources (Desilva and Anderson 1995). Balogun et al (1997) reported improved growth performance of catfish, *Clarias gariepinus,* when fed on formic acid ensiled product consisting of 60% minced fishand 40 % soybean meal. According to Fagbenro and Jauncey (1998a,b), diet made up of silage and soymeal can be used to feed tilapia, *O. niloticus* (omnivorous) and African catfish, *C. gariepinus* (carnivorous) with no change in growth performance and carcass composition. Similar observations were also reported by Tabinda and Butt (2012), who reported significantly higher growth along with lower FCR in grass carp fry fed with chicken intestine @ 30%.Further, in addition to silage supplementation, use of linseed oil showed positive effect on fish growth in all the diets for 30 days feeding. Growth rate of pangas was significantly faster in D4 and D5 as compared to all other experimental diets and control after linseed supplementation. This may be due to the positive impact of linseed oil on fish growth due to improved lipid content of diets leading to improved fish growth (Pei et al 2004, El-Marakby 2006, Zupan et al 2016).

Table 3. Growth and haematological parameters of fish in different diets

Particulars	Diets					
	D1	D2	D3	D4	D5	D6
Av. Initial TBL	18.77^{a}	18.84^{a}	18.73^{a}	18.24^{a}	18.01^{a}	18.24^{a}
Av. Final TBL	28.91^{c}	33.78^{a}	33.85^{a}	33.69^{ab}	33.68^{ab}	30.92^{b}
TBLG	10.14^{c}	14.94^{b}	15.12^{ab}	15.46^{ab}	15.68^{a}	12.68^{c}
Av. Initial BW	58.59^{a}	57.30^{a}	57.35^{a}	57.64^{a}	57.22^{a}	57.53^{a}
Av. Final BW	194.57^{c}	237.98^{b}	249.82^{b}	271.57^{a}	274.36^{a}	195.29^{c}
NWG	135.98^{c}	180.68^{b}	192.47^{b}	214.11^{a}	217.14^{a}	137.76^{c}
SGR	0.76^{d}	0.92^{b}	0.88^{c}	0.96^{b}	1.00^{a}	0.74^{d}
FCR	3.63^{a}	3.50^{a}	2.79^{b}	2.21^{c}	2.37^{c}	3.42^{a}
PER	1.99^{d}	1.99^{d}	2.49^{c}	2.74^{b}	3.08^{a}	2.21^{cd}
K	0.80^{a}	0.81^{a}	0.81^{a}	0.94^{a}	0.99^{a}	0.84^{a}
Hb (g%)	7.33^{c}	10.00^{a}	10.00^{a}	10.23^{a}	10.30^{a}	8.00^{b}
Ht (%)	20.00^{d}	25.00^{c}	26.66^{c}	30.00^{b}	33.33^{a}	21.66^{d}

Values with same superscript (a, b,….d) in a row does not differ significantly ($p \leq 0.05$)

TBL= Total body length, TBLG= Total body length gain, BW= Body weight, NWG= Net weight gain, SGR= Specific growth rate, PER= Protein efficiency ratio, FCR= Feed conversion ratio, K= Condition factor, Hb= Haemoglobin, Ht=Haematocrit

Haematological parameters: Hb (g%) and Ht (%) content improved in all the diets as compared to control with significantly higher values (Table 3) in D5. Haematological indices are essential indicators of physiological and physio-pathological changes in fish (Hrubec et al 2000, Rainza-Paiva et al 2000), which in turn are affected by number of environmental factors including feeding habits. In the present study, Hb and Ht showed improvement in all the diets as compared to control, which indicates the positive effect of dietary manipulation. Further, health promoting effects of fish silage in terms of free amino acid (Madage et al 2015) and linseed oil (Gogus and Smith 2010, Goyal et al 2014) in terms of high content of n-3 linolenic acid, at appropriate level must have improved the haematological parameters of pangas. Aderolu and Akinremi (2009) too reported positive impact of plant oil inclusion on haematological (Hb and Ht) parameters of *C. gariepinus*.

Biochemical parameters: The fish fed on all experimental diets revealed higher total protein, albumin and globulin (g dl^{-1}) as compared to control fed fish (D1) with highest values in D5 and lowest in D6. The differences for Alb/Glb ratio were insignificant among all the experimental diets and control (Fig. 1). The results in terms of improved serum biochemical parameters in all silage fed fish as compared to control are in accordance with the hematological parameters showing maximum values in D5. Najim et al (2014) reported significant increase in total protein and albumin levels in common carp, *C. carpio,* when fish meal was replaced with fish bio silage at different levels.

Antioxidant parameters: SOD (U mgl^{-1} Hb) was significantly higher in D5 (0.54) and minimum in D1 (0.36),whereas LPO (nmol MDAg Hb^{-1}) was significantly higher in D1 (1.84) and minimum in D5 (0.78). The SOD and LPO activity showed an increase and decrease (Fig. 2) with fish silage incorporation. The increased activity of SOD is consistent with the first line of defence against ROS, along with LPO as an indicative of

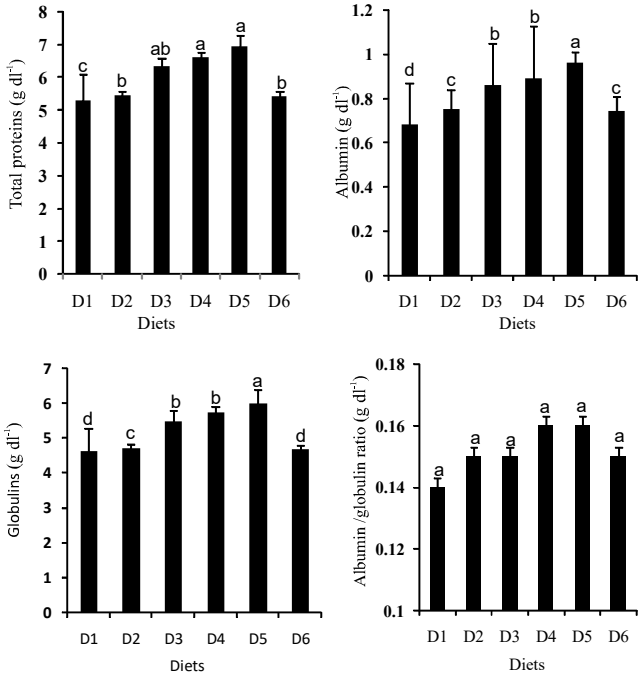


Fig. 1. Changes in biochemical parameters of fish in different diets after completion of experiment

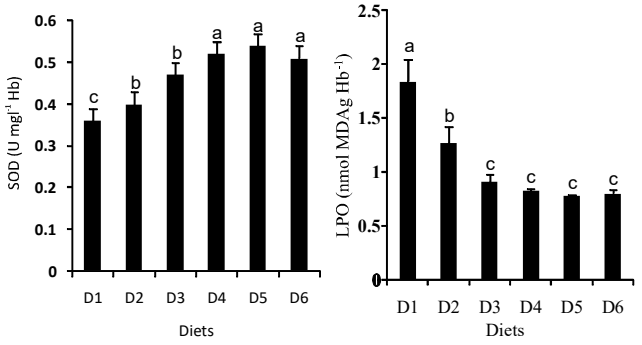


Fig. 2. Changes in antioxidant parameters of fish in different diets after completion of experiment

reduced oxidative stress (Taufek et al2016).Significantly increased antioxidant activities were observed by Dong et al (2013) in gibel carp (*Carassius auratusgibelio*)with dietary supplementation of maggot meal and soybean meal. Furthermore, low level of linseed oil inclusion in fish diet must have resulted in increased SOD activity along with total antioxidant status, which indicates improved total oxidation response of fish (Yu et al 2019).

CONCLUSIONS

Fish silage along with linseed oil can be incorporated in pangas (*P. hypophthalmus*) grow out diet for enhanced growth and improved health status.

REFERENCES

Abedin MJ, Bapary MAJ, Rasul MG, Majumdar BC and Haque MM. 2017. Water quality parameters of some Pangasius ponds at Trishal Upazila, Mymensingh, Bangladesh. *European Journal of Biotechnology and Bioscience* **5**(2): 29-35.

Aderolu AZ and Akinremi OA 2009. Dietary effects of coconut oil and peanut oil in improving biochemical characteristics of *Clarias gariepinus* juvenile. *Turkish Journal of Fisheries and Aquatic Sciences* **9**: 150-110.

Amanlia R 2013. Pengaruh penggunaan papain terhadap tingkat pemanfaatan protein pakan dan pertumbuhan lele dumbo (*Clarias gariepinus*). *Journal of Aquaculture Management and Technology* **2**(1): 136-143.

AOAC (Association of Official Analytical Chemists) 1995. *Official methods of analysis*. Association of Official Analytical Chemists Incorporation. Arlington, USA. p 684.

APHA 2012. *Standards Methods for the Examination of Water and Wastewater.* 22nd Edn. American Public Health Association, Washington D.C. 1360p.

Badillo D, Herzka SZ and Viana MT 2014. Protein retention assessment of four levels of poultry by-product substitution of fishmeal in rainbow trout (*Oncorhynchus mykiss*) diets using stable isotopes of nitrogen (d15N) as natural tracers. *PLoSONE* **9**(9): e107523.doi:10.1371/journal.pone.0107523.

Balogun AM, Fasakin EA and Owolanke D 1997. Evaluation of fish silage/soybean meal blends as protein feedstuffs for *Clarias gariepinus* (Burchell 1822) fingerlings. *Journal of Applied Animal Research* **11**: 129-136.

Bekibele DO, Ansa EJ, Agokei OE, Opara JY, Alozie-Chida VC, Aranyo AA, Uzukwu PU, Gbulubo AJ, Okereke A, Azubuike N, Ezenwa N and Ibemere I 2010. The comparative effect of fish and blood meal based diets on the growth and survival of juvenile tilapia (*Oreochromis niloticus*) in concrete tank. *Proceedings of Fisheries Society of Nigeria (FISON) ASCON*, Badagry 25th-29th October.

Datta SN, Singh A and Mandal A 2018. Effect of different dietary protein sources on hematological parameters of striped catfish *Pangasianodon hypophthalmus*. *Journal of Entomology and Zoology Studies* **6**(2): 3198-3202.

De Silva SS and Anderson TA 1995. *Fish Nutrition in Aquaculture.* Chapmann and Hall Aquaculture Series, U.K, 319 pp.

Dong GF, Yang YO, Song XM, Yu L, Zhao TT, Huang GL, Hu ZJ and Zhang JL 2013. Comparative effects of dietary supplementation with maggot meal and soybean meal in gibel carp (*Carassius auratus gibelio*) and darkbarbel catfish (*Pelteobagrus vachelli*): Growth performance and antioxidant responses. *Aquaculture Nutrition* **19**(4): 543-554.

El-Marakby M 2006. Effect of dietary sources and levels of lipids on growth performance and feed utilization of fry Nile tilapia, *Oreochromis niloticus* (L.). *Journal of Fisheries and Aquatic Sciences* **1**: 117-125.

Fagbenro O and Jauncey K 1998a. Physical and nutritional properties of moist fermented fish silage pellets as a protein supplement for tilapia (*Orechromis niloticus*). *Animal Feed Science and Technology* **71:** 11-18.

Fagbenro O and Jauncey K 1998b. Growth and protein utilization by juvenile catfish (*Clarias gariepinus*) fed moist diets containing autolysed protein from stored lactic-acid-fermented fish-silage. *Bioresource Technology* **48**(1): 43-48.

Gogus U and Smith C 2010. n-3 Omega fatty acids: A review of current knowledge. *International Journal of Food Science and Technology* **45**: 417-436.

Gornall AG, Bardawill CJ and David MM 1949. Determination of serum proteins by means of the biuret reaction. *The Journal of Biological Chemistry* **177:** 751-766.

Goyal A, Sharma V, Upadhyay N, Gill S and Sihang M 2014. Flax and flaxseed oil: An ancient medicine and modern functional food. *Journal of Food Science and Technology* **5**(9): 1633-1653.

Haider SM, Ashraf M, Azmat H, Khalique A, Javaid A, Atique U, Zia M, Iqbal JK and Akram S 2016. Nutritive evaluation of fish acid silage in *Labeo rohita* fingerlings feed. *Journal of Applied Animal Research* **44**(1): 158-164.

Hrubec TC, Cardinale JL and Smith SA 2000. Hematology and plasma chemistry reference intervals for cultured tilapia (*Oreochromis* hybrid). *Veterinary Clinical Pathology* **29**: 7–12.

Madage SSK, Medis WUD and Sultanbawa Y 2015. Fish silage as replacement of fishmeal in red tilapia feeds. *Journal of Applied Aquaculture* **27**: 95-106.

Mukherjee KL 1988. *Medical Laboratory Technology*. Tata Mcgraw Hill Publishing Company Ltd, New Delhi **1**: 2425-2443.

Najim SM, Al-Noor SS and Jasim BM 2014. Effects of fish meal replacement with fish biosilage on some haematological and biochemical parameters in common carp, *Cyprinus carpio* fingerlings. *International Journal of Research in Fisheries and Aquaculture* **4**(3): 112-116.

Nishikimi M, Rao NA and Yagi K 1972. The occurrence of superoxide anion in the reaction of reduced phenazine methosulphate and molecular oxygen. *Biochemical and Biophysical Research Communications* **46**: 849-864.

Oetterer M. 2002. *Industrialização do pescado cultivado*. Livraria e Editora Agropecuária, Guaíba: RS-Brasil. 200p.

Ovie SO and Ovie SI 2007. The effect of replacing fish meal with 10% of groundnut cake in the diets of *H. longifilis* on its growth, food conversion and survival. *Journal of Applied Sciences and Environmental Management* **11**(3): 87-90.

Pei Z, Xie S, Lei W, Zhu X and Yang Y 2004. Comparative study on the effect of dietary lipid level on growth and feed utilization for Gibel carp (*Carassius auratus gibelio*) and Chinese long snout catfish (*Leiocassius logirostris* Gunther). *Aquaculture Nutrition* **10**(4): 209-216.

Placer ZA, Cushman LL and Johnson BC 1966. Estimation of product of lipid peroxidation (malonyl dialdehyde) in biochemical systems. *Annals of Biochemistry* **16**: 359-364.

Rainza-Paiva M, Ishikawa C, Das Eiras A and Felizardo N 2000. Haemotological analysis of 'chara' *Pseudoplatystoma fasciatum* in captivity. Responsible aquaculture in the new millennium. Nice, France, May 2-6, 2000. *European Aquaculture Society* Special Publication vol. 28, p. 590.

Sahli T 1962. *Textbook of Chemical Pathology*. In: Scward E (Ed.) pp. 35. Williams and Williams C. Baltimore, USA.

Received 15 June, 2020; Accepted 12 August, 2020

Santhosh B and Singh NP 2007. *Guidelines for water quality management for fish culture in Tripura*, ICAR Research Complex for NEH Region, Tripura Center, Publication no.29.

Singh AH and Lakra WS 2012. Culture of *Pangasianodon hypophthalmus* into India: Impacts and present scenario. *Pakistan Journal of Biological Sciences* **15**(1): 19-26.

Sogbesan AO and Ugwumba AAA 2008. Nutritional evaluation of termite (*Macrotermes subhyalinus*) meal as animal protein supplements in the diets of *Hetrobranchus longifilis* (Valenciennes 1840) fingerlings. *Turkish Journal of Fisheries and Aquatic Sciences* **8**: 149-157.

Sogbesan OA, Ajuonu ND, Ugwumba AAA and Madu CT 2005. Cost benefits of maggot meal as supplemented feed in the diets of *Heterobranchus longifilis x Clarias gariepinus* (Pisces-*Clariidae*) hybrid fingerlings in outdoor concrete tanks. *Journal of Industrial and Scientific Research* **3**(2): 51-55.

Tabinda AB and Butt A 2012. Replacement of fish meal with poultry by–product meal (chicken intestine) as a protein source in grass carp fry diet. *Pakistan Journal of Zoology* **44**(5):1373-1381.

Taufek MN, Aspani F, Muin H, Raji AA, Razak AS and Alias Z 2016. The effect of dietary cricket meal (*Gryllus bimaculatus*) on growth performance, antioxidant enzyme activities, and haematological response of African catfish (*Clarias gariepinus*). *Fish Physiology and Biochemistry* **42**(4): 1143-1155.

Ugwumba AAA, Ugwumba AO and Okunola AO 2001. Utilization of live maggot as supplementary feed on the growth of *Clarias gariepinus* (Burchell) fingerlings. *Nigerian Journal of Science* **35**(1): 1-7.

Uran PA, Gonçalves AA, Taverne-Thiele JJ, Schrama JW, Verreth JAJ and Rombout JHM 2008. Soy meal induces intestinal inflammation in common carp (*Cyprinus carpio* L.). *Fish and Shellfish Immunology* **25:** 751-760.

Yu J, Li S, Niu H, Chang J, Hu Z and Han Y 2019. Influence of dietary linseed oil as substitution of fish oil on whole fish fatty acid composition, lipid metabolism and oxidative status of juvenile Manchurian trout, *Brachymystax lenok*. *Scientific Reports* **9:** 13846. doi:10.1038/s41598-019-50243-8.

Zupan B, Ljubojevic D, Pelic M, Cirkovic M, Dordevic V and Bogut I 2016. Common carp response to the different concentration of linseed oil in diet. *Slovenian Veterinary Research* **53**(1): 19-28.

Indian Journal of Ecology (2020) 47(3): 726-732

Manuscript Number:3074
NAAS Rating: 4.96

Runoff Estimation of Machhu and Watrak Rivers Basins of Gujarat India using SCS-CN Method and GIS

Darji Kishanlal, Indra Prakash[1*] and Binh Thai Pham[2]

Lukhdhirji Engineering College, Morbi, Gujarat-363 642, India
[1]Bhaskaracharya Institute for Space Application &Geo-informatics, Gandhinagar, Gujarat-382 007, India
[2]University of Transport Technology, Hanoi-100000, Vietnam
**E-mail: indra52prakash@gmail.com*

Abstract: Main objective of the study is to estimate the runoff of Machhu and Watrak river basins of Gujarat for the planning and management of catchments. The Soil Conservation Service (SCS) - Curve Number (CN) method was used to estimate runoff. For Machhu river basin threshold value of rainfall is 250 mm and for Watrak river basin 400 mm. This difference of threshold values is due to different topography, geology and soil conditions of these two catchment areas. Regression analysis of observed rainfall and simulated runoff of these two river basins indicated good correlation (R^2: 0.85 and 0.735). The present rainfall-runoff study of the two widely separated river basins suggests applicability of simple SCS-CN method in different areas having different geo-environmental conditions.

Keywords: SCS-CN, AMC, Regression analysis, Machhu, Watrak, Runoff, Curve number

Estimation of runoff of a river basin plays important role in the watershed management such as flood prediction, water quality management, hydropower production, land use planning and industrial development. Nowadays, rapid industrialization and population growth especially in developing countries like India require accurate estimation of runoff of river basins for optimum utilization of surface water resources in conjunction with ground water for the development of a region. Rainfall and runoff relationship which is based on meteorology, topography and other geo-environmental factors is important for the development of hydraulic models. Recently, irregular pattern of rainfall has been observed in many parts of the world including the study area as a result of global climate change. Rainfall-Runoff estimation would help in the proper understanding of the ecosystem of the area. Hydrologic models are used for hydrological assessment of the catchment in different parts of the world (Mazi et al 2004). Many physical and statistical methods have been used to determine watershed runoff in hydrological modelling (Van Dijk 2010, Abon et al 2011). The SCS-CN method which is based on single parameter Curve Number (CN) is a simple and practical method for estimating the runoff (USDA 1986). The Soil Conservation Service Curve Number (SCS-CN) developed by the US Department of Agriculture (USDA) is widely used for the determination of depth of surface runoff of a catchment (basin). This method is also known as Natural Resources Conservation Service Curve Number (NRCS-CN) method. SCS-CN method is also used for the design of water conservation practices, watershed evaluation, and erosion control of catchment. In this method, effects of several important hydrological processes integrated into single parameter curve number (CN) for estimating runoff (Garen and Daniel 2005).

Different researchers have conducted studies to define curve numbers for different situations. Many researchers who have attempted to modify the SCS-CN method for estimating surface runoff based on local conditions (Sahu et al 2012, Kabiri et al 2014, Vij et al 2015, Jayantilal et al 2016) found that CN varied inversely with drainage area. Some of the studies carried out earlier for runoff modelling in Gujarat state include Meshwo river watershed (Shah et al 2017), Shetrunji River catchment (Chauhan et al 2016), Jamnagar city area (Shah et al 2015), Macchu III river basin (Songara et al 2015) and Ahmedabad city area (Bhura et al 2015). These studies are based on the simple SCS-CN method. In the present study we have considered local conditions for the estimation of runoff of Machhu river basin and Watrak river basin, which are located in different geo-environment at a distance of 320km. Objective of the present study is to evaluate estimated runoff of these two basins under different geo-environmental conditions for wider application of SCS-CN method in other geographically separated areas.

MATERIAL AND METHODS

Study area: In this study, two catchment areas of Gujarat have been used for runoff modelling namely Machhu river basin and Watrak river basin (Fig. 1). The Machhu river basin is located between 22° 10′ to 23° 10′ North latitudes and 70° 40′ to 71° 15′ East longitudes. The Machhu river originates in the hills of Chotila taluka of Surendranagar district at an

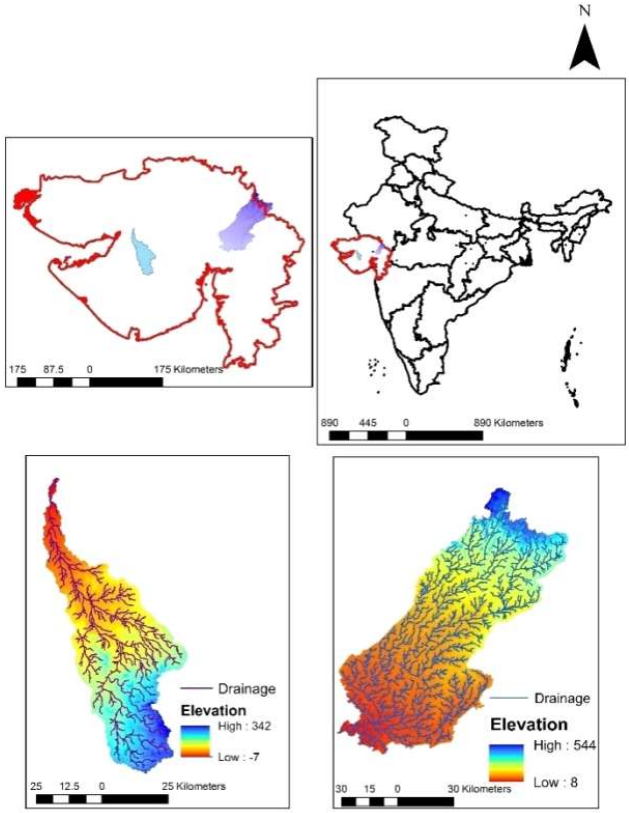


Fig. 1. Location map of Machhu and Watrak river catchment

elevation of 220 m (above mean sea level). It flows in north-westerly direction and debouches near Malia in the little Rann of Kachchh. Total length of this river from its origin to its outfall is 141.75 km (https://swhydrology.gujarat.gov.in). Part of the river with its tributaries flows through hilly area (52%) and part in plain region (48%). Total area drain by Machhu river is about 2515 sq km. Three Irrigation dams namely Machhu I, II and III are located across main river. This region is characterized by a semi-arid climate, with warm and dry summers and mild winter conditions. The monsoon season is from mid-June to early October. The average rainfall in the Machhu river catchment area is 533.5 mm, average maximum temperature is 41°C and average minimum temperature is 14°C (http://cwc.gov.in). Land use pattern in the area include agriculture, built-up, forest, grass land, waste land and water bodies (Fig.4). Geologically the area is occupied by Deccan basalt. Dhrangadhra Sandstone is exposed in the lower reaches of the river. River valleys are occupied by alluvium. The soil exposed in the catchment area belongs to Hydrological Soil group (HSG) C (clayey, clayey skeletal and fine loamy) and B (loamy and loamy skeletal).

The Watrak river basin is located between 22.895° to 22.924° latitudes and 72.154° to 73.990° longitudes in the north-eastern part of Gujarat state. The Watrak river originates in Panchara hills in Dungarpur district of Rajasthan and flows in southwest direction and joins Sabarmati river on left bank after travelling about 248km through rugged terrain. Confluence of both the rivers is at Vautha place (Lat 22.66°N, long.72.537°E). Elevation in the area ranges from 8m to 544m.Temp in the area varies from 8°C to 48°C. Average rainfall in the Watrak river basin is 690 mm in a year. Geology in the Watrak river basin comprises of folded and faulted metamorphic rocks (phyllite, schist and quartzite) of Arvalli group in the upper hilly reaches and quaternary sediments (alluvium and soil) along valleys and in lower reaches, near the confluence of Sabarmati river. Mainly loamy soil (mixture of sand, silt and clay) occupy the catchment area.

Thematic maps: The thematic maps (soil, land use, drainage, rainfall, etc.) were prepared from the available published data, Digital Elevation Model (DEM), Landsat and Google Earth images using GIS software. Soil map was Classified into five classes: Clayey, Clayey skeletal, Fine loamy, Loamy and Loamy skeletal for Machhu and Watrak catchments (Fig. 2 and 3).

Methodology: Methodology of runoff estimation of Machhu and Watrak catchments is described in flow diagram (Fig.6). The SCS-CN method was used for the estimation of direct

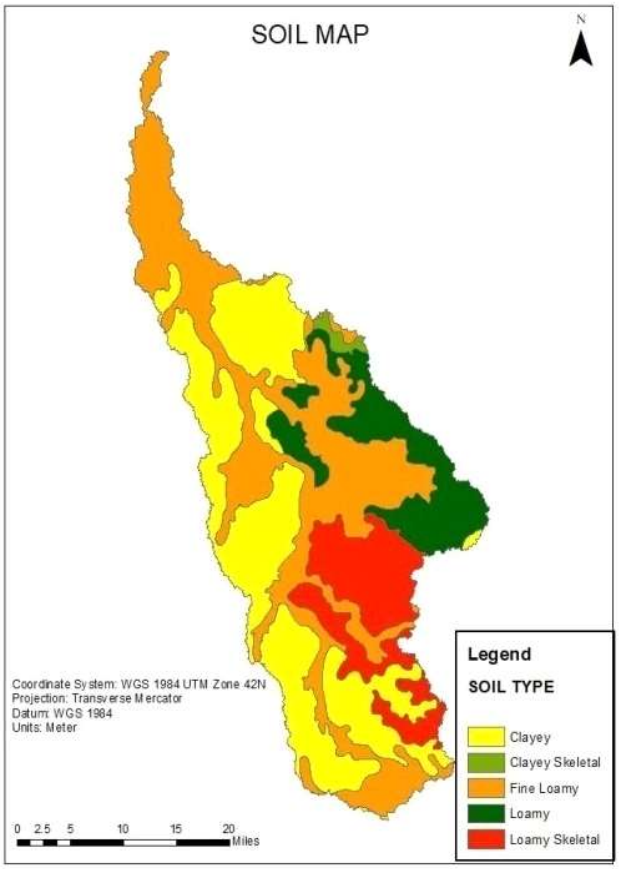


Fig. 2. Soil map of Machhu river catchment

runoff depth based on storm rainfall depth. This method is based on the water balance equation:

$$P=Ia+F+Q \quad \ldots(Eq.\ 1)$$

Where, P-Precipitation, Ia-Initial abstraction, F-Cumulative infiltration (excluding Ia), and Q-direct surface runoff within known time interval (Δt).Methodology of SCS-CN method is described in four main steps 1.Watershed delineation 2. Curve number estimation 3. Estimation of average precipitation 4. Estimation of runoff:

Watershed delineation is important part of the hydraulic model study of the catchment. In this study, watersheds of the Machhu and Watrak rivers were delineated from Aster DEM (30m) using Arc Hydro tools for carrying out hydrological model study (Fig. 7 and 8).

Curve number (CN) determination: The CN is an empirical parameter used for predicting direct runoff and infiltration from rainfall excess. The SCS-CN method governs by single parameter CN which depends on the watershed characteristics, land use classes (agricultural, grassland and shrubs (range), Forest, etc.), Antecedent Moisture Content (AMC), Hydrologic Soil Group (A, B, C and D), and hydrologic surface condition (Poor, Fair, and Good) of a watershed. For the determination of curve number TR 55 (USDA 1986) was used.

Estimation of average precipitation: Average precipitation of the catchment is determined by the analysis of of rainfall

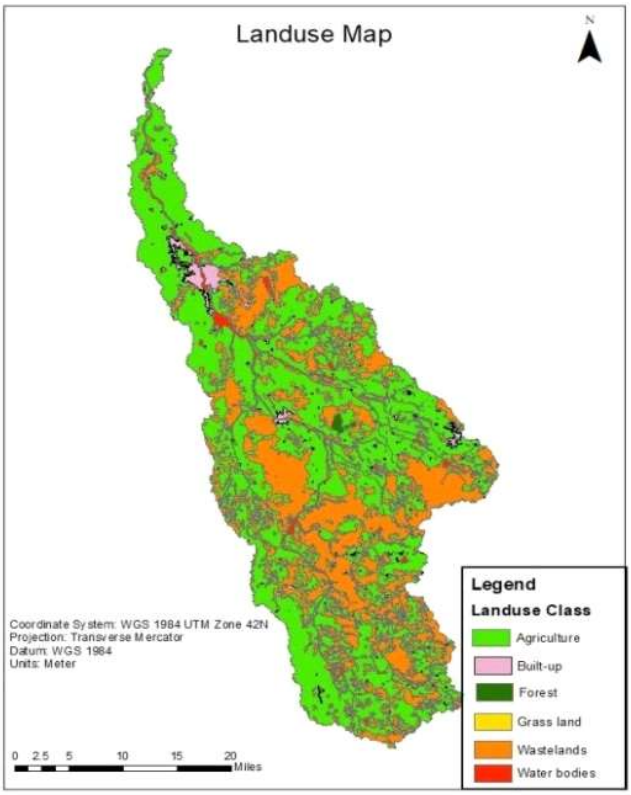


Fig. 4. Land use map of Watrak river catchment

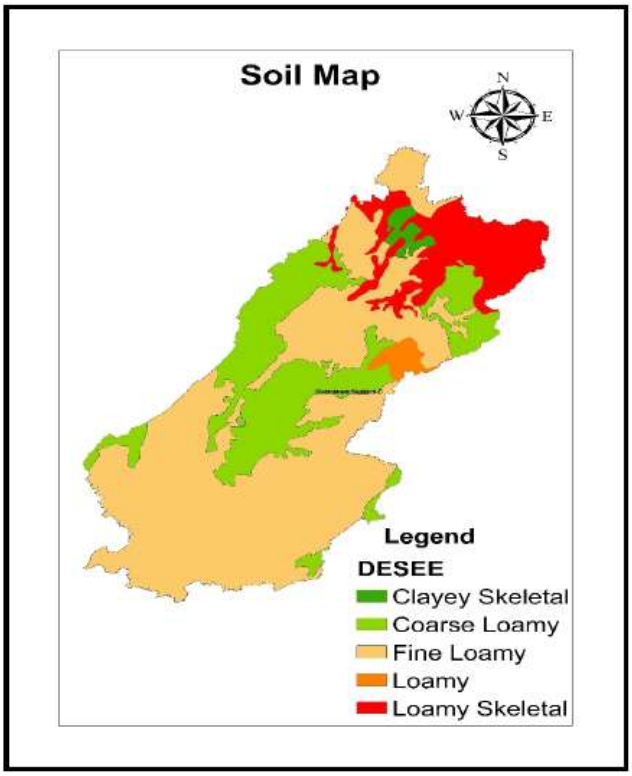


Fig. 3. Soil map of Watrak river catchment

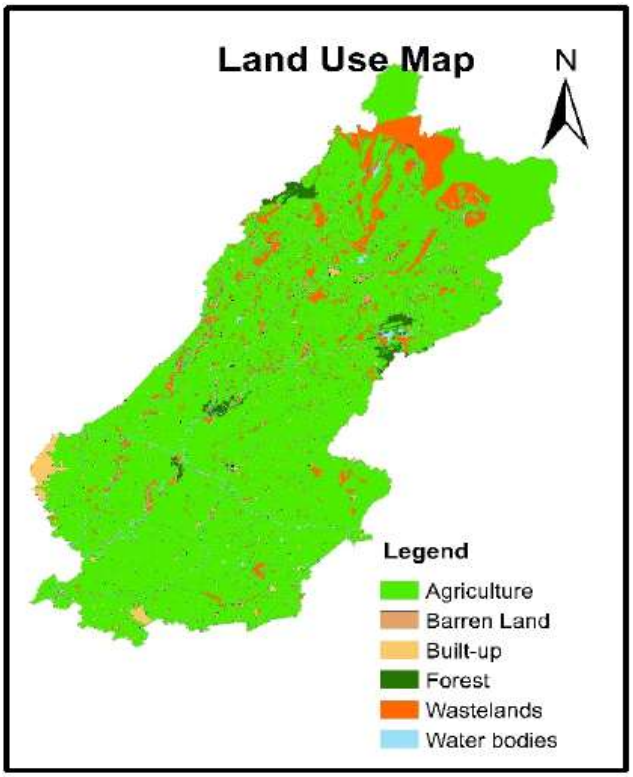


Fig. 5. Land use Map of Watrak river catchment

data of rain gauges located in the basins. In the Machhu river catchment 12 rain gauges were utilized to obtain average precipitation using Theissen-polygon method. In this method, rainfall data of each station was given weightage on the basis of area of polygon which enclosed the station. Following are equations of average rainfall (Pavg) calculations:

Pavg = (P1A1+ P2A2+..+PmAm)/ (A1+ A2+…..+Am) Eq. 2)

$$Pavg = \sum_{i=1}^{m} Pi(\frac{Ai}{A}) \quad \text{Eq. 3}$$

Where, P1 to Pm are the amount of rain fall at respective stations in mm and m is the number of station. A1 to Am are the respective area of Thiessen polygon.

The Ratio Ai/A is called the weightage factor for each station.

Where, i= 1, 2….. m.

Based on this method rainfall was calculated for the Machhu and Watrak basins. The average annual rainfall during the period 1987 to 2017 varies from 140 to 1020 mm in Machhu catchment and from 325 to 1450 mm in Watrak catchment (Fig. 9 and 10).

Estimation of runoff: For the estimation of runoff, Initial abstraction (Ia) and Infiltration (F) was estimated. Ia and F depend on the Antecedent Moisture Condition (AMC) of soil which is present at the beginning of the rainfall event. SCS classified AMC into three classes as below (Subramanya 2017):

AMC-I: Where soil is dry but not at wilting point thus satisfactory cultivation can take place. AMC-II: Average conditions, AMC-III: Saturated soil conditions created when sufficient rainfall occurred within the immediate past 5 days.

The equations for determining Curve Number I is as below for AMC condition I:

CNI= CNII/ (2.281-0.01281CNII). …(Eq. 4)

The curve number for AMC condition II has to be determined from the table of TR-55.

For AMC condition III, Curve number can be determined by using following equation:

CNIII= CNII/ (0.427+0.00573CNII) …(Eq. 5)

For the determination of runoff we have to determine potential maximum retention (S) by using CN (AMC condition I/II/III) in the following equation:

S = (25400 / CN) – 254 …(Eq. 6)

Then we have to calculate Initial abstraction using following equation:

Ia= λ*S where λ for Indian condition is 0.3 …(Eq. 7)

Finally, direct Runoff for the catchment can be determined using Average Precipitation (P), Initial Abstraction (Ia) and Potential maximum Retention (S) values in following equation:

Q = (P – Ia) 2 / P – Ia +S …(Eq. 8)

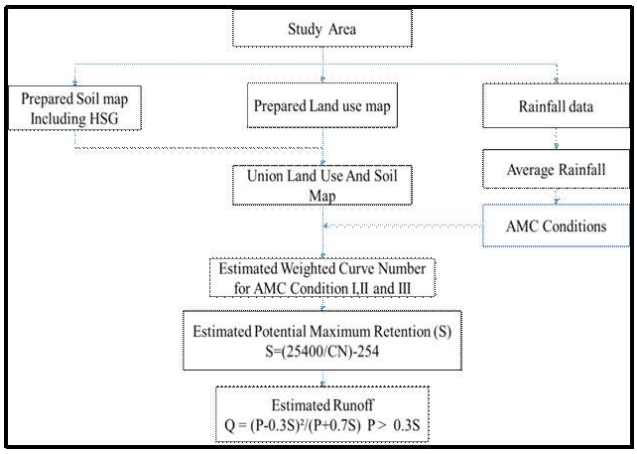


Fig. 6. Flow chart of estimation of runoff (SCS-CN method)

Q = (P – 0.3S) 2 / P – 0.7S …(Eq. 9)

Runoff will occur only when rainfall will be more than Ia that is Q=0 when precipitation is lower or equal to initial abstraction (P≤λS).

Regression analysis of rainfall and runoff: Regression analysis of the Machhu and Watrak river basins rainfall was done. Following equations were obtained by regression analysis for the estimation of runoff (Y) of the Machhu catchment and Watrak catchment for given precipitation (X) (Fig.13 and 14):

Y (mm) =0.4506* X (mm)-109.22 (for Machhu catchment) …(Eq. 10)

Y (mm) =0.491* X (mm)-163.9 (for Watrak catchment) …(Eq. 11)

Regression analysis of observed rainfall and simulated runoff of the Machhu and Watrak river basins Indicated that that R^2 (Goodness of fit measure) values are 0.85 and 0.735, respectively (Fig. 13 and 14).

RESULTS AND DISCUSSION

Distribution of HSG in the Machhu river catchment area (%) are of three types: B (26%), C (39%), and D (35%), whereas distribution of land use land cover are: agriculture (61%), built-up (1%), waste land (35%) and water body (3%). Similarly in the Watrak catchment area (%) distribution of HSG types are: A (33%), B (8%), C (26%) and D (33%) types and distribution of land use land cover types are: Agriculture (87%), Built-up (1%), Waste land (8%), Forest (2%) and Water bodies (2%). AMC II condition (average condition) was considered for selecting run off curve number for land use pattern and corresponding HSG for obtaining the value from the Tr 55 table. Weighted curve number was calculated from the equation:

CN Weighted= CN x Area of land use/ Total area of catchment …(Eq. 12)

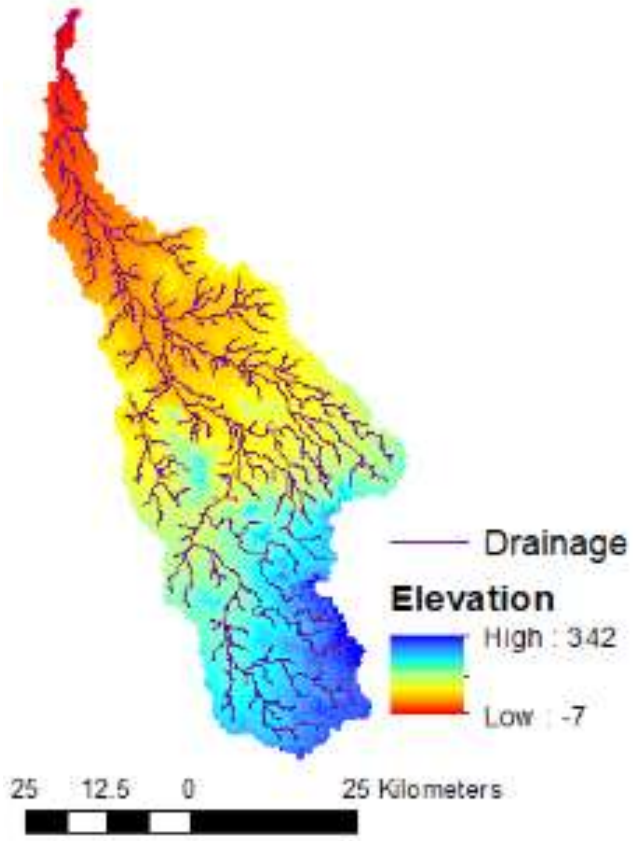


Fig. 7. Watershed drainage map of Machhubasin

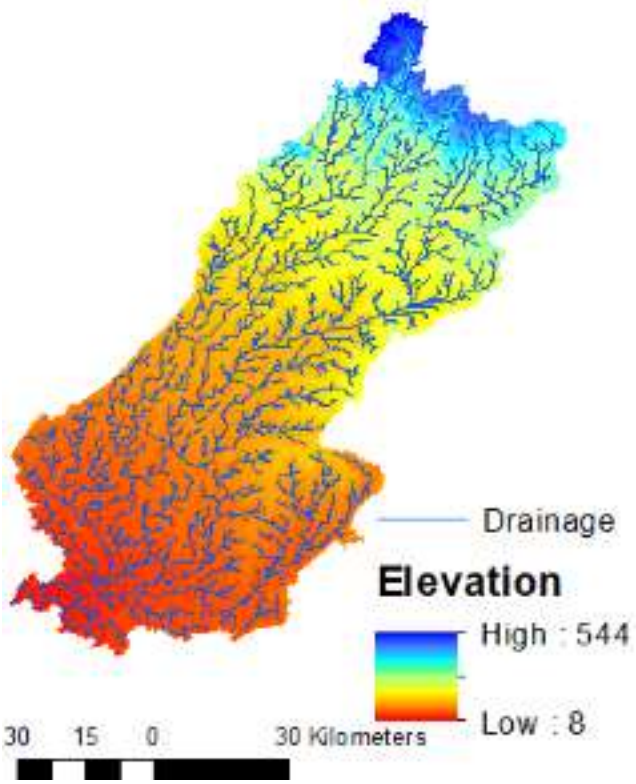


Fig. 8. Watershed drainage map of Watrak basin

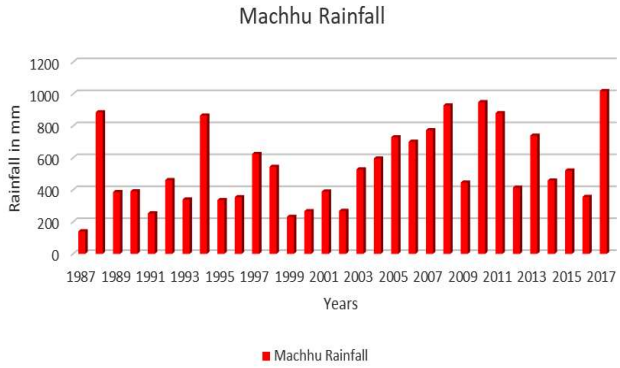


Fig. 9. Average annual precipitation in Machhu river catchment

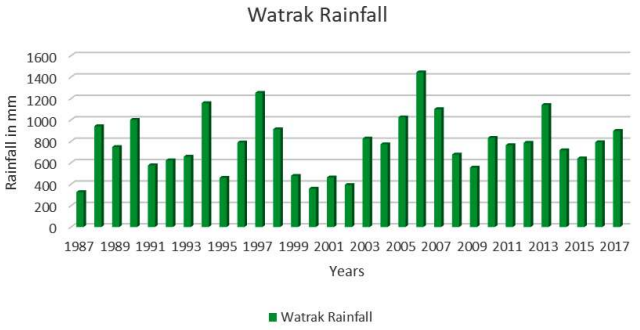


Fig. 10. Average annual precipitation in Watrak river catchment

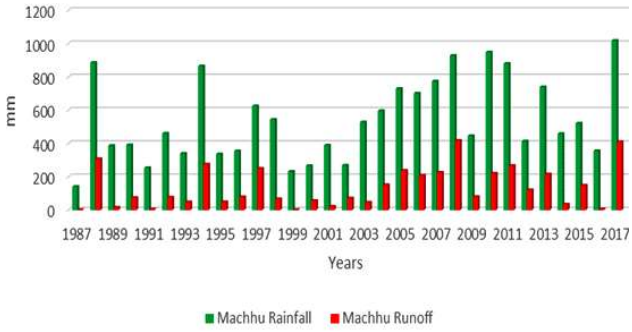


Fig. 11. Rainfall Runoff of Machhu river catchment

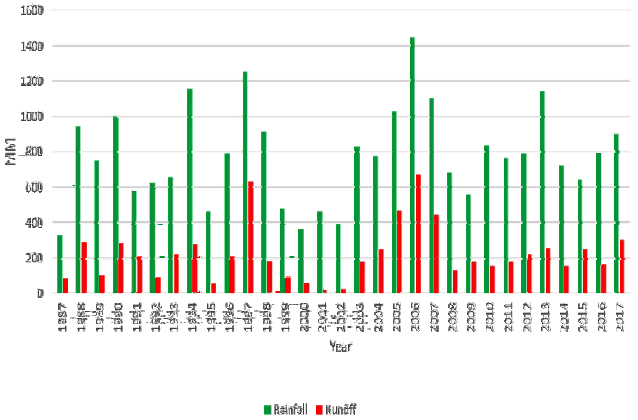


Fig. 12. Rainfall runoff of Watrak river catchment

Accordingly, weighted CN values for Machhu catchment for AMC-I, II and III conditions are 76, 88, 94, respectively. From these calculated CN values, parameter 'S' representing the potential maximum retention was calculated using the equation (Eq. 6). After this runoff 'Q' per day was calculated for the 31 years period (1987-2017) by using the equation (Eq. 8). Annual total runoff was calculated using standard statistical method which was presented in the graph (Fig.11 and 12).Analysis of the result of SCS-CN method of Machhu river catchment for the period 1987 to 2017 show that maximum runoff depth 415 mm occurred in the year 2008, corresponding to rain fall 930 mm. Average rainfall and runoff during this period was 542 mm and 135 mm, respectively. It is observed that runoff depth is varying with the total amount of rainfall in this catchment every year. It is also observed that no runoff was observed in the model study during the years1987, 1991, 1999 and 2016 when the rainfall was less than 250 mm. Reason for the no runoff can be attributed to the initial abstraction of rain fall by infiltration of rain water in the groundmass. Therefore, it can be concluded that threshold value of rainfall for runoff in this area is 250mm.Similar results were obtained for the Watrak catchment area. The SCS-CN model study of this basin showed that maximum runoff depth 666 mm occurred corresponding to rain fall 1450 mm in the year 2006. Average rainfall and runoff during this period was 778 mm and 218 mm, respectively. Here also, runoff depth is varying with the total amount of rainfall in this catchment every year. In the model study, no runoff was observed during the years 2001

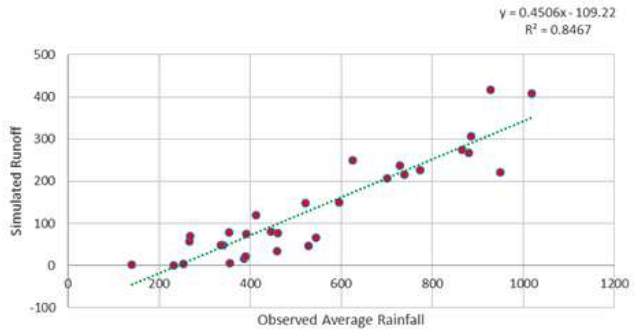


Fig. 13. Rainfall runoff correlation of Machhu river catchment

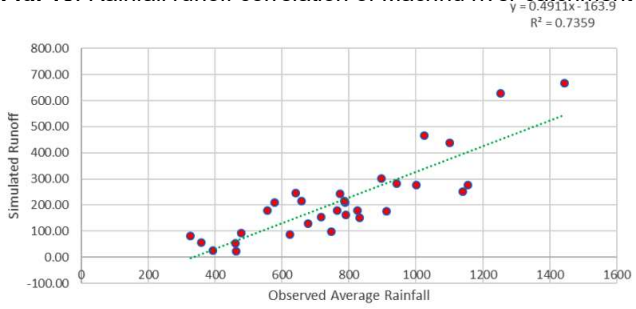


Fig. 14. Rainfall runoff correlation of Watrak river catchment

and 2002 when the rainfall was less than 400 mm. Reason for the no runoff can be attributed to the initial abstraction of rain fall by infiltration of rain water in the groundmass. Therefore, it can be concluded that threshold value of rainfall for runoff in this area is 400 mm in this catchment.

Analysis of the results, suggest that threshold values of rainfall (mm) for starting runoff in these two river basins is different. For Machhu river basin threshold value of rainfall is 250 mm and for Watrak river Basin 400 mm. This difference of threshold values is due to different topography, geology and soil conditions of these two catchment areas (Fig.2, 3, 4 and 5). Regression analysis of observed rainfall and simulated runoff of the Machhu and Watrak river basins Indicated that that R^2 (Goodness of fit measure) values are 0.85 and 0.735, respectively (Fig. 13 and 14). These values suggest good correlation between observed rainfall and modeled (estimated) runoff as the values of R^2 above 0.7 are considered good (Subramanya 2017).

CONCLUSIONS

In this study, SCS-CN method was applied for the estimation of runoff of two widely separated (320 km) river basins in Gujarat: Machhu and Watrak located in different geological and geo-environmental set up. Regression analysis results of rainfall and runoff data of these two basins indicated that R^2 values of Machhu and Watrak river basins are 0.85 and 0.735, respectively. These values suggest good correlation between observed rainfalls and simulated runoff as R^2 values above 0.7 are considered good. Comparison of the results of Machhu and Watrak river basins suggest that threshold values of rainfall for starting runoff in these two river basins are different, that is 250 mm for Machhu basin and 400 mm for Watrak basin. This difference of threshold values can be attributed to different groundmass conditions (geology, topography, soil, land use, etc.) of these two catchment areas. It is true for all other basins having different ground mass conditions. The present study of the two widely separated river basins in Gujarat suggests that simple SCS-CN method can be applied for the correct estimation of Runoff in different areas having different geo-environmental conditions. It is proposed to correlate simulated runoff based on the SCS-CN method with the actual runoff data for the validation of this method for wider applicability in other river basins.

REFERENCES

Amutha R and Porchelvan P 2009. Estimation of surface runoff in Malattar sub-watershed using SCS-CN method. *Journal of Indian Society of Remote Sensing* **37**(2): 291-304.

Chauhan NB, Gadhavi MS, Indra Prakash and Khalid Mehmood 2016. Determination of surface runoff in Amreli district Gujarat,

India using GIS based SCS Curve number method. *International Journal for Scientific Research and Development* **2**(11): 367-372.

Chirag S, Bhura NP, Singh PR, Mori and Indra Prakash 2015. Estimation of surface runoff for Ahmedabad urban area using SCS-CN method and GIS. *International Journal of Science Technology and Engineering* **1**(11): 2349-2784.

Chow VT, Maidment DK and Mays LW 2002. *Applied Hydrology*, McGraw-Hill Book Company, New York, USA.

Hawkins RH, Ward TJ, Woodward, DE and Van Mullem JA 2009.*Curve Number Hydrology: State of the Practice. American Society of Civil Engineers* Reston:1-106.

IMSD 1995. Technical guidelines, integrated mission for sustainable development, national remote sensing center (NRSC). Department of Space, Government of India.

Jun LI, Changming LIU, Zhonggen Wang and Kang L 2015. Two universal runoff yield models: SCS versus LCM. *Journal of Geographical Science* **25**(3): 311-318.

Kadam Ajaykumar, Sanjay Kale, Nagesh Pande, Pawar N and Sankhua R 2012. Identifying potential rainwater harvesting sites of a semi-arid, Basaltic Region of Western India, using SCS-CN method. *Water Resource Management* **26**: 2537-2554.

Kishanlal Darji, Vidhi Khokhani, Indra Prakash, Khalid Mehmood and Binh Thai Pham 2019. Rainfall-runoff modeling using HEC-HMS model: An application of regression analysis. *Journal of Emerging Technologies and Innovative Research* **6**(5): 226-234.

Kudoli AB and Oak RA 2015. Runoff estimation by using GIS based technique and its comparison with different methods: A case study on Sangli Micro-watershed, *International Journal of Emerging Research in Management* **4**(5): 2278-9359.

Ly S, Charles C and Degré A 2013. Different methods for spatial interpolation of rainfall data for operational hydrology and hydrological modeling at watershed scale. A review. *Biotechnology Agronomy Society and Environment* **17**(2): 392-406.

Mishra SK, Jain MK and Singh VP 2004. Evaluation of the SCS-CN based model incorporating, antecedent moisture. *Water Resource Management* **18**: 567-589.

Nagarajan N and Poongothai S 2012. Spatial mapping of runoff from a watershed using SCS-CN method with remote sensing and GIS. *Journal of Hydrologic Engineering* **17**(11): 1268-1277.

Pawar NJ, Pawar JB, Kumar S and Supekar A 2008. Geochemical eccentricity of ground water allied to weathering of basalt from the Deccan volcanic province, India: insinuation on CO_2 consumption. *Aqua Geochem* **14**: 41-71.

Ponce VM and Hawkins RH 1996. Runoff curve number: has it reached maturity. *Journal of Hydrology Engineering* **1**(1): 11-19.

Rallison RE 1980. Origin and evolution of the SCS runoff equation. Proceeding of the Symposium on Watershed Management. *American Society of Civil Engineering* **2**: 912-924.

Saravanan S and Manjula R 2015. Geomorphology based semi-distributed approach for modeling rainfall-runoff modeling using GIS. *Proceeding* **4**: 908-916.

Shah MK, Vishvam H. Pancholi, Motiani AT and Indra Prakash 2015. Estimation of runoff for Jamnagar district using SCS-CN method and Geographic Information Systems. *International Journal for Scientific Research and Development* **3**(3): 777-780.

Shah K, Motiani AT, Indra Prakash and Khalid Mehmood 2017.Application of SCS-CN method for estimation of runoff using GIS. *International Journal of Advance Engineering and Research Development* **4**(4): 558-567.

Solanki VK, Neelkanth Bhatt, Indra Prakash, Kishanlal Darji and Binh Thai Pham 2019. Application of SWAT model in the estimation of runoff and sedimentation of Watrak River basin, north Gujarat, India. *Journal of Emerging Technologies and Innovative Research* **6**(5): 556-566.

Songara JC, Indra Prakash, Kadivar HT and Joshipura NM 2015. Estimation of surface runoff of Machhu Dam III catchment area, Morbi, Gujarat, India, using curve number method and GIS. *International Journal for Scientific Research & Development* **3**(3): 2038-2043.

Subramanya K 2017. *Engineering Hydrology*. TATA McGraw Hill Education Private Limited, New Delhi, India.

USDA 1986. Urban hydrology for small Watersheds, TR-55. United States Department of Agriculture: 1-164p.

USDA 1972. *Soil Conservation Service*, National Engineering Handbook. Hydrology Section 4. Chapters 4-10.

Vinithra R and Yeshodha L 2016. Rainfall–runoff modelling using SCS-CN method: A case study of Krishnagiri District, Tamilnadu. *International Journal of Scientific Research* **5**(3): 2319-7064.

Received 20 May, 2020; Accepted 19 August, 2020

Indian Journal of Ecology (2020) 47(3): 733-738

Manuscript Number: 3075
NAAS Rating: 4.96

A Rapid Exploration of Insect Pests and their Ecology along Chitwan Annapurna Landscape, Nepal

Daya Ram Bhusal, Shivish Bhandar[1], Tara Maya Gurung[1] and Kishor Chandra Ghimire[2]

Central Department of Zoology, Tribhuvan University Kantipur, Kathmandu, Nepal
[1]Himalayan Biodiversity Network Nepal, Bharatpur 11, Chitwan, Nepal
[2]Birendra Multiple Campus, Bharatpur, Chitwan, Nepal
**E-mail: drbhusal@cdztu.edu.np*

Abstract: This study was conducted in agriculture areas of the Kaligandaki and Marsyangdi river basins of Chitwan Annapurna Landscape, and the aim were to explore the diversity of insect pests in agriculture farming. The field sampling was carried in the summer of 2018 and we surveyed between 1000 to 3000 m asl. We identified 19 species of insect pests belonging to twelve families. The maximum types of insects were observed from family Aphididae (61%) whereas the least number and diversity was identified from Meloidae (0.35%). Our study indicated that the highest abundance of insect pests was observed in Cowpea Bean (*Vigna unguiculata*) and the least on the Lima Bean (*Phaseolus lunatus*). The frequency of insect pests showed that positive correlation with temperature and altitude however, negatively related to the relative humidity of the sampling area. The frequency and diversity of insect pests showed statistical significance ($P < 0.5$) affected by the families of different crops of sampling areas. There was higher species diversity ($H= 2.07$) in Kaligandaki River Basin comparing to Marshyangi Basin sites.

Keywords: Agroecology, Diversity, Bioclimatic parameters, Altitude, Sustainable agriculture

The vegetable is the important crop grown in Nepal playing a vital role in Nepalese economy (CBS 2013, MoF 2014, Mo-AD 2015). The most common cultivated vegetables throughout the country are mainly cauliflower, potato, tomato and cabbage, bean, broadleaf, etc. (Pandey et al 2017). Some of the insects associated with vegetable crops are gradually attaining the major pest status in different regions of Nepal. It is reported that insect pests in Nepal damage about 35% of crops. The recent change in land use pattern and climate change causing the rapid expansion of vegetable pests across the many parts of this country majorly potato tuber moth (*Phthorimaea operculella*), cutworm (*Agrotis* sp.), green aphid (*Myzus persicae),* Ladybird beetles (Epilachna spp.) and semi-looper (Achaea janata). Similarly, *Pieris brassicae nepalensis* , *Spodoptera litura*, *Spilarctia casigneta*, *Plutella xylostella, Lipaphis erysimi,* and *Brevicoryne brassicae* are the dominant insect pests of many cruciferous vegetables in the mid ecological zone that includes present study area. Monitoring of population dynamics and species diversity of insect pest is highly demanding throughout the country including the present study area (Ghimire et al 2016). This area is highly vulnerable due to land-use change, rapid infrastructure development, rapid human migration, changing in the cropping system and climate change. Therefore, the rigorous investigation is needed for the species inventory, ecological status and reproductive strategies of insect pests in Chitwan Annapurna Landscape (CHAL). Furthermore, rapidly invasion of South American Tomato Leaf Miner (*Tuta absolut*a) (Bajracharya et al 2016) and Invasive weeds: *Parthenium hysterophorus* (Shrestha et al 2018) area being a major problem in different parts of CHAL that playing major role for habitat alteration creating vast ecological change on the local scale for many agricultural sites of this region. The management of insect pest especially focusing on bio-rational strategies is urgently needed for sustainable crop production in CHAL region. Similarly, the development of a forecasting system for insect pests of major crops is urgent for Nepal including present study. This paper deals about the listing of insect pest and ecological study of major insect pest of the study area focusing on vegetable insect pests in potential agricultural farms along Kaligandaki and Marsyangdi river basin in CHAL.

MATERIAL AND METHODS

Study area: This study was conducted across Chitwan-Annapurna Landscape (CHAL- 27.0'35" and 29.0'33" N and 82.0'88" and 85.0'80" E) especially focusing on agriculture sites along Kaligandagi and Marshyandi river basins. The sampling area ranges from 1000 m to 3000 m als. The sampling points were randomly selected focusing most important agricultural areas.

Insect collection: An extensive field survey was done in the summer 2019. Insects were collected from each sampling

point selecting 30% cropping land of that particular point. The collection was carried out in the daytime (7 am to 5 pm). Netting, stem beating, and handpicking methods were used to collect the insects. During the collection, the altitudes and local habitat characteristics were also noted. The collected species were brought to the laboratory in the Central Department of Zoology, Tribhuvan University for further identification; physical parameters (temperature, humidity, and coordinates) were also noted from sampling points.

Species identification: Collected specimens were identified by using identification keys (Borrer et al 1964, Richards and Davies 1977, Hill 1983, Blackman and Eastop 1984, Joshi 1994, Mohamed 1994, Neupane 2000) and through kinds of literature. Later some specimens were also reconfirmed by comparing with collected specimen in Nepal Agricultural Research Council Kathmandu Nepal.

Data analysis: To quantify the diversity status in two study sites of CHAL (Kaligandaki river basin Marsyangdi basin sites) we performed Shannon Wiener Diversity (H) = Σ pi* lnpi where, Pi= n/N= Relative abundance of each species. Similarly, Relative frequency (%) = (n/N) *100) of the insect pest was analysed. To find the effect of insect abundance with their families we applied the generalized linear model (glm) to find the abundance of insect pests in the different host plants The model was selected based on the lowest value of Akaike's entropy-based information Criterion (AIC).

RESULTS AND DISCUSSION

In the present study 19 insect pests belonging to 12 families infesting 11 vegetable crops were collected (Table 1) and especially of Hemiptera, Lepidotpera, Orthoptera and Coleoptera. The highest frequency was observed for *Pieris brassica*-18%), whereas the lowest number of frequency was observed for *Alcidodes* sp. (2%) from our sampling areas (Fig. 1). The diversity was analyzed comparing two study sites (Kaligandaki and Marsyangdi), the highest pest diversity was obtained in Kaligandaki (H= 2.07) than Marsyangdi (H=1.88) river basin (Table 3). Probably, it is attributed to the variation of microclimates and host plant types, parts. Furthermore, the usage of pesticides and the application of organic practices by farmers within these sites are the determining factors for such variation of pest availability. The previous study also showed, higher dependence on chemical pesticides in vegetable production was also reported in many parts of CHAL (Koirala et al 2010, Rijal et al 2018).

To understand the pattern of species richness across elevation range, there was necessary to understand the distribution range-size (Gaston 1996, Jetz 2002) of insect pest across altitudinal gradients of our area. It is generally known that Organisms living at high altitudinal areas, where climatic conditions are highly variable, have broader physiological thermal tolerances (Chen et al 2016; García-Robledo et al 2016) and variation in host-herbivory interaction (Rasmann et al 2018). To find the altitude specificity of insect pest in this region, we determined the altitudinal range of the different insects based on their frequency status. Some insect pests were recorded within the particular range of elevation whereas others showed only specific altitude (e.g. *Aplosonyx chalybaeus* and *Melanoplus* sp.) (Table 2).

There was significant variation (F= 4.82) for the mean frequency of insects with the different families of crops. In our glm analysis, the abundance of insect pests was significantly affected by the host plant especially for cowpea bean, broadleaf mustard, green bean, cabbage, cauliflower and potato (Table 4). The highest mean frequency of insect pests was for Aphididae and the least mean frequency of insect pests from Tenebrionidae (Fig. 2). These analyses indicated the abundance of insect pests was significantly different from different host plants type indicating the performance of defense variability of host plants (Via 1990). The

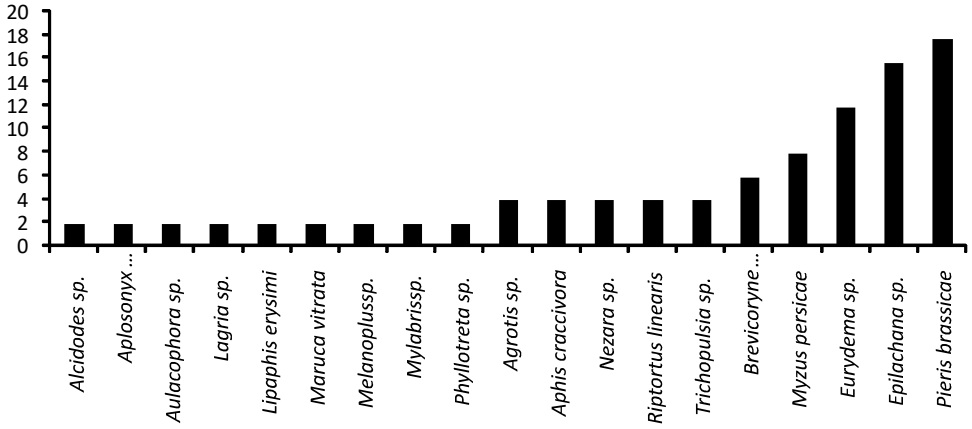


Fig. 1. Rank abundance of insects in study areas

Table 1. Insect pests from study areas

Common name	Scientific name	Insect family	Host plant
Legume pod borer	*Maruca* sp	Crambidae	Lima bean
Large cabbage white butterfly	*Pieris brassicae*	Pieridae	Cauliflower, Cabbage
Black cutworm	*Agrotis* sp.	Noctuidae	Potato
Cabbage looper	*Trichopulsia* sp.	Noctuidae	Cabbage, Cauliflower
Bean gall weevil	*Alcidodes* sp.	Curculionidae	Green Bean
Darkling beetle	*Lagria* sp.	Tenebrionidae	Green Bean
Pumpkin beetle	*Aulacophora* sp.	Chrysomelidae	Pumpkin
Taro corm- borer	*Aplosonyx chalybaeus*	Chrysomelidae	Taro
Banded blister beetle	*Mylabris* sp.	Meloidae	Sponge gourd
Epilachna beetle	*Epilachna vigintioctopunctata*	Coccinellidae	Potato
Cowpea aphid	*Aphis* sp.	Aphididae	Cowpea
Mustard aphid	*Lipaphis erysimi*	Aphididae	Broad leaf mustard
Cabbage aphid	*Brevicoryne brassicae*	Aphididae	Cabbage, cauliflower
Potato peach aphid	*Myzus persicae*	Aphididae	Potato
Spur-throated grasshopper	*Melanoplus* sp.	Acrididae	Green Bean
Pod sucking bug	*Riptortus* sp.	Alydidae	Green Bean
Shield bug	*Eurydema* sp.	Pentatomidae	Cauliflower, cabbage
Green stink bug	*Nezara* sp.	Pentatomidae	Bean, potato
Pumpkin beetle	*Aulacophora lewisii*	Chrysomelidae	Sponge gourd
Epilachna beetle	*Epilachna vigintioctopunctata*	Coccinellidae	Potato
Green stink bug	*Nezara* sp.	Pentatomidae	Poato, bean
Potato peach aphid	*Myzus persicae*	Aphididae	Potato
Black cutworm	*Agrotis* sp.	Noctuidae	Potato
Large cabbage white butterfly	*Pieris brassicae*	Pieridae	Cabbage , cauliflower
Mustard aphid	*Lipaphis erysimi*	Aphididae	Broad leaf mustard
Cabbage aphid	*Brevicoryne brassicae*	Aphididae	Cabbage, cauliflower
Pod sucking bug	*Riptortus* sp.	Alydidae	Bean
Cabbage looper	*Trichopulsia* sp.	Noctuidae	Cauliflower, cabbage
Flea beetle	*Phylloterta* sp.	Chrysomelidae	Cabbage
Flea beetle	*Monolepta signata*	Chrysomelidae	Cauliflower
Painted bug	*Bagrada* sp	Pentatomidae	Caulliflower
Spotted beetle	*Epilachana* sp	Coccinelidae	Black bean

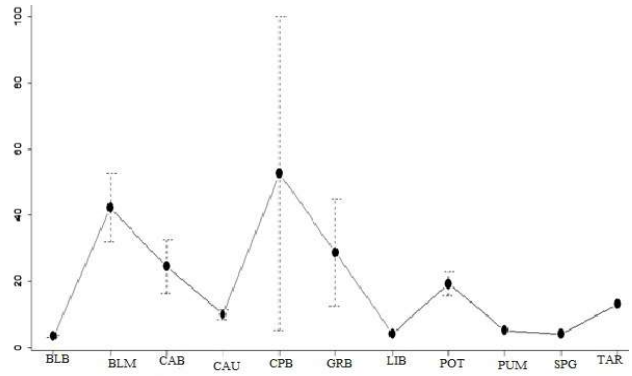


Fig. 2. Insect pest abundance comparing with different host plants

morphological characteristics of host plants which were interfere with insect movement, feeding, or reproduction limit the variability of insect abundance and diversity (Bernays and Chapman 2007). The abundance of these insects depends on resource availability with space and time (Kremen et al 2007). In our study, the family Aphididae of the order Hemiptera was most abundant in both sites. Bhat and Ahangar (2018) in the Northern mountainous region of India obtained similar conditions in vegetables. Aphids are particularly sensitive to temperature changes due to certain specific biological features and these are in the face of global changes (Hulle et al 2010, Thomson et al 2010). Probably,

Table 2. Insect recorded in altitudinal range and number of individuals of particular species

Pest species	Lowest altitude range (m. asl.)	Upper altitude range (m asl.)	Frequency
*Agrotis*sp	2236	2724	2
Alcidodes sp	1472	1600	1
Aphis craccivora	1581	1690	2
Aplosonyx chalybaeus	1506	-	1
Aulacophora sp	1472	-	1
Brevicoryne brassicae	1896	2270	3
Epilachana vigintioctopunctata	2408	2724	8
Eurydema sp	1996	2536	3
Lagria sp	1472	1645	1
Lipaphis erysimi	2353	2774	6
Maruca vitrata	1320	-	1
Melanoplus sp	1690	-	1
*Mylabris*sp	1690	-	1
Myzus persicae	2416	2724	4
Nezara sp	2723	2750	2
Phyllotreta sp	1904	-	1
Pieris brassicae	2284	2774	9
Riptortus linearis	1688	1904	2
Trichopulsia sp	2584	2633	2

Table 3. Species richness and diversity status of insect pest in two regions of study area (Kaligandaki and Marsyangdi river basin sites)

Sampling sites	Species number (S)	Diversity index (H)
Kaligandaki	19	2.07
Marsyangdi	13	1.88

Table 4. Summary of generalized linear model for the effect of host plants on insect frequency in study sites

Coefficient	Estimate	Std. error	t- value	P-value
CPB (Cowpea bean)	0.09	0.03108	2.895	0.006
BLM (Broad leaf mustard)	-0.08944	0.03109	-2.877	0.006
CAB (Cabbage)	-0.08832	0.0311	-2.84	0.006
BLB (Broad leaf bean)	-0.07954	0.03129	-2.542	0.014
GRB (Green bean)	-0.08964	0.03109	-2.883	0.006
CAU (Cauliflower)	-0.08878	0.03111	-2.854	0.006
LIB (Lima bean)	-0.0275	0.05142	-0.535	0.595
POT (Potato)	-0.08729	0.0311	-2.807	0.007
PUM (Pumpkin)	-0.05	0.04272	-1.17	0.248
SPG (Sponge guard)	-0.0275	0.05142	-0.535	0.595
TAR (Taro)	-0.08408	0.03186	-2.639	0.011

such variations of insect frequency with host plant types could be further relevant to pest management strategies by local farmers as well as the impact of climate change (Lima et al 2009).

In our principal component analysis (PCA) the local habitats and host plant types were the major factors for the variation in insect pests as suggested by Altieri (1999) as well as Khan and Talukder (2017). The first canonical axis explains 43.62% and the second axis explains 29.95% of the total variance of the data set (Fig. 3). There is high influence of bioclimatic parameters such as temperature and humidity for the abundance of insect pests in our study areas (Boggs 2016). Temperature is probably the single most important environmental factor influencing insect behavior, distribution, development, survival, and reproduction and temperature is the crucial factor for the distribution of insects' population (Estay et al 2009). In our study, this physical factor showed the major limiting factor for the abundance and distribution of insect pests across different elevation level (Estay et al 2014, Heino et al 2015). Among the other insect groups, Aphids are particularly sensitive to temperature changes due to certain specific biological features and these are in the face of global changes (Hulle et al 2010, Thomson et al 2010). It was found that the abundance of insect pests shows a significantly positive correlation with temperature and altitude (Hodkinson 2005) whereas negative correlation with relative humidity. Therefore, the structural heterogeneity of agricultural landscapes influences on many groups of arthropods affecting ecosystem services such as pest and pollination (Weibull et al 2003, Tscharntke et al 2005). The abundance of these insects depends on resource availability with space

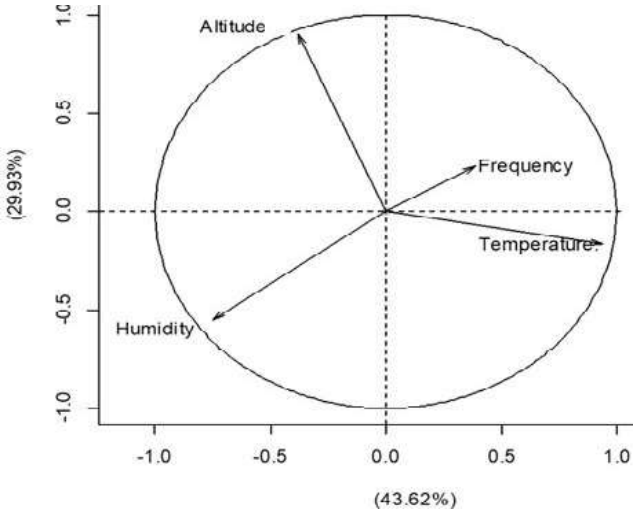


Fig. 3. PCA diagram showing the relationship insect the frequency with physical parameters (temperature, altitude, and relative humidity)

and time (Kremen et al 2007). The abundance of insect pest species had increased with an increase in temperature. This result is in agreement with the findings of (Vidya et al 2011) in which the abundance of insect pests of cruciferous vegetables had increased with the increase in temperature. Similarly, the relative humidity also directly or indirectly affects the life of insects, increasing or decreasing the development processes and reproductive activities (Chang et al 2008). Therefore, the effects of landscape complexity on insect pests as well as on their natural enemies is necessary to identify the appropriate landscape management across spatial scales (Kremen et al 2007, Chaplin-Kramer et al 2013) under climate change the scenario in this agriculturally important CHAL region (Malla 2008).

There was high influence of bioclimatic parameters such as temperature and humidity for the distribution and variation of insect pests across these sites. The temperature is the major factor for the abundance and distribution of insect pests. The pattern of host plant availability is also another major factor for the distribution and abundance of insect pests in this region. There is a need for more detail species inventory of insect pests of the vegetables from this region under the climate change scenario. Overall results suggest that habitat management in agricultural areas of CHAL is urgently needed to explore the suitable management strategies for insect pests to enhance the sustainable vegetable production. Extension of integrated pest management (IPM) focusing on eco-friendly techniques are the most suggestive for this region. It is urgent to provide training on IPM especially focusing on pesticide handling, disposal and dissemination of alternative technology through field demonstration to enhance the eco-friendly pest management techniques for sustainable vegetable production in CHAL.

ACKNOWLEDGEMENTS

Authors thank to University Grant Commission Nepal (UGC-Nepal) for the partial field support for this work and Himalayan Biodiversity Network Nepal (HBN- Nepal) for the equipment support in the field.

REFERENCES

Altieri MA 1999. The ecological role of biodiversity in agroecosystems. In *Invertebrate Biodiversity as Bioindicators of Sustainable Landscapes*. pp. 19-31.

Atreya K 2007. *Pesticide use in Nepal; understanding health costs from short-term exposure*. South Asia Network for Development and Environmental Economics (SANDEE), Kathmandu, Nepal.

Bajracharya ASR, Mainali RP, Bhat B, Bista S, Shashank PR and Meshram NM 2016. The first record of South American tomato leaf miner, Tuta absoluta (Meyrick 1917) (Lepidoptera: Gelechiidae) in Nepal. *Journal of Entomology and Zoology Studies* **4**: 1359-1363.

Bernays EA and Chapman RF 2007. *Host-plant selection by phytophagous insects* (Vol. 2). Springer Science & Business Media.

Bhat DM and Ahangar FA 2018. A systematic checklist and species richness of insect pest associated with vegetable crops in Jammu and Kashmir State, India. *Journal of Entomology and Zoology Studies* **6**: 328-338.

Blackman RL and Eastop VF 1984. *Aphids on the world's crops: An Identification and Information Guide*. John Wiley & Sons, Chichester, England. 466 pp.

Boggs CL 2016. The fingerprints of global climate change on insect populations. *Current Opinion in Insect Science* **17**: 69-73.

Borrer DJ, De Long DM and Triplehorn CA 1964. *An introduction to the study of insects 5th ed*. Saunders College Publishing, Philadelphia, 872 pp.

CBS 2013. Nepal vegetable crops survey 2009-10. A Statistical Report. National Planning Commission Secretariat, Central Bureau of Statistics, Kathmandu, Nepal.

Chan WP, Chen IC, Colwell RK, Liu WC, Huang CY and Shen SF 2016. Seasonal and daily climate variation have opposite effects on species elevational range size. *Science* **351**: 1437–1439.

Chang XN, Gao HJ, Chen FJ and Zhai BP 2008. Effect of environmental moisture and precipitation on insects: A review. *Chinese Journal of Ecology* **27**: 619-625.

Chaplin-Kramer R, de Valpine P, Mills NJ and Kremen C 2013. Detecting pest control services across spatial and temporal scales. *Agriculture, Ecosystems & Environment* **181**: 206-212.

Estay SA, Lima M and Bozinovic F 2014. The role of temperature variability on insect performance and population dynamics in a warming world. *Oikos* **123**: 131-140.

Estay SA, Lima M and Labra FA 2009. Predicting insect pest status under climate change scenarios: Combining experimental data and population dynamics modelling. *Journal of Applied Entomology* **133:** 491-499.

García-Robledo C, Kuprewicz EK, Staines CL, Erwin TL and Kress WJ 2016. Limited tolerance by insects to high temperatures across tropical elevational gradients and the implications of global warming for extinction. *Proceedings of the National Academy of Sciences* **113**: 680-685.

Gaston KJ 1996. Species-range-size distributions: Patterns, mechanisms and implications. *Trends in Ecology & Evolution* **11**: 197-201.

Ghimire B, Dhakal SC and Sharma S 2016. Prospects of adopting eco-friendly measures of soil sustainability among vegetable producers in Dhading, Nepal. *Universal Journal of Environmental Research and Technology* **6**: 195-202.

Heino J, Melo AS, Bini LM, Altermatt F, Al-Shami SA, Angeler DG and Dangles O 2015. A comparative analysis reveals weak relationships between ecological factors and beta diversity of stream insect meta-communities at two spatial levels. *Ecology and Evolution* **5**: 1235-1248.

Hill DS 1987. *Agricultural Insect Pests of Temperate Regions and Their Control.* Cambridge University Press, Cambridge, 659 pp.

Hodkinson ID 2005. Terrestrial insects along elevation gradients: Species and community responses to altitude. *Biological Reviews* **80**: 489-513.

Hulle M, d Acier AC, Bankhead-Dronnet S and Harrington R 2010. Aphids in the face of global changes. *Comptes Rendus Biologies* **333**: 497-503.

Jetz W 2002. Geographic range, size and determinants of avian species richness. *Science* **297**: 1548-1551.

Joshi SL 1994. *Nepal ma tarakri baalika mukhya hanikarak kiraharu.* Entomology division, Nepal Agricultural Research Council, Khumaltar, Lalitpur, Nepal, 187 pp.

Khan MMH and Talukder S 2017. Influence of weather factors on the abundance and population dynamics of *Spodopter alitura* F. and

Pieris brassicae L. on cabbage. SAARC.

Koirala P, Tamrakar AS, Bhattarai BP, Yadav BK and Humagain S 2010. Use and handling practice of pesticides in vegetables: A case study on some selected districts of Nepal. *Journal of Food Science Technology* **6**: 105-109.

Kremen C, Williams NM, Aizen MA, Gemmill-Herren B, LeBuhn G, Minckley R and Vázquez DP 2007. Pollination and other ecosystem services produced by mobile organisms: A conceptual framework for the effects of land-use change. *Ecology Letters* **10**: 299-314.

Lima EA, Ferreira CP and Godoy WA 2009. Ecological modeling and pest population management: A possible and necessary connection in a changing world. *Neotropical Entomology* **38**: 699-707.

Malla G 2008. Climate change and its impact on Nepalese agriculture. *Journal of Agriculture and Environment* **9:** 62-71.

MoAD 2015. Ministry of Agricultural Development website: www.moad.gov.np .

MoF 2014. Economic survey, Fiscal year 2013/14: Government of Nepal, Ministry of Finance, Singhadurbar, Kathmandu, Nepal.

Mohamedsaid MS 1994. The genus *Aulacophora* Chevrolat from Peninsular Malaysia (Coleoptera: Chrysomelidae). *Malyan Nature Journal* **47**: 375-392.

Neupane FP 2000. *Tarakari Baliharuma Lagne Kiraharuka Ekikrit Byawasthapan (Integrated management of vegetable insects)*. Sajha Prakashan, Pulchowk, Lalitpur, 188 pp.

Pandey G, Basnet S, Pant B, Bhattarai K, Gyawali B and Tiwar A 2017. An analysis of vegetables and fruits production scenario in Nepal. *Asian Research Journal of Agriculture* **6**: 1-10.

Rasmann S, Alvarez N and Pellissier L 2018. The altitudinal niche-breadth hypothesis in insect-plant interactions. *Annual Plant Reviews* **47:** 339-359.

Richards OW and Davies RG 1977. *Imm's general textbook of entomology 10th ed. vol. II*. Classification and Biology, Springer Netherlands, 934pp.

Rijal JP, Regmi R, Ghimire R, Puri D, Gyawaly S and Poudel S 2018. *Farmers' knowledge on pesticides safety and pest management practices: A case study of vegetable growers in Chitwan, Nepal*. Sustainable Agriculture Nepal, 1-11 pp.

Shrestha UB, Sharma KP, Devkota A, Siwakoti M and Shrestha BB 2018. Potential impact of climate change on the distribution of six invasive alien plants in Nepal. *Ecological Indicators* **95**: 99-107.

Thomson LJ, Macfadye S and Hoffmann AA 2010. Predicting the effects of climate change on natural enemies of agricultural pests. *Biological Control* **52**: 296-306.

Tscharntke T, Klein AM, Kruess A, Steffan-Dewenter I and Thies C 2005. Landscape perspectives on agricultural intensification and biodiversity–ecosystem service management. *Ecology Letters* **8**: 857-874.

Via S 1990. Ecological genetics and host adaptation in herbivorous insects: the experimental study of evolution in natural and agricultural systems. *Annual Review of Entomology* **35:** 421-446.

Vidya S, Premlatha S, Sanil R, Jeyasankar A 2011. Diversity of high altitude insect pests in edible crucifers. *Environmental Science an Indian Journal* **6**: 257-262.

Weibull AC, Östman Ö and Granqvist Å 2003. Species richness in agroecosystems: The effect of landscape, habitat and farm management. *Biodiversity & Conservation* **12:** 1335-1355.

Young AM 1982. *Population Biology of Tropical Insects*. New York. USA: Plenum Press, 511 pp.

Received 27 May, 2020; Accepted 31 July, 2020

Indian Journal of Ecology (2020) 47(3): 739-745

Manuscript Number: 3076
NAAS Rating: 4.96

Status of Zooplankton Diversity, Abundance in Relation to Hydrography of Ganga River and its Tributaries at Rishikesh

D.S. Malik, Amit Kumar Sharma* and Arvind Kumar Sharma

Department of Zoology and Environmental Science
Gurukula Kangri Vishwavidyalaya, Haridwar, Uttarakhand-249 404, India
**E-mail: amitpandit100192@gmail.com*

Abstract: The Ganga River is one of the largest river in India and fifth longest river in the world. The river originates from the ice cave of Gaumukh (33° 55'N, 79° 07' E) at the snout of Gangotri glacier in the Garhwal portion of Western Himalaya, at an elevation of about 4100 meters. During the present study different species of zooplankton ware recorded to access the present status of zooplankton population, their abundance and also its relation to water quality. Four important groups as Cladocera, Copepods, Protozoa and Rotifers mainly contributed to zooplankton population along the Ganges riverine system. The value of Shannon Weiner Diversity (H'), Evenness (J') and Simpson diversity indices indicated low to medium diversity of zooplanktons in the selected zones. Water temperature, water velocity and dissolved oxygen contributed as major influential ecological factors for zooplankton richness and their distribution in the Ganges riverine ecosystem.

Keywords: Zooplankton diversity, Abundance, Ganga River, Shannon Weiner index, Simpson index

The main stream of the river Ganga, the Bhagirathi originates from the ice cave of Gaumukh (33° 55'N, 79°07'E) at the snout of Gangotri glacier. The Alaknanda, the sister streams of Bhagirathi rise beyond Mana pass, 8 km from Badrinath (33° 44'N, 79° 29'E) joins at Devprayag. It is below this confluence; the united stream is known as Ganga River. The Ganges riverine ecosystem may be divided into three stretches: the upper stretch (from Gaumukh to Haridwar), the middle stretch (from Haridwar to Varanasi) and the lower stretch (from Varanasi to Ganga Sagar). These divisions reflect variations in geology, geomorphology, soil type, climate and socio-economic issues. The upper Ganga riverine system is flowing in the mountainous region of the Garhwal Himalaya. The lotic ecosystem of upper Ganges is characterized by cold water, high velocity, low temperature and distinct biodiversity with abundant rapids, runs, riffle and few deep pools. Zooplankton is important column tropic component in any aquatic ecosystems. Zooplankton are dependent on phytoplankton or algae for food and help to maintain the food chain in water body. Cladocerans Copepods, and Rotifers groups are the main components of zooplankton diversity in any aquatic ecosystem because of small lifespan, few weeks to a few months, marked fluctuations in the population diversity are evident in short periods of time. The experimental study of freshwater fauna mainly zooplankton, is very broad and complicated due to several factors like physical, geographical, environmental, chemical variations, extrinsic and intrinsic factors. Zooplankton plays a main role in preservation and continuation of ecological balance in any aquatic ecosystem. Fluctuations in the zooplankton diversity and its abundance are well known in any freshwater ecosystem. Zooplankton exhibits a seasonal bimodal oscillation varies from monsoon and post monsoon season in the lakes, rivers and reservoirs. This fluctuation in abundance of zooplankton communities is greatly influenced by the variations in the water temperature along with many other ecological factors. Zooplankton rapidly responds to any physical, chemical as well as biological changes in aquatic ecosystem, and can also indicate environmental disturbances as per Simoes et al (2012). So, these types of the commune provide a direct link between primary producers and higher tropic levels such as fish. All carnivorous fish species mainly depends upon the zooplankton for food and feeding from their larval phases to their entire life cycle (in some fish species) by Madin et al (2001). The physicochemical parameters of any water body play an important role in prevailing the assemblage of plankton which is the main as well as natural food source of many fish species. Water bodies exhibit high spatio-temporal variations in temperate and tropical regions that influence the distribution pattern and biodiversity Abhishek et al (2020), Singh et al (2020). Aquatic ecosystem, mainly in the form of rivers are one of the most threatened natural ecosystems worldwide, due to the various anthropogenic and natural calamities factors like damming (Nilsson et al 2005, Dudgeon et al 2006, Malik et al 2018). The main aim of the present research was to establish the relation between the diversity, abundance and biotic indices of zooplankton with water quality in Ganga River and its tributaries.

MATERIAL AND METHODS

Study area: The study was focused in the Ganga river system along with its two tributaries (Fig. 1-4) during 2017-2018. An extensive field survey was conducted for collecting the primary data. The study area was divided into four sampling zones and every zone has further three stations for the collection of hydrological parameters and zooplankton species.

Collection and preservation of samples: Monthly samples were collected from four sampling zones during September 2017 to August 2018 from the surface of the water as well as column of the river. Qualitative collections were done by towing surface water column and quantitative samples were collected by filtering 100 litres of water through a plankton net made bolting silk (No. 25), 62 µm mesh sizes. The collected samples were transferred to a clean polyethylene container which is about 250 ml capacity and preserved in 4% neutralized formaldehyde solution and containers were labelled.

Analysis of physico-chemical and biological parameters: Monthly physico-chemical parameters viz., water temperature, pH, TDS, Conductivity were recorded in the field with the help of digital electronic testers. Water samples were collected in clean polyethylene containers (1 litre) for estimation of the chemical parameters. Dissolved oxygen content was estimated through Winkler's method. Rest of physico-chemical parameters was analysed following standard methods APHA (2012).

Sedgwick–Rafter Cell method: The quantitative collection was estimated following the Sedgwick-Rafter cell method and the results were expressed in ind/L (Welch, 1948). The Sedgwick Rafter Cell is a special kind of slide similar to the Haemocytometer. The cell has a 50 mm x 20 mm x 10 mm rectangular cavity that holds 1 ml sample. The cell is moved in horizontal directions on the stage of an inverted microscope and planktonic species encountered in the field are enumerated. A number of replicate samples are enumerated to calculate plankton/ litre.

$$\text{No. of plankton/ml} = \frac{\text{No. of organism counted}}{\text{No. of replicates taken}}$$

$$\text{(Plankton/l)} = \frac{(a \times 1000)c}{L}$$

Where,

n= no. of plankton/ litre of water, a= Average number of plankton in one small counting chamber of S-R cell, c= ml of plankton concentrates, l=volume of original water filtered in litre

Identification: From the concentrated sample, the slides for the zooplankton were prepared. Then these slides were placed under a microscope, and the zooplankton was observed in 100 X in the binocular microscope. The images of the zooplanktons were captured by using a digital camera. Later on, the zooplankton was identified by using the Needham and Needham (1962).



Fig. 1. Sampling zone (Z1)



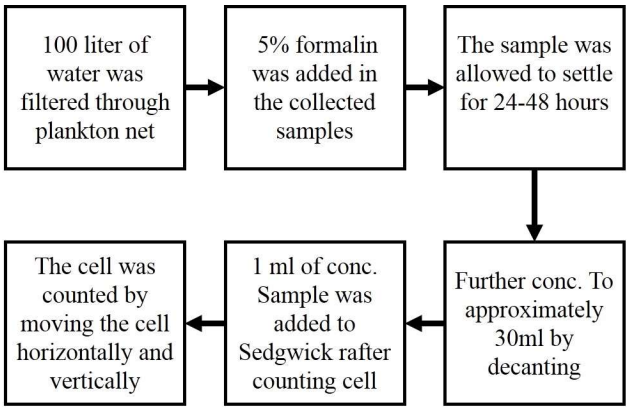
Fig. 2. Sampling zone (Z2)



Fig. 3. Sampling zone (Z3)



Fig. 4. Sampling zone (Z4)



Outline showing procedure for zooplankton analysis

Statistical and diversity indices

Species diversity (Shannon- Wiener index, H'), Evenness (e^H/S') and Simpson index (1-D) etc were analysed.

Shannon Weaver diversity index (H'): was calculated using the following formula:

$$(H) = \sum_{i=1} \left(\frac{n_i}{N}\right) Log\ 2\left(\frac{n_i}{N}\right)$$

Where,

H'= Shannon Diversity Index,

n_i= Total no of individuals of the species

N= Total no of individuals of all species

Species Evenness:

$(J') = H' / H'_{max}$

Where

H' = number of derived from the Shannon diversity index

H'_{max} = maximum possible value of H'. (If every species was equally likely, equal to:

$$H'_{max} = \sum_{i=1}^{S} \frac{1}{S} In 1/s = InS$$

Simpson's Diversity index:

(D) = Σ n (n-1)/ N(n-1)

Where,

n = total number of organisms of a particular species, N = total number of organisms of all species

Dominance: was calculated

$$D = \frac{\Sigma i\ ni\ (ni - 1)}{n\ (n - 1)}$$

where *ni* = number of individuals of taxon *i*.

Margalef diversity index: Margalef diversity index was calculated by using the formula

$$D = \frac{S - 1}{\log N}$$

Where, d = Margalef's diversity index, S = number of species, N = number of individuals

Menhinick's richness index: was calculated by using the formula

$$\frac{S}{\sqrt{N}}$$

Where, S = number of species, N = number of individuals

Equitability: Equitability was calculated by dividing Shannon diversity with logarithm of number of taxa.

Canonical Correspondence Analysis (CCA): CCA was performed using Paleontological Statistics (PAST, Version 3.06) and XLSTAT Software to determine relationship between zooplankton species and important physico-chemical parameters.

RESULTS AND DISCUSSION

Minimum water temperature was 10.9±0.14°C at Zone 1 during January where the maximum was 21.2±1.5°C at Zone 4 during July, it can be due to direct relationship between bright sunshine, its duration and air temperature. The maximum water temperature in summer season was recorded because of low water level, high air temperature. The maximum water temperature obtained in June and July due to the long photoperiod, excess of short wave radiation, fall in water level due to increased evaporation, rapid heat exchange as result of increase in day length, causes heating of atmosphere by Manjhare et al (2010); Sharma et al (2006). Maximum values of pH were in February and minimum in June and July during monsoon season and average of pH ranged from 7.2 to 8.2 due to the availability of many types of carbonates and bicarbonates in water which enhance dissolve carbon dioxide level by dissociation and acts as a raw material for photosynthesis. Maximum values of pH may be due to increase by bathing/washing activities in the Ganga river. Kumar et al (2018) reported that pH of water has an important impact on both plankton and microbial production. Alkaline nature of upper Ganga river, was also reported by Khanna et al (2012). Direct relation of pH value during winter season may be due to utilization of free carbon dioxide by phytoplankton in aquatic ecosystem. Minimum values of total dissolved solids were recorded from the month of January during winter season from all sampling zones. Maximum values of total dissolved solids were in monsoon season and highest peak was in month of August. Whereas annual average values of total dissolved solids ranged between 63.7 to 235 mg L^{-1}. Mishra et al (2003); Sharma et al (2018) reported total dissolved solids ranged between 32 mg L^{-1} to 299 mg L^{-1}in river Ganga and also reported by Rana et al (2016) in district Solan under different Land use. Maximum EC value was in monsoon season at zone 4, because of high influx of nutrients through the inlet and minimum value was in winter season at Zone 1. Electrical conductivity in selected sampling zones ranged from 109.0 to 369.8 μmhos/cm^2 during 2017-18. Similar trend about the electric conductivity was also reported by Sharma et al (2018) in the hill streams of Garhwal Himalaya. In Ganga River, water becomes turbid in all sampling zones starts from summer season and becomes very much turbid in the monsoon season. Maximum turbidity 395 ± 0.17 NTU was in August and minimum 52 ± 0.3 NTU in January. High turbidity during rainy season was due to the

Table 1. Geo-Coordinate of selected sampling zones

Sampling zone	Name	Geo-coordinates		Elevation
		Latitude	Longitude	
Zone 1	Upstream Ganga river (at Kaudiyala)	30° 6'14.05"N	78°23'3.10"E	1183 ft
Zone 2	Nayar River	30°08'12.69" N	78°23'17." E	1306 ft
Zone 3	Henval River	30° 7'19.66"N	78°23'2.76"E	1232 ft
Zone 4	Downstream Ganga river (at Shivpuri)	30°07'38.47" N	78°23'2.51" E	1360 ft

land drainage and resultant increase in particulate suspended matter in river. Minimum DO was in summer season because higher rate of decomposition of organic matter and limited flow of water and leading to consumption of oxygen. DO was ranged from 7.1 to 9.3 mg L^{-1} during the year 2017-18. Similar rise and fall of DO in winter and summer months was reported by Sharma et al (2006). BOD fluctuated between 1.0 to 2.06 mg L^{-1}during 2017-18. Highest BOD was in summer season due to high temperature favours microbial activity. Similar observation was reported by Bhadra et al (2005) along the Ganga river basin. Maximum free CO_2 was 4.2 mg L^{-1} in month of August during monsoon season at sampling zones Z4 due to high turbidity and water temperature whereas minimum 1.3 mg L^{-1} during winter season in month of February at sampling zones Z1 because in winter, water temperature was decreased and turbidity was lowest due to the decomposition of some substances and various metabolic activity of the living organisms. Similar trend was recorded by Kumar et al (2015) and Semy and Singh (2019). Barai and Kumar (2012) reported that the Ganga River contains maximum free CO_2 in rainy season. Four groups of zooplankton included Cladocera, Copepoda, Protozoa and Rotifera, were recorded in Ganga river basin and its tributaries. Five genera of Cladocera represent as *Bosmina sp., Ceriodaphnia sp., Chydorus sp., Daphnia sp.,* and *Monia sp*. were present. Four genera of Copepoda as *Pleuroxus sp., Cyclops sp., Mesocyclops sp.,* and *Diaptomus sp.,* were found. Three species of Protozoa as *Arcella sp., Vorticella sp.,* and *Zoothamnium sp.* were found. Three species of Rotifera as *Asplanchana sp., Keretella sp., Filinia sp.,* were present in selected sampling zones. The dominant genera were recorded as *Bosmina sp., Ceriodaphnia sp., Pleuroxus sp., Cyclops sp., Mesocyclops sp.,* and *Diaptomus sp*. Cladocera reach their maximum during winter (January) when the water temperature ranges from 10-13ºC. The population decreased during monsoon when the temperature found Higher and water velocity also reaches higher. Cladocera was observed maximum 210 unit/l in zone 2 and minimum 112 unit/l at zone 4. Copepoda was observed maximum 219unit/l in zone 3 and minimum 114unit/l at zone 4. Protozoa was observed maximum 86 unit/l in zone 2 and minimum 38 unit/l was observed at zone 4 and Rotifera was observed maximum 112 unit/l in zone 2 and minimum 170 unit/l at zone 4 during 2017-2018. Cladocera were dominant

Table 2. Seasonal variation in physico-chemical parameters of Ganga River at zone 1 and Zone 2 during 2017-2018

Zones/Parameters	Zone 1			Zone 2		
	Pre-monsoon	Monsoon	Post-monsoon	Pre-monsoon	Monsoon	Post-monsoon
Water temperature (^{0}C)	16.2±2.26	19.6±0.75	12.78±2.24	16.38±2.27	19.23±1.53	12.66±1.99
pH	7.52±0.25	7.4±0.20	7.84±0.27	7.55±0.17	7.33±0.15	7.78±0.16
TDS (mg L^{-1})	92.57±5.25	214.7±18.00	116.9±64.17	91.65±5.15	208.40±15.08	113.1±65.89
Conductivity	144±6.38	336.7±25.17	185.2±99.19	142.00±8.52	329.33±17.62	179.6±101.15
Turbidity (NTU)	81.5±5.74	281.7±104.31	147.3±97.78	83.75±7.63	281.43±97.61	149.52±93.27
DO (mg L^{-1})	7.87±0.60	7.7±0.21	8.56±0.53	7.95±0.58	7.70±0.10	8.58±0.51
BOD (mg L^{-1})	2.15±0.53	2.4±0.12	1.52±0.43	2.23±0.43	2.33±0.12	1.56±0.40
Free CO_2(mg L^{-1})	2.35±0.65	3.3±0.74	1.78±0.37	2.40±0.73	3.37±0.67	1.86±0.34

Table 3. Seasonal variation in physico-chemical parameters of Ganga River at zone 3 and Zone 4 during 2017-2018

Zones/Parameters	Zone 3			Zone 4		
	Pre-monsoon	Monsoon	Post-monsoon	Pre-monsoon	Monsoon	Post-monsoon
Water temperature (^{0}C)	15.35±1.94	19.10±2.03	12.24±1.99	16.53±2.50	19.87±1.74	13.6±1.98
pH	7.625±0.15	7.40±0.10	7.78±0.19	7.58±0.25	7.43±0.06	7.64±0.25
TDS (mg L^{-1})	93±3.75	212.57±14.59	115.68±66.83	93.58±7.87	217.43±18.36	118.92±64.40
Conductivity	142.95±7.47	330.97±17.32	185.76±99.04	145.18±8.13	342.40±28.34	189.52±99.69
Turbidity (NTU)	81.025±7.75	272.80±88.31	142.84±78.56	91.75±5.60	260.70±58.28	162.72±208.35
DO (mg L^{-1})	7.9±0.59	7.73±0.21	8.4±0.42	7.78±0.74	7.60±0.20	8.32±0.48
BOD (mg L^{-1})	2.15±0.29	2.43±0.12	1.54±0.42	2.13±0.57	2.53±0.06	1.58±0.40
Free CO_2(mg L^{-1})	2.525±0.56	3.53±0.55	2.04±0.36	2.55±0.73	3.47±1.02	1.92±0.40

among zooplankton during summer might be due to optimal thermal and nutritional conditions and lower concentration of oxygen in river reported by Ojha et al (2007); Sharma et al (2019). Few ecological studies also suggested that increase in zooplankton diversity was found to be highest in summer and lowest in winter in flow riverine system described by Tripathi et al (2006). The values of diversity indices were calculated according to month and stations (Table 5). Highest Dominance index (D) (0.0816) was in Zone 3 and lowest (0.0700) in zone 1. Higher Simpson index was in January (0.9275) and low in June (0.916). Highest Shannon index (H) (2.682) was in Zone 1 and lowest (2.59) in zone 3. Shannon index (H) was high in January (2.666) where low in May (2.546). Shannon index ranged from 2.546 to 2.666 indicated

Table 4. Temporal and spatial species abundance of zooplankton in Ganga River and its tributaries during 2017-2018

Code	species	No.	%	Z1	Z 2	Z3	Z4	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug
Cladocera																			
Z1	*Bosmina sp.*	176	9.342	28	62	51	35	8	11	12	14	31	26	17	13	10	15	10	9
Z2	*Ceriodaphnia sp.*	160	8.493	32	50	49	29	12	14	21	13	24	12	14	13	15	10	5	7
Z3	*Chydorus sp.*	124	6.582	26	48	30	20	5	6	13	13	17	13	10	11	12	7	10	7
Z4	*Daphnia sp.*	75	3.981	27	14	19	15	8	6	7	10	13	5	6	6	3	6	3	2
Z5	*Moina sp.*	87	4.618	22	36	16	13	5	2	3	6	17	14	12	7	5	6	5	5
	Total	622	33.016	135	210	165	112	38	39	56	56	102	70	59	50	45	44	33	30
Copepoda																			
Z6	*Pleuroxus sp.*	162	8.599	32	49	57	24	11	12	18	18	21	23	15	12	11	7	5	9
Z7	*Cyclops sp.*	183	9.713	38	52	61	32	9	15	18	16	25	22	16	18	12	9	13	10
Z8	*Mesocylops sp.*	162	8.599	25	51	54	32	5	12	16	21	18	19	18	16	10	10	9	8
Z9	*Diaptomus sp.*	132	7.006	24	35	47	26	10	9	13	15	14	16	13	12	8	6	8	8
	Total	639	33.917	119	187	219	114	35	48	65	70	78	80	62	58	41	32	35	35
Protozoa																			
Z10	*Arcella sp.*	86	4.565	16	26	28	16	7	6	8	9	14	8	6	7	3	7	5	6
Z11	*Vorticella sp.*	80	4.246	25	29	16	10	6	7	5	2	12	14	9	7	4	4	7	3
Z12	*Zoothamnium sp.*	77	4.087	19	31	15	12	4	7	9	6	12	14	8	6	4	3	2	2
	Total	243	12.898	60	86	59	38	17	20	22	17	38	36	23	20	11	14	14	11
Rotifera																			
Z13	*Asplanchana sp.*	71	3.769	16	25	17	13	12	10	7	6	15	6	5	3	1	2	1	3
Z14	*Keretella sp.*	122	6.476	25	39	34	24	16	8	10	11	20	16	12	8	5	8	5	3
Z15	*Filinia sp.*	187	9.926	29	58	64	36	14	12	20	21	25	21	17	14	12	13	11	7
	Total	380	20.171	70	122	115	73	42	30	37	38	60	43	34	25	18	23	17	13
Grand total		1884	100.00	384	605	558	337	132	137	180	181	278	229	178	153	115	113	99	89

Table 5. Temporal and spatial variation in diversity indices of zooplankton in Ganga River and its tributaries during 2017-2018

	Z1	Z 2	Z3	Z4	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug
Individuals	384	605	558	337	132	137	180	181	278	229	178	153	115	113	99	89
Dominance_D	0.0700	0.0739	0.0816	0.0766	0.0772	0.0761	0.0803	0.0804	0.0725	0.0768	0.0750	0.0775	0.0864	0.0801	0.0839	0.0799
Simpson_1-D	0.9299	0.9261	0.9184	0.9234	0.9228	0.9239	0.9196	0.9196	0.9275	0.9232	0.9249	0.9225	0.9136	0.9199	0.916	0.9201
Shannon_H	2.682	2.65	2.59	2.631	2.629	2.63	2.6	2.594	2.666	2.626	2.641	2.623	2.546	2.606	2.568	2.599
Evenness_e ^H/S	0.9746	0.9434	0.8888	0.9262	0.9243	0.925	0.8973	0.8926	0.9587	0.9216	0.9352	0.9185	0.8501	0.9026	0.869	0.8968
Menhinick	0.7655	0.6098	0.635	0.8171	1.306	1.282	1.118	1.115	0.8996	0.9912	1.124	1.213	1.399	1.411	1.508	1.59
Margalef	2.353	2.186	2.214	2.405	2.867	2.846	2.696	2.693	2.488	2.577	2.702	2.783	2.951	2.961	3.047	3.119
Equitability_J	0.9905	0.9785	0.9565	0.9717	0.9709	0.9712	0.96	0.9581	0.9844	0.9699	0.9753	0.9686	0.94	0.9621	0.9481	0.9598

Table 6. CCA biplot scores of habitat ecological parameters and zooplankton species at Ganga River and its tributaries during 2017-2018

	September 2017 to August 2018			September 2017 to August 2018	
	Axis 1	Axis 2		Axis 1	Axis 2
Z1	-0.364	-1.038	Zone 1	0.199	0.131
Z2	-0.170	0.114	Zone 2	0.071	-0.131
Z3	0.852	-1.089	Zone 3	-0.171	0.042
Z4	1.415	3.817	Zone 4	-0.071	0.015
Z5	1.956	-1.139	Water temperature	0.299	-0.027
Z6	-0.513	0.373	Turbidity	-0.042	-0.142
Z7	-0.412	0.718	DO	0.608	-0.168
Z8	-0.934	-0.399	BOD	-0.614	-0.605
Z9	-1.033	0.757	Water velocity	0.763	0.749
Z10	-0.541	0.155	Eigen value	0.019	0.010
Z11	2.329	0.416	Percentage of variance	62.700	30.980
Z12	1.730	-1.012			
Z13	0.825	-0.376			
Z14	0.095	-0.017			
Z15	-1.003	-0.293			

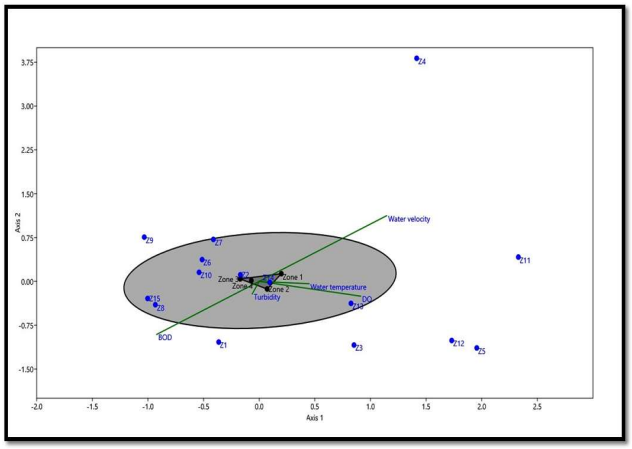


Fig. 6. CCA biplot of habitat ecological parameters and zooplankton species during 2017-2018

low to medium diversity of zooplankton. Highest evenness was (0.9587) in January and lowest (0.8501) in May. Highest Menhinick index (0.8171) was in Zone 4 and lowest (0.6098) was in zone 2. Higher Margalef index was in August (3.119) where low in January (2.488). Highest Equitability index (J) (0.9905) was in Zone 1 and lowest (0.9565) in zone 3. No significant difference was found in the mean value of diversity indices value among the months and zones.

CCA analysis of species abundance and water parameters: The results obtained from first two axis were plotted in (Fig. 6 and Table 6). The vector length of a given variable indicates the importance of the variable in CCA analysis and the longest vector of water velocity showed significant correlation with zone Z1. Vector length of dissolved oxygen showed significant with zone Z2 where water temperature showed significant relation with zone Z1. High values of water velocity are associated with *Keretella sp., Amphora sp.* High values of DO are positive correlated with *Asplanchana sp.* High values of water temperature are positive correlated with *Keretella sp*. High values of BOD are positive correlated with *Bosmina sp., Ceriodaphnia sp., Mesocyclpos sp.* and *Keretella sp.* Eigen value of axis 1 (0.019) explained 62.70% relationship between environmental parameters and zooplankton community. Whereas, Eigen value of axis 2 (0.010) explained 30.98% relationship during 2017-2018.

CONCLUSION

The present research study revealed that, the distribution and diversity of zooplankton generally depends upon the physico-chemical parameters prevailing in the environment. The result indicates that the maximum number of genera occurred during winter season than summer and monsoon season. In winter, the biotic interaction operating through feeding pressure rather than water quality it seems to affect the zooplankton diversity and density particularly the stocked fish species play an important role in harvesting species of Copepoda and Cladocera, thereby reducing their predatory pressure on other groups. The rotifers and particle feeder Cladocera were higher in winter can be linked to

favourable temperature and availability of abundant food in the form of bacteria, nanoplankton and suspended detritus. The population of Copepods was more diverse than Cladocerans, Rotifer and Protozoan's. The copepods were numerically abundant than Rotifers and Cladocerans during the study period in Ganga river and its tributaries.

REFERENCES

Abhishek N, Naveen K, Yadav SS, Rao AS, Singh N and Gulia SS 2020. Water quality assessment of pond water of Kalanaur Block, Rohtak, Haryana. *Indian Journal of Ecology* **47**(1): 1-6

APHA 2012. *Standared methods for the examination of water and wasteland*. 22th edition. Am. Public health Association Washington, D C, p 450.

Barai SR and Kumar S 2012. Evaluation of the physico- chemical characteristics of river Varuna at Varanasi, India. *Journal of Environmental Biology* **34**: 259-265.

Bhadra B, Mukherjee S, Chakraborty R and Nanda K 2005. Physico-chemical and bacteriological investigation on the river Torsa of North Bengal. *Journal of Environmental Biology* **24**(2): 125-133.

Dudgeon D, Arthington AH, Gessner MO, Kawabata ZI, Knowler DJ, Leveque C, Naiman RJ, Prieur- Richard AH, Soto D, Stiassny MLJ and Sullivan CA 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews of the Cambridge Philosophical Society* **81**: 163-182.

Khanna DR, Bhutiani R, Matta G, Singh V and Ishaq F 2012. Physico-chemical and microbiological status of River Asan in Dehradun Uttarakhand. *Environment Conservation Journal* **13**(1&2): 145-150.

Kumar A, Singhand C and Saini P 2015. Seasonal variation in physico-chemical and microbiological analysis of sewage water in Gwalior City, India. *Indian Journal of Ecology* **42**(1): 279-281.

Kumar V, Malik DS and Sharma AK 2018. Study on distribution pattern of benthic diversity in relation to water quality of river Ganga and its tributaries. *Journal of Emerging Technologies and Innovative Research* **5**(5): 88-103.

Madin LP, Horgan EF and Steinberg DK 2001. Zooplankton at the Bermuda Atlantic Time Series Study (BATS) station: Diel, seasonal and interannual variation in biomass 1994-1998. *Deep Sea Research* **48**: 2063-2082.

Malik DS, Sharma AK and Bargali H 2018. Status of phytoplankton diversity in relation to water quality of Bhagirathi riverine system in Garhwal Himalaya. *International Journal of Advanced Science and Research* **3**(1): 30-37.

Manjare SA, Vhanalaker SA and Muley DV 2010. Analysis of water quality using physico-chemical parameters Tamdalge tank in Kohlapur district, Maharashtra. *International Journal of Advance Biotechnology and research* **1**(2): 115-119.

Mishra S and Joshi BD 2003. Assessment of water quality with few selected parameters of River Ganga at Hardwar. *Himalayan Journal Environment and Zoology* **17**(2):113-122.

Needham JG and Needham PR 1962. *A guide to the study of freshwater biology*, 5th edn. Holden Inc., San Francisco, USA, p 250.

Nilsson C, Reidy C, Dynesius M and Revenga C 2005. Fragmentation and flow regulation of the world's large river systems. *Science* **308**: 405-408.

Ojha P, Mandloi AK and Dube KK 2007. Diel variations of physico-chemical parameters influence zooplanktons fluctuations in a small irrigation reservoir Bamoo Jabalpur, M. P. *Journal Natcon* **19**(2): 375-385.

Rana A, Bhardwaj SK and Thakur M 2016 Surface water quality and associated aquatic insect fauna under different land-uses in Solan (District Solan) Himachal Pradesh, India. *Indian Journal of Ecology* **43**(1): 58-64.

Semy K and Singh MR 2019. Assessment on the water quality of Tsurang River, Nagaland affected by coal mining drainage India. *Indian Journal of Ecology* **46**(4): 845-849.

Sharma AK, Malik DS and Bargali H 2018. Food and feeding habits of *Schizothorax richardsonii* (Gray 1832) inhibiting Bhagirathi River Tehri Garhwal, India. *International Journal of Recent Scientific Research* **9**(4): 25562-25565.

Sharma AK, Malik DS and Bargali H 2018. Present status of fish diversity and population abundance of selected fish species in Bhagirathi river at Uttarakhand. *International Journal of Creative Research Thoughts* **6**(1): 432-438.

Sharma MP, Sharma S, Goel V, Sharma P and Kumar A 2006. Water quality assessment of Behta River using benthic macro invertebrates. *Life Science Journal* **3**(4): 68-74.

Sharma AK, Malik DS, Tyagi D 2019. Food and feeding habits of *Tor tor* (Hamilton, 1822) and *Schizothorax richardsonii* (Gary, 1832) inhibiting Bhagirathi river Tehri Garhwal, India. *International journal of Science and Nature* **10**(1): 97-103.

Simoes N, Lansac-Toha F, Velho L and Bonecker C 2012. Intra and inter-annual structure of zooplankton communities in floodplain lakes: A long-term ecological research study. *Revista de Biologia Tropical* **60**: 1819-1836.

Singh M and Parikh P 2020. Freshwater Diatoms as Bio-Indicators in Urban Wetlands of Central Gujarat, India. *Indian Journal of Ecology* **47**(1): 7-11.

Tripathi RB, Singh I and Tiwari DD 2006. Qualitative and quantitative study of zooplankton in Seetawar Lake of Shravasti UP, India. *Flora and Fauna* **12**(1): 37-40.

Welch PS 1948. *Limnological methods.* The Blakiston Co, Philadelphi, p 381.

Received 28 May, 2020; Accepted 19 August, 2020

Indian Journal of Ecology (2020) 47(3): 746-750

Manuscript Number: 3077
NAAS Rating: 4.96

Seasonal Variation of Physicochemical Parameters of Aquaculture Ponds in District Karimganj, Assam

Piyali Das and Mithra Dey

Department of Ecology and Environmental Science
Assam University, Silchar-788 011, India
E-mail: daspiyali0047@gmail.com

Abstract: In the present study seasonal variation of physicochemical parameters of water from different aquaculture ponds of Badarpur, Assam were done during February 2018 to January 2019 for analysis of water quality. The parameters were compared as per WHO , BIS standards,. With the exception of pH, all the parameters varied significantly in four sampling seasons. Pearson's correlation was used to determine the relation among different parameters. The results of all the physico-chemical parameters measured were within the recommended limits of national and international standards. Constant monitoring of different physicochemical parameters of water is necessary for improving the productivity of aquaculture ponds.

Keywords: Water quality, Aquaculture, Physico-chemical parameters

The productivity of fish depends upon the water quality of fresh water fish aqua culture ponds. The physico-chemical condition of water in fish culture mostly depends on the regional climatic condition and geographical condition of the area that is affected by biotic factors (Shinde et al 2011). Water quality indicates the chemical, physical, biological, and radiological characteristics of water (Diersing 2009). Study of physicochemical parameters of water helps to determine the suitability of ponds water for artificial fish culture. Water quality generally signifies the components of water which must be present for optimum growth of aquatic organisms (Saha et al 2017). The determinant of good growth in water body includes pH, conductivity, dissolved oxygen, hardness, alkalinity, temperature, free CO_2 and contents of chloride, phosphate, nitrate and potassium etc. Different studies were carried out regarding the seasonal variation physicochemical parameters of water from ponds as well as other water bodies in different areas (Kumar et al 2017, Nasim 2017, Adedeji et al 2018). However, Joshua et al (2018) reported seasonal variation of physicochemical parameters in river Asu, Nigeria. A study was also carried out regarding the seasonal variation domestic water supplies in system tank by Ragunath and Sundar (2018). Meanwhile, limited reports are available regarding the physicochemical parameters of aquaculture ponds. A large number of aquaculture ponds engaged in commercial fish production were present in Karimganj district but such culturist are not so much conscious regarding the water quality management studies which will help them to increase the productivity of fish culture. Optimum fish production is dependent on physical, chemical and biological quality of water to a great extent (Bhatnagar and Devi 2013). The present study therefore investigates the seasonal variation of physicochemical parameter of water from selected Aquaculture ponds of Badarpur, Karimganj district, Assam.

MATERIAL AND METHODS

Description of study site: The study area is within Badarpur Block of Karimganj district. Karimganj is one of the three districts of Barak Valley, located in the Southern region of Assam, Northeast India. The geographical location of the Karimganj District in between longitudes 92^0 15′& 92^0 35′East and latitudes 24^0 15′& 25^0 55′North. For this study a survey was undertaken and six different aquaculture ponds of Badarpur, which are the major sources of fishes in this region, were selected.

Sampling and methods: Water samples were collected monthly from March, 2018 to February, 2019 from the above mentioned ponds in plastic bottles, each of two liter size. The containers were properly washed with diluted hydrochloric acid and then rinsed with normal water followed by distilled water and then with sample water. Temperature of water (WT) was measured by using mercury bulb thermometer. pH was measured with a pH meter (Systronics). Conductivity was measured by conductivity meter (Systronics). Total alkalinity (TA) was measured titrimetrically against .01 N HCl (APHA, 2005). Dissolved oxygen (DO) was estimated by Winkler Method, fixation of sample was done in the field using magnesium sulphate and potassium iodide. Free Carbon dioxide (FCO_2) was measured by titrating against 0.05 N

sodium hydroxide using phenolphthalein indicators (APHA, 2005). Hardness was measured titrimetrically against EDTA. Nutrients like Nitrate and phosphate was estimated by using the Spectrophotometer UV and Visible Spectrophotometer (Systronics).

RESULTS AND DISCUSSION

The highest mean air temperature was in monsoon (34.09°C) while the lowest in winter (23.73°C). Water temperature also indicated the same trend. The results were also within the standards WHO and BIS**.** The most favorable water temperature for fish viability has been reported to be between 20-30°C (Ani et al 2016, Hemlata et al 2013 and Prameena et al 2016).

The highest value of pH was in winter (7.41) and lowest was recorded during monsoon (6.72).The pH value of water for all the seasons were within the safe limits as set for protection of aquatic life by USEPA, BIS and WHO. Sandhya and Benerjee (2016) reported the acceptable range of pH for fish production 6.5 to 9.0. The pH value in water was more or less uniform in different seasons throughout the study period. The low value during monsoon season may be due to the dilution of rain water. The results of the study were in accordance with Jesu et al (2013), Shobana et al (2014). The highest conductivity was during post monsoon (110.3 μscm^{-1}) and lowest during monsoon (78.90 μscm^{-1}). Hulyal et al (2011), Ramulu et al (2013), Dinesh et al (2017) also reported similar trend during their study. The values of conductivity for all the seasons were within the acceptable limit set by FAO.

The maximum value of DO was observed during winter (8.29 mgl^{-1}) and minimum during monsoon (5.94 mgl^{-1}). The value of DO was slightly lower than the recommended value of WHO. Similar result for dissolved oxygen was also reported by Adedeji et al (2018). During the present study, the highest values of dissolved oxygen were recorded during winter season. These findings were in accordance with the report of Idowu et al (2013) from Ado-Ekiti reservoir. Lewis (2002) observed that at higher temperature the rate of microbial metabolism increases and the level of dissolved oxygen decreases as compared to water with lower temperature. The higher level of nutrient load and other factors caused lower level of DO (Mahananda et al 2010). The free CO_2 was minimum during winter (11.78 mgl^{-1}) and maximum during monsoon (21.60 mgl^{-1}). Hynes (1970) reported 25 mgl^{-1} of free CO2 as upper limit for fish culture. In present investigation highest level of free carbon-dioxide during monsoon may be due to the maximum decomposition of organic matter and the respiration of aquatic flora and fauna at high temperature, however minimum free carbon dioxide during winter is probably due to a decrease in the photosynthetic activity of aquatic flora at low temperature as reported by Harney et al (2013). Gonjari and Patil (2008) observed that the level of free carbon-dioxide was maximum during summer and minimum during winter while studying at Triputi reservoir near Satara, Maharashtra. The alkalinity was maximum during winter (46.85 mgl^{-1}) and minimum during monsoon (34.65 mgl^{-1}). Ehiagbonare and Ogunrinde (2010) reported Alkalinity values of between 35mgl^{-1} and 135mgl^{-1} for fish pond water. The values of alkalinity in all the seasons were within the desirable limit set for aquatic life. Highest total alkalinity value observed during winter season may be due to dissolution of carbon dioxide present in soil region and forms carbonic acid, which leads to reaction between the weathered rock and acidic water, results in to increase in leached ions into the solution and makes water alkaline. Similar observations on total alkalinity during winter season were observed by Naser (2006). Dinesh et al (2017) reported that low alkalinity during the monsoon season may be because of dilution due to rain water.

The mean values of hardness were maximum during

Table 1. General features of six studied aquaculture ponds

Fish pond	Location	Surface area (m^2)	Depth appx. (cm)	Source of water	Fish species cultured during study period
Pond1	Alakergul area of southern Badarpur	12500	300	Rain water, surface run off, Deuchaprabeel	*Labeorohita, Catlacatla, Mrigala*, *Labeobata, Heteropneuste sfossilis,*
Pond2	Nayagram area of Badarpur	16400	100	Rain water, surface run off, Deuchaprabeel	*Labeo rohita, Catla catla, Cyprinus carpio*, *Ctenophryng odonidella, Heteropneustes fossilis*
Pond3	Bogligul area of Badarpur.	5600	150	Rain water, surface run off	*Tilapia sp*, *Pangasiussuchi*, *Labe orohita, Catla catla, Mrigala*, *Cyprinus carpio, Ctenophryng odonidella.*
Pond4	Jumbosti area of Badarpur	4200	200	Rain water, surface run off	*Labeo rohita, Catla catla, Mrigala*, *Labe obata, Clarious batracus.Ctenophryng odonidella.*
Pond5	Bogligul area of Badarpur.	8400	300	Rain water, surface run off	*Labeo rohita, Catla catla, Mrigala*, *Labeo bata, Clarious batracus. Tilapia sp.*
Pond6	Nayagram area of Badarpur	7000	100	Rain water, surface run off Deuchaprabeel	*Channa, Labeo rohita, Catla catla, Cyprinus carpio. Heteropneustes fossilis*

winter (83.13 mgl^{-1}) and minimum during monsoon (34.65 mgl^{-1}). According to Guidelines for Water Quality Management for fish culture in Tripura, the ideal value of hardness for fish culture is 30-180 ppm. The values of hardness in all the seasons were within the desirable limit set for aquatic life. In the present study the total hardness content in water recorded higher during winter season was due to leaching of materials rocks and dissolution in waters. Naser (2006) also reported similar results during their study. The nitrate concentration was maximum during monsoon (0.93mgl^{-1}) and minimum during pre-monsoon (0.43 mgl^{-1}). The values for all the seasons were lower than the maximum permissible limit of 10 mgl^{-1}. The low concentration of nitrate might be due to absence of eutrophication. However, this finding is in accordance with the findings of Ehiagbonare and Ogunrinde (2010) who reported nitrate value between 2.21mgl^{-1} and 4.91mgl^{-1}. In the present investigation, maximum concentration of nitrate was recorded during the monsoon and minimum during the winter season. Khabade et al (2002) reported the maximum nitrate during monsoon season and minimum during the winter season in site-II of Lodhe water reservoir of Tasgaontahsil, Maharashtra. Jakher and Rawat (2003) also observed the maximum level during the monsoon season and minimum during the winter season in a tropical lake of Jodhpur, Rajasthan. The phosphate level was maximum during monsoon (0.74 mgl^{-1}) and minimum during winter (0.34 mgl^{-1}). However, this finding is in agreement with the work of Ehiagbonare and Ogunrinde (2010) also reported phosphate values ranges between 1.40mgl^{-1} and 4.51mgl^{-1}. This low values of phosphate may be due to the type of fish feed introduced into the pond or surface run off, and could also be from the building materials used in the construction of the ponds.

With the exception of water pH that showed no significant variations at ($p< 0.05$), all other parameters showed significant variations in different sampling seasons

Table 2. Physicochemical parameters of aquaculture ponds in four sampling seasons

Parameters	Pre monsoon	Monsoon	Post monsoon	Winter	WHO standard	BIS standard	CD
Air temperature	30.44 ± 0.48^{a}	34.09 ± 0.63^{bx}	31.13 ± 0.36^{c}	23.73 ± 0.55^{dy}	-	-	0.36
Water temperature	23.62 ± 0.78^{a}	25.69 ± 0.40^{bx}	22.92 ± 0.84^{c}	19.53 ± 0.67^{dy}	-	-	0.48
pH	6.91 ± 0.33^{a}	6.72 ± 0.35^{ay}	6.88 ± 0.25^{a}	7.01 ± 0.36^{ax}	6.5-9.5	6.5-8.5	0.20
Conductivity(µs cm^{-1})	92.38 ± 3.86^{a}	78.90 ± 5.9^{by}	110.3 ± 10.23^{cx}	87.01 ± 5.86^{d}	500	-	4.86
TA (mg l^{-1})	41.39 ± 7.8^{a}	34.16 ± 5.02^{by}	39.25 ± 4.74^{a}	46.85 ± 7.35^{cx}	200	200	4.50
DO (mg l^{-1})	6.28 ± 0.92^{a}	5.94 ± 0.99^{ay}	6.73 ± 0.49^{a}	8.29 ± 1.02^{bx}	8-10	6	0.62
Hardness (mg l^{-1})	44.05 ± 8.51^{a}	34.65 ± 6.67^{by}	58.53 ± 10.47^{c}	83.13 ± 13.2^{dx}	300		8.89
Free CO_2 (mg l^{-1})	16.34 ± 5.6^{a}	21.60 ± 6.72^{bx}	12.38 ± 4.61^{ac}	11.77 ± 4.52^{cy}	-	-	4.01
Nitrate (mg l^{-1})	0.43 ± 0.12^{ay}	0.93 ± 0.46^{bx}	0.57 ± 0.20^{a}	0.47 ± 0.18^{a}	50	45	0.19
Phosphate (mg l^{-1})	0.65 ± 0.40^{ab}	0.74 ± 0.63^{ax}	0.57 ± 0.36^{b}	0.34 ± 0.27^{cy}	-	-	0.12

The different letters (a, b, c, d) represent significant differences ($P < 0.05$) of physicochemical parameters between sampling seasons. The letters x and y represents highest and lowest value of physicochemical parameters among different sampling season. WHO-World Health Organization, BIS-Bureau of Indian standards, CD-Critical Difference

Table 3. Correlation matrix among different physico- chemical parameters

	Air temperature	Water temperature	pH	Conductivity	Alkalinity	DO	free CO_2	Hardness	Nitrate	Phosphate
Air temperature	1									
Water temperature	0.31	1								
pH	-0.36	-0.15	1							
Con	0.65*	0.75*	0.67*	1						
Alkalinity	-0.20	-0.26	0.58*	-0.49	1					
DO	-0.77*	-0.50*	0.33	0.79*	0.40	1				
free Co2	-0.34	-0.46	-0.003	0.079	0.09	-0.53	1			
Hardness	0.25	-0.43	0.64*	-0.20	0.05	-0.05	-0.41	1		
Nitrate	-0.05	0.018	-0.33	0.07	-0.35	0.47	-0.62*	0.31	1	
Phosphate	-0.08	-0.33	0.28	-0.55	-0.19	0.011	-0.10	0.74*	0.43	1

(Table 2). Air temperature and water temperature correlated positively with conductivity) and negatively with DO and free CO_2) (Table 3). pH shows positive correlation with total alkalinity and hardness. It also shows significant positive correlation with conductivity) and low negative correlation with nitrate. Electrical conductivity showed positive correlation with DO and negative correlation with phosphate. DO showed negative correlation with free CO_2 and positive correlation with nitrate. Hardness showed positive correlation with phosphate. Free CO_2 showed negative correlation with nitrate and nitrate showed significant positive relation with phosphate.

CONCLUSION

Analysis of water quality is an integral part for determining the environmental condition which is important to maintain balanced environmental health. The characteristics of water bodies are influenced by seasonal variations. A clear knowledge of the physicochemical parameters of water is very important in order to determine its suitability for use. The study of different physico-chemical parameters is very important for understanding the metabolic activities in aquatic ecosystem. Present investigation provides a data for the conservation and monitoring of the fish culture ponds of Badarpur. In this study, it can be concluded that there are marked seasonal variation of different parameters in ponds. The physico-chemical parameters of the water samples from ponds were fall within the desirable range of national and international standards. Hence the fish culture ponds can be considered as a good, stable and healthy aquatic ecosystem and suitable for increased fish productivity.

REFERENCES

Acharya GD, Hathi MV, Patel AD and Parmar KC 2008. Chemical properties of groundwater in Bhiloda Taluka Region, North Gujarat India. *Journal of Chemistry* **5**(4): 792-796.

Adedeji HA, Idowu TA, Usman MA and Sogbesan OA 2018. Seasonal variations in the Physico-chemical parameters of Lake Ribadu, Adamawa state Nigeria. *International Journal of Fisheries and Aquatic Studies* **7**(1): 79-82.

American Public Health Association 2005. *Standard methods for the examination of water and wastewater.* American Public Health Association, American Water Works and Water Pollution Control Federation 20th Edition. Washington DC, USA.

Ani C, Okogwu OI, Nwonumara GN, Nwani CD and Nwinyimagu AJ 2016. Evaluation of physicochemical parameters of selected rivers in Ebonyi State, Southeast, Nigeria. *Greener Journal of Biological Sciences* **6**(2): 34-41.

Bhatnagar A and Devi P 2013. Water quality guidance for the management of pond fish culture. *International Journal of Environmental Science* **3**(6): 801-993.

Diersing N 2009. *Water quality: Frequently asked questions.* Florida Brooks National Marine Sanctuary, Key West.

Dinesh KG, Karthik M and Rajakumar R 2017. Study of seasonal water quality assessment and fish pond conservation in Thanjavur, Tamil Nadu India. *Journal of Entomology and Zoology Studies* **5**(4): 1232-1238.

Ehiagbonare JE and Ogunrinde YO 2010. Physicochemical analysis of fish pond in okada and its environs, Nigeria. *African Journal of Biotechnology* **9**(36): 5922-5928.

Gonjari GR and Patil RB 2008. Hydro biological studies on Triputi reservoir near Satara, Maharastra. *Journal of Aquatic Biology* **23**(2): 73-77.

Harney NV, Dhamani AA and Andrew RJ 2013. Seasonal variations in the physico-chemical parameters of pindavani pond of central India. *Weekly Science* **1**(6): 2321-7871.

Hemlata M 2013. Study of physico-chemical characteristics of water ponds of Rajnandgaon Town, Chhattisgarh. *International Journal of Scientific & Engineering Research* **4**(8): 738-748.

Hulyal SB and Kaliwal BB 2011. Seasonal variations in physico-chemical characteristics of almatti reservoir of Bijapur district, Karnataka State. *Indian Journal of Environmental Protection* **1**(1): 58-67.

ICMR 1975. Manual of standard of quality for drinking water supplies. *Indian Council of Medical Research* **44**(2): 27.

Idowu EO, Ugwumba AA, Edward JB and Oso JA 2013.Study of the seasonal variation in the physico-chemical parameters of a tropical reservoir. *Greener Journal of Physical Sciences* **3**(4): 142-148.

Jain CK and Seethapati PV 1996. Limnological studies of kay Amkula Lake. *Indian Journal of Environment Protection* **16**(3): 61-68.

Jakher GR and Rawat M 2003. Studies on physico-chemical parameters of a tropical lake, Jodhpur, Rajasthan. *Indian Journal of Aquatic Biology* **18**(2): 79-83.

Jesu A, Prabudoss Kumar L and Dheenadayalan MS 2013. Environmental impact of ground water in Dindigul District Tamil Nadu, India. *Research and Reviews Journal of Engineering and Technology* **2**(2): 26-32.

Joshua NA, Idumah OO, Nkwuda NG and Chijioke A 2018. Seasonal variation in physicochemical parameters and its relationship with zooplankton abundance in river Asu, Nigeria *Indian Journal of Ecology* **45**(1): 60-65.

Jonassen TM, Sland AK and Stefansson SO 1999. The interaction of temperature and size on growth of juvenile Atlantic Halibut. *Journal of Fish Biology* **54**(3): 556-572.

Lewis WM 2002. Basis for the protection and management of tropical Lakes. *Lakes and Reservoirs* **5**(1): 35-48.

Nasim AA 2017. Seasonal variations in physicochemical characteristics of water samples of surajpur wetland, national capital region, India. *International Journal of Current Microbiology and Applied Science* **6**(2): 971-987.

Ogbeibu AE and Victor R 1995. Hydrological studies of water bodies in the okomu forest reserves (sanctuary) in south Nigeria. *Physicochemical Hydrology Tropical Freshwater Biology* **4**(4): 83-100.

Prameena JL and Sheeja 2016. Physico-chemical characterization of pond water from Vaduvur, Mannargudi (TK), Thiruvarur District (India). *Der Pharma Chemica* **8**(3): 6-11.

Ramulu NK and Benarjee G 2013. Physicochemical factors influenced plankton biodiversity and fish abundance- A case study of Andhra Pradesh. *International Journal of Lifesciences Biotechnology and Pharma Research* **2**(2): 248-260.

Ragunath S and Sundar ML 2018. Water quality index assessment of domestic water supplies in system tank. *Indian Journal of Ecology* **45**(2): 384-387.

Sandhya K and Benarjee G 2016. Physico-chemical properties of some selected fresh water fish ponds in relation to fish production in Warangal Area. *International Journal of plant, Animal and Environmental sciences* **6**(4): 23-31.

Shobana R, Suriyakala K, Arockia SP, Dharmalingam V and Soruba

R 2014. Evaluation of water quality of Sriperumpudur in Kancheepuram District in Tamilnadu. *Der Chemica Sinica* **5**(5): 91-97.

Shibam S, Abhrajyoti M and Diptimoyee S 2017.Study of physico-chemical parameters of three different urban pond water of Nadia district, West-Bengal, India. *International Journal of Fisheries and Aquatic Studies* **5**(6): 23-27.

Shinde SE, Pathan TS, Raut KS and Sonawane DL 2011.Studies on physico-chemical parameters and correlation coefficient of Harsool-savangi Dam, District Aurangabad, India. Middle-East. *Journal of Scientific Research* **8**(3): 544-554.

Received 28 June, 2020; Accepted 19 August, 2020

Solomon W, Olatunde GO and Matur BM 2013. Some physicochemical parameters of selected fish ponds in gwagwalada and kuje area councils, federal capital territory, Nigeria. *Global Advanced Research Journal of Agricultural Science* **2**(1): 17-22.

Stevens C 2007. Dissolved Oxygen. *Science and Technology* **5**(4): 1-5.

United States Environmental Protection Agency 1974. *Quality criteria for water*. Washington, D.C. USA 24p.

World Health Organization 2009. *Guidelines for drinking water quality*. World Health Organization, Geneva 199p.

Indian Journal of Ecology (2020) 47(3): 751-754

Manuscript Number: 3078
NAAS Rating: 4.96

Isolation and Characterization of a Biosurfactant Producing *Pseudomonas* and *Bacillus* from Hydrocarbon-Contaminated Site

Preeti N. Gajghate, Pranali A. Shete and Vishal R. Dhundale

Post Graduate Department of Microbiology
Smt Chandibai Himathmal Mansukhani College, Ulhasnagar-421 003, India
E-mail: pranalikale2@gmail.com

Abstract: A total of twenty four bacterial cultures were isolated from the marine water and sediment samples collected from the Mumbai site. Out of them G.C -1, G.C-5 and DKS-3 were selected for production and, partial characterizations of biosurfactant. A Gram negative bacterium was identified as *Pseudomonas sp.,* Gram positive bacteria were identified as *Staphylococcus sp*. and *Bacillus sp*. by morphological, physiological and biochemical characterization. The *Pseudomonas* sp. and Staphylococcus sp. grew in sodium chloride (NaCl w/v) from 0.5 to 24% and Bacillus sp. grew at 20% NaCl Concentration indicated that these organisms were halophilic in nature. The production of a biosurfactant by these organisms was studied by oil displacement and oil spreading assay technique. Heavy metal tolerance for three isolates was performed. The heavy metals like cadmium chloride, lead, zinc dust, copper sulphate, mercuric chloride and cobalt chloride were used at 5 different concentrations. These bacteria showed metal tolerant activity against tested heavy metal. These findings further indicated that the isolate could be useful for bioremediation of hydrocarbon in ocean and sea in presence of heavy metals.

Keywords: Haloalkaliphiles, Pseudomonas, Staphylococcus and Bacillus biosurfactants, Heavy metals

Biosurfactants are super amphiphilic metabolites, produced by a different types of microorganisms from various biochemical process and enable to reduce the surface tension of aqueous medium (Bodour et al 2003, Rivardo et al 2009). The biosurfactant are favourable due to their structural diversity leads to unique in nature, the possibility of cost effective production, and their biodegradability (Banat et al 2001, Mulligan et al 2001, Mulligan 2005). Biosurfactants are alternative sources of synthetic chemical surfactant because of their biodegradability and reduced toxicity, produced from cheap raw materials, biocompatibility, and the effectiveness in extremophilic environment (Singh and Cameotra 2004, Plaza et al 2006). Chemically synthesized surfactants overcome with the biosurfactant due to their properties and they are developed the interest because of their antibacterial activity (Kosaric 2001). An oil spill is the release of a liquid petroleum hydrocarbon into the environment, especially the marine ecosystem due to human activity. These oil spills are effects on the habitat and ecosystem so it is required to breakdown of hydrocarbon (Dhundale et al 2018). Mostly oil spills occur in marine environment such as sea, ocean and costal area and in these prospective, the best candidature for deterioration of petroleum products. These problems overcome with the chemical surfactant and synthetic chemicals to minimize such harmful products are effective with environmental exposure to danger. The aims of these studies the isolation and characterization of halotolerant bacterial culture was isolated from marine environment able to produces biosurfactants.

MATERIAL AND METHODS

Sampling site description: Marine water sample from various sources were collected in sterile plastic containers. Total seven water samples and Soil samples which were exposed to oil leaked from ship also collected.

Enrichment and isolation of bacteria: A few grams of soil sample and 10mL water sample were transferred to 500 ml Erlenmeyer flask containing 100 ml of minimal salt medium with 2% (vv -1) of crude oil as carbon source. Flasks were incubated at 37°C on a rotary shaker (200 rev min -1) for 7 days. The isolation of bacterial culture was carried out in a sterile nutrient agar medium. Nutrient agar was added with 5% of NaCl for growth of halophilic bacteria. The pH of media was adjusted to 7.4.

Screening for bio surfactant producing isolates: The strains G.C- 1, G.C- I, and DKS-3 were inoculated in 150 ml side arm flask having 100 ml nutrient broth. One ml of water soluble diesel was added to the experimental flask. Flasks were incubated at 37°C in an orbital shaker at 100 rpm. The culture was grown for 72 hours. The cell-free suspensions were prepared by centrifuging at 10,000 rpm for 20 min and tested for the presence of biosurfactant by using the emulsification activity (E24) and oil displacement method

Oil displacement assay: Qualitative oil displacement test was performed in petri plates. 25 ml of distilled water was



Fig. 1. Sample collected from Kalyan, Dombivi and soil contaminated with oil from Dombivli

taken in a petri plate and 20 µl of hydrocarbon source kerosene was added making a thin layer of oil on the surface of water. Then, 10µl aliquot of supernatant was delivered onto the oil. Distilled water was used for negative control and displacement of oil was considered as positive (Mounira and Abdelhadi 2015)

Heavy metal tolerance of potent isolates: Heavy metals used were cadmium chloride, lead, zinc dust, copper sulphate, mercuric chloride and cobalt chloride. Five different concentrations 0.05, 0.1, 0.5, 1, 2% of six heavy metals was prepared using sterile saline. Thereafter 5 wells were dug with the help of sterile borer and each concentration was added into the well. The plates were incubated at 37°C for 24 hours and the zone of inhibition (mm) was observed.

Haemolysis activity: Strains G.C- 1, G.C- I, and DKS-3 were streaked onto blood agar plate and incubated for 24 hours at 37°C. The plates were visually observed for the zone of clearness around the colony. The concentration of biosurfactant depends on the diameter of the clear zone (Mounira and Abdelhadi 2015).

Antibacterial activity of the biosurfactant: Antibacterial assay was performed by agar well diffusion assay. The test organisms used were *Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, Klebsiella pneumoniae, Salmonella typhi* and *Streptococcus pyogenes*.

Biochemical characterization: After enrichment the samples were inoculated on solid nutrient agar plate and well isolated and morphologically different colonies were selected and stock culture were prepared and stored at 4°C. All these isolates were further characterized by standard biochemical test according to Bergey's manual of systematic bacteriology.

RESULTS AND DISCUSSION

Three isolate from 17 could grow at concentration of 15% NaCl. These 3 isolates were G.C -1, G.C-5 and DKS-3 (isolated from Girgaon chowpatty water sample and Dombivli soil sample) were able to tolerate higher concentration of salt as compared to other isolates. They were inoculated on plates containing 16, 17, 18, 19 and 20 NaCl. The results were observed after 48 hours of incubation at 37°C. The results showed that all the three isolates could grow at 20% NaCl. The growth of colonies was seen after 4-5 days. G.C-5 and DKS-3 showed growth up to 24% NaCl while G.C-1 could not grow above 20% NaCl. These three bacterial cultures tolerant to NaCl Concentration indicated that these organisms were halophilic in nature (Table 1). These three bacterial culture were screened for the production of biosurfactant on the basis of their halotolerant in nature.

Identification of isolates: From gram staining it was observed that G.C-1 is gram negative and was short-rod shaped. G.C-5 isolate is gram positive and rod shaped with presence of endospores and DKS-3 is gram positive, cocci in clusters. Based on the biochemical, the isolates G.C-1, G.C-5 and D.K.S-3 belong to *Pseudomonas* sp., *Bacillus* sp. and *Staphylococcus* sp. respectively. Dhundale et al (2018) reported that the biosurfactant produced from *Pseudomonas aeruginosa* SJS5 and SJS6 showed tolerant to pH, salinity, temperature and with various types of vegetable oils and *Pseudomonas* are suitable and making it appropriate candidate for bioremediation of hydrocarbon contaminated area.

Biosurfactant assay: The three isolates showed positive results. These results confirmed the presence of surface active compounds (biosurfactant) in the cell free culture broth. It can be applied when the activity and quantity of biosurfactant is low and in haemolytic assay the concentration of biosurfactant depends on the diameter of the clear zone produced. The two isolates SN1 (*Bacillus subtilis*), SN12 (*B. cereus*) with biosurfactant-producing ability and the former with emulsion capacity were isolated from petroleum-contaminated soil Nasr et al (2009). Pseudomonas are the best and suitable candidature for the capable of utilizing and breakdown of hydrocarbon as sole carbon and energy source for the production of biosurfactants (Beal and Betts 2000, Noordman and Janssen 2002, Rahman et al 2002). Glycolipid type biosurfactants are produced by *P. putida, P. chlororaphis* and *P. aeruginosa* is extensively studied.

Haemolytic activity: Strains G.C-1, G.C-5 and DKS-3 were streaked onto blood agar plate and incubated for 24 hours at 37°C. The plates were visually observed for the zone of clearness around the colony. The plates streaked with G.C- 5 showed the β-haemolytic activity. The culture producing beta haemolysis was able to produce more biosurfactants as suggested in a study. Haemolytic assay was also studied by adding the suspension into well of blood agar plates

(Jayshree et al 2013). Results indicate that all three isolates showed haemolytic activity and may that they contain surface active compounds.

Heavy metal tolerance and biosurfactant production: All metals except lead inhibited the growth of G.C.-1, G.C-5 and DKS-3 isolates. They were resistant to the lead metal. The organisms were also not inhibited by zinc at a concentration of 0.1%. The effect of mercury was much higher than that of other metals. Significant increase in zone of inhibition is seen, as the concentration was increased. The halophiles can tolerate heavy salt concentrations and moderately halophilic organisms can tolerate salt concentration from 0.5M to 2.5M. Being an extremophile they possess huge genomic and metabolic diversity thus can be a useful tool for the purpose of detoxification and bioremediation of toxic components from the environment (Jayabarath et al 2009, Agarwal and Singh 2012). Lakshmipathy and Kannabiran (2010) reported that the isolation and identification of two strains *Streptomyces* spp. VITDDK1 and *Streptomyces* spp. VITDDK2 with excellent biosurfactant and heavy metal resistance activity.

Antibacterial activity of the secondary metabolites: The metabolites were aseptically dissolved in ethyl acetate. The test organisms used were *Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, Klebsiella pneumoniae, Salmonella typhi* and *Streptococcus pyogenes*. The secondary metabolites extracted from all the three samples did not show antibacterial activity against all the test organisms. 0.1 % solution was added into the well. As no activity was seen using ethyl acetate as a solvent, distilled water was used to dissolve the metabolite. But the results were same as that of ethyl acetate. In primary screening none of the isolates showed antibacterial activity, so extraction was performed using extreme halophiles. In this method of screening results were same, thus it can be said that the does not contain any antibacterial compound. Marine environment harbors wealth of diverse and complex microbial flora with unique features. The marine ecosystem is an importance of

Table 1. Screening of isolates by increasing the salt concentration in nutrient agar medium using grid plate method

Isolate No.	Salt concentration (%)																			
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
2	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
5	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
G.C -1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
10	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G.C-5	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
16	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DKS-3	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
24	+	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 2. Biochemical characterization of isolates

Test	Isolates		
	G.C- 1	G.C- 5	D.K.S- 3
Gram nature	Gram negative	Gram positive	Gram positive
Catalase	+	+	+
Oxidase	+	+	-
Glucose	-	+	-
Sucrose	-	-	-
Lactose	-	+	-
Maltose	-	-	-
Mannitol	-	-	-
Xylose	-	-	-
Indole test	-	-	-
Methyl red test	-	-	-
Voges proskauer test	-	-	-
Simmon's citrate test	+	-	-
PPA test	-	-	-
Nitrate test	+	+	-
H_2S production	-	-	-

extremophiles. Halophilic organisms that have importance in field of bioremediation were successfully isolated. The isolates were identified as *Staphylococcus* sp., *Bacillus* sp. and *Pseudomonas* sp.

CONCLUSION

Total twenty-four isolates obtained in the isolation exercise and all isolates were studied for their salt tolerance activity. Based on the biochemical, the isolates G.C-1, G.C-5 and D.K.S-3 belong to *Pseudomonas* sp., *Bacillus* sp. and *Staphylococcus* sp., respectively. It was seen from the results that, these three isolates showed positive results for biosurfactants assay. The application of biosurfactants will be enable to environmental remediation, they may be used to enhance oil dispersion and biodegradation and as well as solubilisation of heavy metals.

REFERENCES

Agarwal T and Singh R 2012. Bioremedial potentials of a moderately halophilic soil bacterium. *Journal of Pharmaceutical and Biomedical Sciences* **19**(16): 1-6.

Banat IM, Makkar RS and Cameotra SS 2000. Potential commercial applications of microbial surfactants, *Applied Microbiology and Biotechnology* **53:** 495-508.

Beal R and Betts WB 2000. Role of rhamnolipid biosurfactants in the uptake and mineralization of hexdecane by hydrocarbon assimilation and biosurfactant producing Pseudomonas aeruginosa. *Journal of Applied Microbiology* **89**: 158-168.

Bodour AA, Drees KP and Maier RM 2003. Distribution of biosurfactant-producing bacteria in undisturbed and contaminated arid Southwestern soils. *Applied Environment and Microbiology* **69**: 3280-3287.

Desai JD and Banat IM 1997. Microbial production of surfactants and their commercial potential. *Microbiology and Molecular Biology Research* **61**: 47-64.

Dhundale V, Hemke V and Desai D 2018. Production and optimization of biosurfactant from *Pseudomonas aeruginosa* SJS 5 and SJS6. *Asian Journal of Microbiology Biotechnology and Environmental Science* **20**(1): 310-315.

Falatko DM and Novak JT 1992. Effect of biologically produced surfactants on the mobility and biodegradation of petroleum hydrocarbons. *Water Environmental Research* **64**(2): 163-169.

Jayabarath J, Sundar SS, Arulmurugan R and Giridhar R 2009. Bioremediation of heavy metals using biosurfactants. *International Journal of Biotechnology Applications* **1**(2): 50-54.

Jayshree RC, Rajam C and Rajendran N 2013. Biosurfactant production by halophilic bacteria. *International Journal of Pharma and BioSciences* **4**(4): (B) 904-912.

Kosaric N 2001. Biosurfactants and their application for soil bioremediation. *Food Technology and Biotechnology* **39**: 295-301.

Kumar M, Leo´n V, Sisto Materano AD, Ilzins OA and Luis L 2008. Biosurfactant production and hydrocarbon-degradation by halotolerant and thermo tolerant *Pseudomonas sp*. *World Journal of Microbiology and Biotechnology* **24**: 1047-1057.

Lakshmipathy D and Kannabiran K 2010. Biosurfactant and heavy metal resistance activity of *Streptomyces* spp. isolated from saltpan soil. *British Journal of Pharmacology and Toxicology* **1**(1): 33-39.

Mounira A and Abdelhadi G 2015. Assessment of four different methods for selecting biosurfactant producing extremely halophilic bacteria. *African Journal of Biotechnology* **14**(21): 1764-1772.

Mulligan CN 2005. Environmental applications for biosurfactants. *Environmental Pollution* **133**: 183-198.

Nasr S, Soudi MR, Mehrnia MR and Sarrafzadeh MH 2009. Characterization of novel biosurfactant producing strains of *Bacillus* spp. isolated from petroleum contaminated soil. *Iranian Journal Microbiology* **1**(2): 54-61.

Noordman WH and Janssen DB 2000. Rhamnolipid stimulates uptake of hydrophobic compounds by *Pseudomonas aeruginosa. Applied and Environmental Microbiology* **68**: 4502-4508.

Plaza GA, Zjawiony I and Banat IM 2006. Use of methods for detection of thermophilic biosurfactant-producing bacteria from hydrocarbon-contaminated and bio remediated soils. *Journal Petrol Science and Engineering* **50**: 71-77.

Rahman KSM, Banat IM, Thahira J, Thayumanavan T and Lakshmanaperumalsamy P 2002. Bioremediation of gasoline contaminated soil by a bacterial consortium amended with poultry litter, coir pith and rhamnolipid biosurfactant. *Bioresource Technology* **81**: 25-32.

Rivardo F, Turner RJ, Allegrone G, Ceri H and Martinotti MG 2009. Anti-adhesion activity of two biosurfactants produced by Bacillus spp. prevents biofilm formation of human bacterial pathogens. *Applied Microbiology Biotechnology* **83**: 541-547.

Singh P and Cameotra SS 2004. Potential applications of microbial surfactants in biomedical sciences. *Trends in Biotechnology* **22**: 142-146.

Velikonja, J and Kosaric N 1999. Biosurfactants in food applications. *Surfactant Science Series*: 419.

Volkering F, Breure AM and Rulkens WH 1998. Microbiological aspects of surfactant use for biological soil remediation. *Biodegradation* **8**: 401-417.

Received 18 May, 2020; Accepted 31 July, 2020

Indian Journal of Ecology (2020) 47(3): 755-758

Manuscript Number: 3079
NAAS Rating: 4.96

Algal Diversity and Physio Chemical Qualities of Achankovil River in Monsoon seasons

Meera Krishnan, T. Praveen Dhar[1*], R. Sreejai[1] and Sreeja Thankappan[2]

Research center, University of Kerala, Mahathma Gandhi College, Thiruvananthapuram-695004, India
[1]St. Stephen's College, Pathanapuram-689 695, India
[2]N.S.S. College, Nilamel-691 535, India
**E-mail: dharpraveent@gmail.com*

Abstract: Present research focuses the exploration of the biodiversity of micro and macro algae of Achankovil river during monsoon seasons. The, water samples were collected during pre- monsoon, monsoon and post-monsoon seasons. Samples were collected from the upstream, downstream and midstream regions of the river. The results showed that seventy three types of algae belongs to four major algal class such as Chlorophyceae, Bacillariophyceae, Cyanophyceae and Euglenophyceae were recorded. The algal types include twenty eight Chlorophycian, twenty six Bacillariophycian classes, the remaining sixteen genera belongs to Cyanophyceae and three Euglenophyceae classes. The physio chemical parameters such as temperature, pH, dissolved oxygen and CO_2content were indicated at optimum values. Nitrate, phosphate and silicate shows variation from the river water ranges. The presence of species such as Euglena, Scenedesmus, Navicula and Nitzschia indicates the river water is polluted.

Keywords: Algal diversity, Physiochemical features, Achankovil river, Monsoon seasons

Algae are the major group of primary producers and photosynthetic thallophytes of the universe and are the prime producers in aquatic ecosystem and form important food link of the food web and it make a key role in maintaining the equilibrium between living organism and abiotic factors (Hulyal and Kaliwal 2009). The algal diversity is determined by the level of richness of species and their functional importance of an ecosystem. Depending upon the seasons the algae appeared and disappear (Arulmurugan et al 2011). Physicochemical parameters and quantity of nutrients in water play a significant role in the distribution pattern and algal species, composition and diversity studies are useful tool for the assessment of any type of water body (Pawar et al 2006, Nwonumara et al 2016). Hany et al (2017) studied the phytoplankton assemblages in the river Barak of South Assam this study is based on composition in changing space and time. Achankovil river is one of the important rivers in Kerala, it located the southern tip peninsula and originated from Western Ghats. The present study was undertaken discover the diversity of micro and macro algae and physiochemical properties of water of Achankovil river during the different monsoon seasons.

MATERIAL AND METHODS

The river Achankovil or Achankovilaaru is originating from the hills of Achankovil, have 128 Kilometres long and have diverse flora and fauna. Present investigation explores the algal diversity of upper, middle and low region of Achankovil river. The, water samples collected bimonthly during pre- monsoon (March to May), monsoon (June to September) and post-monsoon (October to December) seasons. Samples were also collected from three regions- upstream, downstream and midstream of the river. The upstream regions including Achankovil, Konni and Aruvappulam, midstream includes Thumpamon, Pandalam and Vettiyar. Downstream comprises of Veeyapuram top and down regions (Fig. 1). Five sampling stations were selected from each area and samples were collected during the early morning before the day break of sunlight. Phytoplankton forms were collected by plankton net-20 silk bolting cloth. The phytoplankton samples were allowed to settle by adding Lugol's Iodine and 4% of formalin for the preservation. Macro algae and attached forms were collected by manually. Algae were identified with the help of Fresh water algal identification key as established by Desikachary (1959), Prescott (1982) and Philipose (1967). Physiochemical parameters such as temperature, pH, dissolved oxygen, amount of CO_2, nitrate, phosphate, silicate and productivity of water samples were analyzed according to standard procedures (APHA 2001). Sediments were collected using Van Veen Grab for the algal species that live in or on these sediments.

RESULTS AND DISCUSSION

The observations of the study revealed that' seventy three different forms of micro and macro algae are present in different region of Achankovil river. The identified seventy

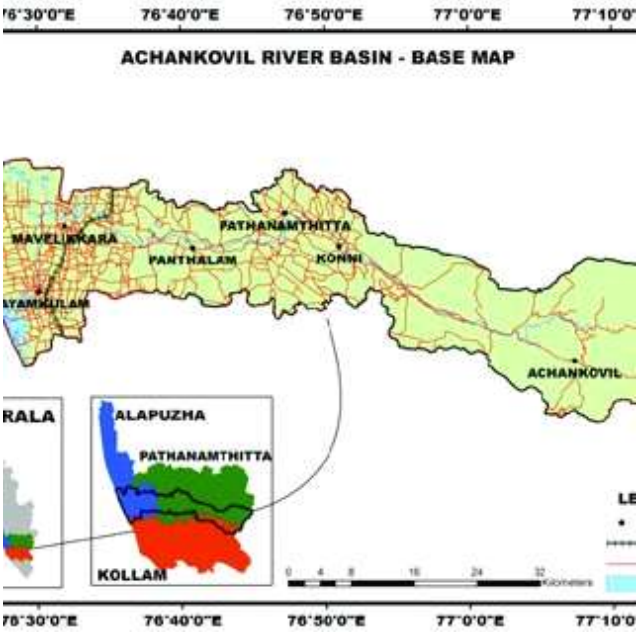


Fig. 1. GPS image showing the sample locations in Achankovil river

three types algae of different genera and species belongs to four major algal class, Chlorophyceae, Bacillariophyceae, Cyanophyceae and Euglenophyceae which includes twenty eight and dominant was Chlorophycian 38.3 % followed by Bacillariophyceae with twenty six genera 35.6 %. The, remaining were sixteen genera of Cyanophyceae with 21.9 % and three genera of Euglenophyceae had 4.1% (Table 1). Temporal variation of phytoplankton in Idukki reservoir, Kerala was studied by Sebastian and Thomas (2016) revealed that phytoplankton was more prevalent during the pre-monsoon season. The, temperature ranged between of 27-30°C. The dissolved oxygen content is in the upper region were more and less at low region and carbon dioxide content an average of four and six. As dissolved oxygen level in water drop below 5 mg/L many life forms are put under pressure (Bowmanet al 2008). Hydrogen ion concentration of the water shows slight alkaline, which indicates increased photosynthetic activity. The nitrate, phosphate, silicate and productivity were in optimum levels (Table 2). Presence of pollution indicator species increased in upstream to downstream of the river. The algal genera Euglena, Scenedesmus, Navicula and Nitzschia are found in organically polluted water. Presence of Euglena indicated the abundance of decaying organic materials in these locations (Girishet al 2018). Presence of pollution tolerant algae like Melosira, Oscillatoria, Pediastrum and Scenedesmus are considered as indicative of enriched water, thus providing evidence of pollution of water (Tessy and Sreekumar 2008). The pollution tolerant algal species found in the Guruvayur

Table 1. Algal diversity in pre- monsoon, monsoon and post-monsoon seasons

Name of the algae	Upstream	Midstream	Downstream
Chlorophyaceae			
Cosmarium manipurense	+	–	+
C. obsoletum	+	+	+
C. puctulatum	–	+	–
Euastrum anasatum	–	+	+
Nephrocytium	–	+	–
Scenedesmus quadricauda	+	+	+
S.bijugatus var.	–	+	–
Ankistrodesmus convolutes	–	+	–
A. falcatus	+	–	–
Chlorella	+	–	+
Chlorococcum	+	–	+
Closterium acutum	–	+	+
Mougeotia	–	–	+
Odogonium	+	+	–
Tetrahedron minimum	–	–	+
Ulothrix	–	+	+
Pediastrum boryanum	+	+	+
P. tetras	–	–	+
Spirogyra	+	+	–
Xanthidium	–	–	+
Desmidium	–	+	+
Coelastrum	–	–	+
Staurastrum	+	+	+
Nephrocytium lunatum	+	+	–
Micrasteria radians	+	–	+
Netriumdigitus	+	–	–
Bulbochaete	+	–	–
Gonatozygon aculeatum	+	+	–
Bacillariophyceae			
Cocconeis	+	+	+
Cymbella	+	+	+
Fragilaria	+	–	–
Navicula pupula	+	+	+
N. salinarum	+	–	–
N. gregarium	–	–	+
N. rostellata	–	+	+
N. mutica	+	+	+
N. veneta	–	–	+
Nitzschia sigmoidea	–	–	+
N. frustalum	+	+	+
N. linearis	+	+	–

Cont...

Cont. Table 1.

Name of the algae	Upstream	Midstream	Downstream
Surirellar obusta	+	+	+
Synedra ulna	+	+	+
Tabellaria flocculosa	+	+	+
Gomphonema	+	+	+
Pinnularia gibba	+	+	+
Amphora	+	+	+
Craticula	–	+	–
Cylotella	–	+	+
Gyrosigma	–	+	–
Pleurosigma	–	+	–
Stephanodiscus	+	–	+
Aulacoseira granulate	–	+	+
Diadesmis confervacea	–	–	+
Melosira	–	–	+
Cyanophyceae			
Anabena spherical	+	+	–
Lyngbya majuscule	–	+	–
Lyngbyabirgei	–	+	+
L. arboricola	+	–	–
Oscillatoria annae	–	+	+
O. agardhii	–	+	–
O. ornata	+	+	+
O. cortiana	+	+	–
O. margaritifera	–	–	+
Spirulina gigantean	–	–	+
S. princeps	+	–	+
Nostoc	–	+	–
Gleocas pafuco-lutea	+	–	–
Merismopedia elegans	+	–	–
M. tenuissima	+	–	–
Gloeocapsa	+	+	–
Euglenophyceae			
Euglena	+	+	+
phacus	–	+	+
Trachelomonas	–	–	+

pond indicate the deteriorated nature of the water. Euglenophyceae show less number of species i.e. only three species. Similar results were reported by Nasare et al (2009).

Table 2. Physio chemical features of water of Achankovil river

Parameters	Upstream region (Mean)	Midstream region (Mean)	Downstream region (Mean)	Optimum as per standard
Temperature (°C)	27	29	30	0-30
pH	6.8	7.3	6.4	7.4
Dissolved oxygen (mg/L)	6	3.6	1.2	6.5-8
CO_2 (mg/L)	4	4	6	<2.0
Nitrate (mg/L)	0.113	0.09	0.032	1
Phosphate (mg/L)	0.027	0.032	0.387	0.005 to 0.05
Silicate (mg/L)	0.168	0.255	0.25	5-25
Productivity (mg/C/l/hr)	0.495	0.375	0.75	

CONCLUSIONS

The results of the investigation reports that seventy three types algae belongs to four major algal class, Chlorophyceae, Bacillariophyceae, Cyanophyceae and Euglenophyceae which includes twenty eight Chlorophycian followed by Bacillariophycian with twenty six genera. The remaining sixteen genera belongs to Cyanophyceae and three Euglenophyceae genera. The physiochemical parameters such as temperature, pH, dissolved oxygen and CO_2content were noticed at optimum standards or river water. Meanwhile nitrate, phosphate and silicate shows variation from the standard value of river water. The parameter productivity showed relative changes during all seasons. The pollution indicator species such as Euglena, Scenedesmus, Navicula and Nitzschia were also found in water.

REFERENCES

APHA 1998. *Standard methods for the examination of water and waste water.* XX Edition, American Public Health Association, American Water Works Association and Water Environmental Federation, Washington DC., pp. 23-1268.

Arulmurugan P, Nagaraj S and Anand N 2011. Biodiversity of fresh water algae from Guindy campus of Chennai. *Indian Journal of Ecobiotechnology* **3**(10): 19-29.

Bowman JL, Floyd SK and Sakakibara K 2007. Green genes-comparative genomics of the green branch of life. *Cell***129** (2): 229-234.

Desikachary TV 1959. *ICAR monograph on algae*, India Council Agricultural Research, New Delhi. pp. 686.

Hany HM, Dalal A and Gupta S 2017. Phytoplankton assemblages in the river Barak, South Assam, India: A study to know its composition in changing space and time. *Indian Journal of Ecology* **44**(3): 492-499.

Hulyal SB and Kaliwal B 2009. Dynamics of phytoplankton in relation to physico-chemical factors of Almatti reservoir. *Environmental Monitoring Assessment* **153**: 45-59.

Nasare PN, Wadhne NS, Harney NV and Sitre SR 2009. Phytoplankton diversity of Khadkilake, Bengali Camp,

Bhadrawati District ChandrapurMaharashtra, India. *Bioinfolet* **6**(3): 232-234.

Nwonumara GN, Okogwu OI, Ani C and Nwinyimagu AJ 2016. Physico-chemistry and phytoplankton characteristics of two tropical rivers in Ebonyi State, Southeast Nigeria. *Indian Journal of Ecology* **43**(2): 443-448.

Pawar SK, Palle JS and Shendge KM 2006. The study on phytoplankton of Pethwadaj Dam,Taluka, Kandhar, Maharashtra. *Journal of Aquatic Biology* **21**(1): 1-6.

Philipose MT 1967. *Freshwater plankton of Inland fisheries*. Proc. Symp. Algal. ICAR New Delhi, pp. 272-291.

Prescott GW 1982. Algae of the Western Great lakes Areas. Otto Koeltz Science Publishers, Germany, pp.662-692.

Sebastian S and Thomas JV 2016. Temporal variation of phytoplankton in Idukki reservoir, Kerala. *Indian Journal of Ecology* **43** (1): 22-27.

Tessy PP and Sreekumar R 2008. A report on the pollution Algae from the Thrissur Kol wetlands (part of Vembanad-Kol, Ramsar site), Kerala. *Nature Environment Pollution Technology* **7**(2): 311-314.

Received 12 June, 2020; Accepted 19 August, 2020

Indian Journal of Ecology (2020) 47(3): 759-763

Manuscript Number: 3080
NAAS Rating: 4.96

Ecological Future Scenario 2020 of Marine Macro Algal Flora of Karwar Coastal Area, Arabian Sea, India

Gulnaz Qureshi and J.L. Rathod

Department of Studies in Marine Biology, Karnatak University, Post Graduate Centre Kodibag, Karwar-581 303, India
E-mail: Afreensyed115@gmail.com

Abstract: Ecological based study was conducted on abundance, composition, monthly variation and vertical zonation pattern of marine macro algae along Karwar coast, Arabian Sea, India. The study reveals Majali rocky shore to be an ideal site for algal diversity with distinctive pattern of zonation combat with the main abiotic environmental stressors like tidal amplitude, dissolved oxygen and salinity. The present study recorded six new species (*Ulva prolifera, Ulva flexuosa, Rhizoclonium tortuosum, Rhizoclonium ramosum, Hypnea pseudomusciformis* and *Hypnea valentine*), which were prior not tabulated during the earlier studies which indicates increased species diversity along Karwar coast.

Keywords*:* Intertidal, Seasonal variation, Seaweeds species composition, Vertical zonation

Majali beach one such rocky shore with coastal stretch comprised of biologically rich environment with different habitats which play a vital rich source as a substratum for attachment or holdfast for algal biodiversity. Seaweeds or marine macro algae are group of economical viable plants that grow in marine water environment capable of photosynthetic ability and serve as a primary source in world's ecological communities. The abundance , assemblages and vertical distribution of marine macro algae and other forms of algae combat with several abiotic factors (tidal amplitude , light, variation in salinity regime, dissolved oxygen, nutrient concentration, air temperature and water temperature) as well as the topography and geomorphological characteristic of coast and substratum availability for secure attachment of algae so that can thrive and flourish the seabed (Reddy et al 2006, Jhansi and Ramdas 2009, Nkwad et al 2019). Diversity, distribution, composition, seasonal variations and cultivation of marine macro algae of Indian marine coast has been explored by number of workers (Rao et al 2011, Kumar and Reddy 2012, Satheesh and Wesley 2012, Prathiban and Anantharaman 2018).

Each region on the marine rocky shore coast has a specific group of organisms forming distinctive horizontal bands or zones. The appearance of dominant species in the littoral zone or Inter tidal zone is called vertical zonation. Seaweeds follow a universal scheme, as an algal community specific to particular area of Inter tidal zone and rocky substratum displaying distinctive pattern of zonation. The vertical distribution of seaweeds diversity is influenced by the most crucial abiotic factors of rocky shore which are amount of light intensity, temperature, wave action, ability to withstand desiccation, specificity of light intensity, quality and its duration. The diversity range of seaweeds can be observed during lesser amplitude of tide where seaweeds diversity declines with the higher altitudes which indicates the harshness of the sea, decreasing the survivability of the seaweeds. Zonation pattern of Resilient Inter tidal biodiversity profile was studied by Naik and Shivakumar (2012) and Sowjanya et al (2017). The present work envisages on the vertical zonation pattern of Marine macro algae along the coastline of Karwar, Karnataka. Further the study emphasis on the seaweeds flora composition and evaluate monthly variation in distribution pattern of Rocky shore.

MATERIAL AND METHODS

Study area: Majali located in Northern sector of Karwar taluka Lat $14^0$53' 54.42"N and Long $74^0$5' 45.65"E with 2km of sandy cum rocky shore extends north southerly with boulders and rocky pools at supra littoral Intertidal region (Table 1).

Sampling procedure: Study was conducted fortnightly basis in collection of seaweeds using random sampling method (1m^2 quadrant) from January 2018 to January 2019. The results were pooled and interpreted season wise. The Inter tidal belt for assessment was thoroughly surveyed during the exposure of area at lesser amplitude period referring Tidal chart of West coast of India (2018-2019). The collected samples were washed thoroughly and preserved in wet and dry form as herbarium. Authentications of samples were done through standardized taxonomical keys (Beligirianga 2006, www.agalbase.com). The monthly

physico parameters analysis such as temperature, salinity using refractometer, dissolved oxygen bu hand held DO meter (HACH), pH by pH meter, nitrate, nitrite and ammonium nutrients were measured by using API nutrient analysis kits (APHA1995). Environmental parameters such as water temperature ranged from 24.3℃ to 28.3℃, air temperature from 25.1 to 30.6℃, pH 7.1 to 7.5 ,dissolved oxygen 5.0 to 6.5 mg/L, nitrate and nitrite ranged 2 to 4.25 mg/L ,0.1 to 0.4 mg/L, respectively. Sampling site and its geomorphological features with topography are notified in Table 1. Occurrence of seaweeds are categorized as abundant (+++), less abundant (++), sparsely abundant (+) and absent (-).

RESULTS AND DISCUSSION

The occurrence of rich marine macro algae and species composition at Majali justify the diversified coastal habitats of varied topographical features and various environmental stressors .The coasts topography and semi diurnal tidal amplitude supports the vertical zonation of seaweeds seasonally. A total of 38 species of seaweeds were recorded belonging to 3 phyla: 14 species belongs to Chlorophyta, 9 to Phaeophyta and 15 to Rhodophyta (Fig. 2). At family level, the highest number of family as well as species was recorded in Rhodophyta, followed by Chlorophyta and Phaeophyta. Highest number of species represented by class Chlorophyta, family Ulvaceae (7) followed by Cladophoraceae (7). In Phaeophyta maximum was in family Sargassaceae (5), followed by Dictyotaceae (4) and least number in Sphacelariaceae (1). Rhadophyta group contributed by Gracilariaceae and Cystocloniaceae with 3 species each, Rhodomelaceae with 2 species, Ceramiaceae, Gelidiaceae, Gelidiellaceae, Lithophyllaceae, Corallinaceae, Halymeniaceae and Lomentariaceae with 1 species each. A dendrogram showing Brays-Curtis similarity reveals similar clusters at Monsoon and Post Monsoon (49.1%). The observation on abundance of monthly variation of seaweeds composition exhibits dominance of Chlorophyta members during June to August whereas there was shift of dominance from Chlorophyta to Rhodophyta members from November to February during study period.

Distribution of Marine algae in littoral zone of entire Karnataka coast Venkataram and Wafer (2005) listed 39 species of seaweeds from south Karnataka coast. Naas (2003) reported 39 spp of seaweeds from Karnataka coast where as Oza and Zaidi (2001) updated the Indian Marine Macro algae list to ample number of species up to range of 830 species. Naik et al (2012) recorded 13 species of Chlorophyta, 8 species of Phaeophyta and 4 species of Rhodophyta with a total number of 26 species from Majali, West coast of India. Naik et al (2015) reported diversification of seaweeds with relation to environmental condition of Karwar bay recorded 32 species of seaweeds belonging to 19 genera comprising of all three groups. In contrast to above findings the present study reported 38 species of seaweeds indicating in graded trends in seaweeds diversity, species composition of Marine macro algae and keen observation of rocky shore along Karwar coast, Arabian sea. The distribution, species composition and the richness of algal forms (macro and micro) are endured by the environmental stress factors studied by Nkwuda et al (2019) and Jawad et al (2017). The increased number of vertical zonation of algae is result of proper investigation method and appropriate methods in throw surfacing of rocky shorelines. The lower littoral region is densely filled with foliose and filamentous red species many low shore species are found in rocky pools created by tidal influence of emergence. Large rocky pools provide good algal diversity various morphological forms such as encrusting and erect coralline forms, filamentous and cartilaginous forms. In the most huge couloirs various turfs of overlapped intermingled epiphytic as well as species of all three groups were present. On the side of boulders and steep rocks several outcrops and overhangs especially *Hypnea valentine, Chaetomorpha* species and *Cladophora* species were recorded. Abundance of Phaeophyta algal groups were luxuriant in monsoon season, which are contrary to Sowjanya et al (2017) in Bay of Bengal, India. The diversity of seaweeds on rocky shore increases down the infralittoral fringe. Vertical distribution along rocky shore is

Table 2. Zonation based on tidal amplitude at Majali, West coast of India

Zone	Height (metres)
Spray zone (rocky shore)	2.1
Midlittoral (rocky pool and sandy shore)	1.0 to1.5
Lower littoral (rocky gravel bed, rocky shore and sandy pools)	0.7 below
Lower littoral (rocky shore and sandy pools)	-0.2 below

Table 1. Sampling site with physical morphological and topographical features of Karwar coast

Sampling site	Physical features of substratum	Geomorphological characteristic	Topography of the beach
Majali	Large boulders, rocky platform and shingles	Rocky boulders pebbles, rock pools ridges, rocky platforms with small pools	Sandy and rocky substratum

Table 3. Occurrence, abundance and monthly distribution of seaweeds at Majali, west coast of India

Marine algae	J18	F	M	A	M	J	J	A	S	O	N	D	J19
Chlorophyta													
Family Ulvaceae													
Ulva intestinalis	-	-	+	-	-	++	-	-	++	-	+++	-	-
U. clathrata	-	-	+++	-	-	+++	-	-	--	-	-	-	-
U. lactuca	++	-	-	-	-	++	-	-	+	+++	-	-	++
U. compressa	-	-	+	-	-	++	-	-	-	-	+	+	+
U. flexuosa	+	-	-	-	--	-		-	+	-	+	-	-
U. prolifera	-	+	+	-	-	+	-	-	-	+	++	+	-
U. rigida	+	-	-	-	-	-	-	-	-	-	-	-	-
Family Cladophoraceae													
Chaetomorpha antennina	-	++	+	+	-	-	-	-	-	+	+	+	+
C. linum	-	++	++	-	-	-	-	-	-	-	-	-	-
Cladophora vagabunda	-	+	-	-	-	-	-	-	-	-	+	-	-
C. rupestris	-	-	+	++	-	-	-	+	++	-	-	-	-
C.sercenica	+	+++	+	+	++	-	-	+	+	++	+++	++	+
Rhizoclonium ramosum	-	-	-	-	-	++	-	-	-	+	++	-	++
R. tortuosum	-	-	-	-	-	++	-	-	-	+	++	-	++
Phaeophyta													
Family Dictyotaceae													
Dictyota dichotoma	-	-	+	++	-	-	-	-	-	+	+	-	-
Padina tetrastromatica	-	-	+	+	+	-	-	-	-	-	-	-	-
Spatoglossum asperum	-	-	+	+	-	-	-	-	-	-	-	-	-
Stoechospermum polypodiodes	-	-	-	-	-	-	-	-	-	+	+	-	-
Family Sargassaceae													
Sargassum cinereum	-	-	-	-	-	-	-	-	-	+	+	-	-
S. swartzii	-	-	+	+	+	+	+	-	-	-	-	-	+
S. ilicifolium	-	-	+	+	+	+	+	-	-	+	+	+	-
S. polycystum	-	-	-	-	-	-	-	-	-	+	-	+	+
S. tenerrium	-	-	-	+	+	+	+	-	-	+	+	-	+
Family Sphacelariaceae													
Sphacelaria tribuloides	-	-	-	--	-		-	-	-	+	+	-	-
Rhadophyta													
Family Rhodomelaceae													
Acanthophora muscoides	+	++	-	-	-	-	-	-	-	+	-	-	-
A. specifera	+	++	+	+	-	-	-	-	-	+	+	-	-
Family Ceramiaceae													
Centroceras clavulatum	-	-	+	-	-	-	-	-	-	++	++	+	+
Family Gelidiaceae													
Gelidium pusillum	+	+	+	+	+	+	-	-	-	-	-	+	+
Family Gelidiellaceae													
Gelidiella acerosa	-	-	+	-	-	-	-	-	-	-	-	-	-
Family Lithophyllaceae													
Amphiroa fragilissima	-	-	++	-	-	-	-	--	-	-	-	-	-
Family Corallinaceae													
Jania spectabile	-	-	+	++	++	-	-	-	-	-	+	-	-
Family Halymeniaceae													
Grateloupia lithophila	-	-	-	-	-	+	-	-	-	++	+	-	++
Family Gracilariaceae													
Gracilaria corticata	++	++	+	+	-	-	-	-	-	+	+	-	-
G. folifera	+	++	+	+	-	-	-	-	+	+	+	-	-
G.gracilis	-	++	++	-	-	-	-	+	++	+	+	-	-
Family Cystocloniaceae													
Hypnea valentine	-	-	++	-	-	-	-	-	-	-	+	++	+
H. pseudomusciformis	-	-	+	-	-	-	-	-	-	-	+	+	+
H. musciformis	-	-	+	+	-	-	-	-	-	-	+	+	-
Family Lomentariaceae													
Ceratodictyon intricatum	-	-	+++	++	-	+	-	+	+++	-	-	-	-

Abundant (+++), less Abundant (++),sparsely Abundant (+) and Absent (-).Pre Monsoon-(Feb-May), Monsoon-(Jun-Sep), Post Monsoon-(Oct-Jan).

Table 4. Algal Intertidal vertical zonation observations at Majali, west coast of India

Supralittorial fringe	Midlittorial fringe	Infralittorial fringe
Ulva intestinalis	*Chaetomorpha antennina*	*Gelidium pusillum*
Chaetomorpha antennina	*Acanthophora spicifera*	*Grateloupia lithophila*
Ulva compressa	*Acanthophora muscoides*	*Padina tetrastromatica*
Acanthophora spicifera	*Cladophora fasicularis*	*Sargassum tenerrium*
Acanthophora muscoides	*Amphiroa fragilissima*	*Sargassum swartzii*
Gracilaria corticata	*Gelidium pusillum*	*Spatoglossum asperum*
Gracilaria folifera	*Sargassum polycystum*	*Stoechospermum polypodiodes*
Ulva lactuca	*Sphacelaria tribuloides*	*Dictyota dichotoma*
Centroceros clavulatum	*Padina tetrastromatica*	*Jania spectabile*
Ulva clathrata	*Hypnea valentiae*	
Cladophora rupestris	*Spatoglossum asperum*	
Rhizoclonium ramosum	*Gracilaria gracilis*	
Rhizoclonium tortuosum	*Ceratodictyon intricatum*	



Fig. 2. Few Algal species collected from Majali Beach, West coast of India

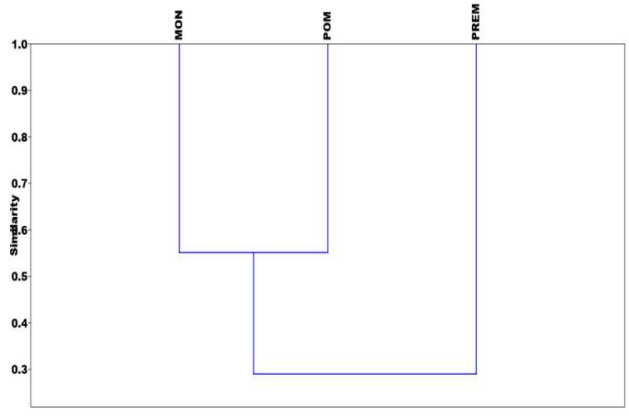


Fig. 3. Dendogram of complete linkage diversity showing similarity matrix of seaweeds season wise in intertidal area (PREM-Pre-monsoon, MON-Monsoon, POM-Post monsoon)

direct consequence of amplitude and height of tide studied by Venkataraman et al (2005). Vertical zonations in each fringe are nearly integrated and overlapping to closely towards a line of demarcation is virtually not a possible criteria, which resembles to findings of Naik et al (2012). Similar observations were recorded for Chlorophyta group species, which were maximum dominance in Majali during Monsoon period. The present study also reveals similar findings at Majali coast were in the vertical gradient represents the species *of Chaetomorpha, Ulva* and *Entermorpha* occupies higher levels on rocks exposed to light promote healthy algal growth. Certain seaweeds follow different zone pattern in accordance and variable to both West and East coast in relation to tidal amplitude and the upwelling process occurring in Monsoon responsible for fluctuation in growth and abundance of marine macro algae as in accordance to Deborah et al (2007).

CONCLUSION

The Karwar coastline is rich in luxuriant algal growth with varied algal species. Data collected will be useful in acknowledgement of farming economical seaweeds, conservation aspects and Educational learning. Geomorphological and Topographical features of the coast are ideal condition for seaweeds production via commercial field which can boost fishermen's economic status. The study prevails an awareness among scholars, students and researchers who can avail the benefit of live study of natural museum of varied algal species.

REFERENCES

APHA: American Public Health Association 1995. *Standard Methods: For Examination of Water and Waste water*, APHA,

AWWA, WEF/1995, APHA Publication.

Beligirianga V 2006. *Studies on the distribution and abundance of marine algae* (Seaweeds) *in the Karwar coast*. Ph.D. thesis karnatak University, Dharwad, India.

Deborah JDS, Sherman T and Wyllie-Echeverria S 2007. Do dessication tolerances control the vertical distribution of intertidal sea grasses. *Aquatic Botany* **87**: 161-166.

Jawad HJ ,Mohammed JM and Alwan AH 2017. An ecological study for diatomic ephiphytic algae population on phragmits australis and *Ceratophyllum demersum* plants in Bani-Hassan River in Holy Kerbala Province-Iraq. *Indian Journal of Ecology* **44**(2): 201-209.

Jhansi M and Ramdas V 2009. Effect of salinity and dissolved nutrients on the occurrence of some seaweeds in Manakkudy estuary. *Indian Journal of Marine Sciences* **38**(4): 470-473.

Kumar M and Reddy CRK 2012. *Oxidative Stress Tolerance Mechanisms in Marine Macroalgae (Seaweeds): Oxidative Stress in Seaweeds*. LAP Lambert Academic Publishing, Germany, p. 160.

NAAS 2003. *Seaweed cultivation and utilization policy paper 22*. National Academy of Agricultural Sciences, India, p.1-6.

Naik UG, Beligiriranga V and Shivakumar HB 2015. Seaweeds of Karwar Bay, Arabian Sea, West Coast of India: A Diversity Profile. *International Journal of Science and Nature* **6**: 728-732.

Naik UG and Shivakumar HB 2012. Resilient intertidal biodiversity profile of Majali coast, Karwar, West coast of India. *Cibetch Journal of Zoology* **1**(1): 68-78.

Received 22 June, 2020; Accepted 19 August, 2020

Nkwuda NG, Chijioke A, Okechukur OI and Joshu NA 2019. Assessment of physicochemistry, periphyton species composition, diversity and biomass of Asu River South East, Nigeria. *Indian Journal of Ecology* **46**(2): 227-234.

Oza RM and Zaidi SH 2001. *A Revised checklist of Indian marine algae*. Central Salt and Marine Chemicals Research Institute, Bhavnagar, 296 p.

Prathiban C and Anantharaman P 2018. Diversity and biomass of drift seaweeds from the Tuticorin Coast, India. *Species* **19:** 72-86.

Rao KS, Murty KP and Rao GMN 2011. Seasonal studies on marine algae of the Bhimili coast, East coast of India. *Journal of Algal Biomass Utilization* **2**(2): 69-82.

Reddy CRK, Rao PVS, Ganesan M, Eswaran K, Zaidi SH and Mantri VA 2006. The Seaweed Resources of India, 25p. In: Critchely AT, Ohno M and Largo Db (eds.). *World Seaweed Resources*. Eti Information Services Ltd., Wokingham, Berkshire, UK.

Satheesh S, Wesley SG 2012. Diversity and distribution of seaweeds in the Kudankulam coastal waters, South-eastern coast of India. *Biodiversity Journal* **3**: 79-84.

Sowjanya IV and Sekhar PSR 2017. Ecology of marine agal flora of Vishakhapatnam coastal areas, Bay of Bengal, India. *Journal of Threatened Taxa* **9**(3): 9911-9919.

Venkataraman K and Mohideen Wafar 2005. Coastal and marine biodiversity of India. *Indian Journal of Marine Sciences* **34**(1): 57-75.

Indian Journal of Ecology (2020) 47(3): 764-768

Manuscript Number: 3081
NAAS Rating: 4.96

Effect of Physico-Chemical Properties of Water on Macrophyte Diversity with Special Reference to Bhoj Wetland

Prerna Gupta, Sadhna Tamot[1] and Vinoy K. Shrivastava

Laboratory of Endocrinology, Department of Biosciences, Barkatullah University, Bhopal-462 026, India
[1]Department of Zoology, Sadhu Vaswani Autonomous College, Bairagarh, Bhopal-462 026, India
E-mail: prernag1707@gmail.com

Abstract: The present study was carried out to characterize the impacts of physico-chemical properties of water on the diversity of macrophytes with special reference to Bhoj Wetland. During the study, a total of 12 macrophytes species belonging to 8 families were recorded, with 2 dominant species at 5 sites of wetland. The deplorable water quality with invasive species was found in all sites except site III as it is colonized by submerged vegetation with high level of DO and low TDS. Unethical activities of the local inhabitants have not only decreased the diversity, distribution, density and productivity of macrophytes but also the overall health of the lake ecosystem.

Keywords**:** DO, Quadrate method, Ramsar site, upper lake, Water chemistry

Wetlands are the biological indicators of aquatic ecosystem and are known as hotspots of biodiversity (Biswal 2019). Globally these ecotones are considered as the most productive natural ecosystems on the earth. (Sarkar et al 2019). They provide vital services for plants and animals while maintaining moderate atmospheric temperature (Singh and Parikh 2020). Macrophytes and their litter create much of wetland's physical structure and they modify the local environmental conditions of water (Van der valk 2006). The varied assembly of these plants have different adaptations, life history strategies and environmental tolerances that facilitate their survival in both saturated and flooded water (Bradley 2005). Therefore, the growth of these plants gets easily influenced by the addition of allochthonous nutrients and organic loading into the water.

Due to pollution native species of macrophytes decline and gets replaced by foreign and exotic species (Pandiarajan 2019). Thus, aquatic macrophytes act as indicators of ecological conditions of surface water quality (Sethu 2019). A part from this, mismanagement of the resources have also destabilized these fragile ecosystem raising problems like shrinkage of surface area, poor quality of water causing eutrophication etc. (Upadhyay et al 2012). This is all due to the necessity to fulfil the human need for pure water. The present study was carried out to characterize the impacts of physico-chemical properties of water on the diversity of macrophytes with special reference to Bhoj Wetland, India. Madhya Pradesh is the second largest geographical unit in the Indian country with an area 3,08,252 km^2. It is rich with different aquatic ecosystem 0.46 million hectares are under reservoirs and has the maximum water spread area under man-made lakes.

MATERIAL AND METHODS

Study area: Bhopal city with a current population of approximately 23 lakhs according to UN World Urbanization Prospects is located at 23.2599° N and 77.4126° E with a highest elevation of 550 m above mean sea level spreading over seven hills (Chouhan et al 2009). Being the oldest man-made lake in the central India, the Upper Lake was created in the early 11th century by king Bhoj across the Kolans River, a rain fed tributary of the Betwa River. This lake is an east westerly elongated shallow lake with irregular margins and has a dense growth of aquatic macrophytes and algae. The catchment area of this lake is 370 sq km, maximum water area is 3105 ha, storage capacity 100.8 million cubic meters with a water spread area 12.2 sq miles and maximum depth is 6 meters. The Lower Lake was built in 1794. This lake is situated in the heart of the city and almost entire catchment is occupied by human settlements. The Lower Lake has a surface area (water spread) of 1.29km^2, and its catchment area is 9.6km^2. The lake receives subsurface seepage from the Upper Lake. The maximum and minimum depths of both the lake were 10.7m and 6.16m, respectively. Both the Upper and Lower lake are together known as Bhoj Wetland. The 6 different stations of Bhoj Wetland were Behata village, Opposite to Christian graveyard between Lalghati, Kamla park, MVM College, Hamidia College and Lilly Talkies.The water samples were collected from the surface layer of the lake nearby shore area at a depth of 1 m by using DO sampler in three different seasons i.e. Pre-monsoon (June 2016), Monsoon (September 2016) and Post-monsoon (January 2017). The various physico-chemical parameters were temperature, dissolved oxygen and pH, which were

determined on site, where as turbidity (Aqua fast II Orion AQ 2010) chloride, alkalinity, total hardness, calcium hardness, magnesium hardness, nitrate and phosphate were determined in laboratory as per the standardized methods given in (Adoni 1985, APHA 1998). Macrophytes were collected in poly bags by an iron hook by keeping a quadrate of 1m×1m in lakes (Quadrate Method) and identified by (Adoni 1985).

RESULTS AND DISCUSSION

During the study, overall 12 species of macrophytes belonging to 7 families were observed throughout at the shore of Upper and Lower lake. Maximum number of species were related to free floating (6 species) followed by submerged (5 species), and rooted-floating type (1 species). The Araceae and Potamogetonacea family were noticed to be highly dominant in the free-floating and submerged macrophytes. The invasive species of *Eicchornia crassipes* and *Spirodella polyrhiza* were highly dominant in Site I and II during the pre-monsoon season, contributing a significant plant biomass to the lake. At sampling site III submerged species of macrophytes were more dominant. The name of macrophytes and their classification in to families have been shown in Table 1 and the physico-chemical properties during the three seasons have been listed in Table 2. Freshwater bodies are subjected to variations in the environmental factors. These factors are responsible for distribution of organisms in different habitats according to their adaptation, which allow them to survive in that specific environment. The addition of various kinds of nutrients and pollutants into water bodies brings about a series of changes in the biotic communities and physico-chemical characteristics of fresh water. So, the eutrophication of freshwaters, together with increases in groundwater abstraction and the increase of temperature may all contribute in decreasing the diversity, distribution, density and productivity of macrophytes by favoring competitive, invasive and stress-tolerant species (Sethu 2019).

Morphometric details of the sampling sites	Latitude	Longitude
Behata village in Bairagarh (Site I)	23.2653° N	77.3357°E
Christian graveyard (Site II)	23.2740° N	77.3550° E
Kamla park (Site III)	23.2506° N	77.3958° E
MVM college (Site IV)	23.2481° N	77.4016° E
Hamidia college (Site V)	23.2508° N	77.3979° E
Lilly talkies (Site VI)	23.2527°N	77.4130° E

In the present study variations in physico-chemical parameters were observed during different seasons. Spatial changes in water temperature were observed during different seasons due to the direct absorption of solar radiation by water and exothermic chemical processes of the humans which further increase the temperature (Khan et al 2017). Khan et al (2015) reported that air and water temperature of Bhoj wetland varied from 21°C to 40°C and 22.2°C to 33.8°C respectively which coincides with the present study. The pH is a key feature of an aquatic ecosystem because all the biochemical functions and retention of physico-chemical attributes of the water are greatly dependent on the pH of the surrounding medium. The pH ranges (7.2-8.9) were slightly high due to the increased rate of photosynthetic activities,

Table 1. Seasonal variations in different growth forms of Macrophytes of Bhoj wetland

Macrophytes	Family	Behta village			Christian cementry			Kamla park			Hamidia			MVM college			Lilly talkies		
		S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W
Eicchornia crassipes	Pontederiaceae	+	+	+	+	+	+				+	+		+	+		+	+	+
Spirodella polyrhiza	Araceae	+	+	+	+	+	+		+		+	+		+	+		+		+
Wolfia globosa	Araceae	+		+	+						+		+	+		+	+		+
Pistia	Araceae										+			+			+		
Azolla	Salviniaceae	+									+			+			+		
Nymphaeoids hydrophila	Menyanthaceae		+	+		+	+						+			+			
Trapa bispinosa	Trapaceae	+		+	+						+			+					+
C. demersum	Ceratophyllacea	+		+	+		+	+			+		+			+	+		
P. lucens	Potamogetonaceae			+			+	+		+						+			+
P. crispus	Potamogetonaceae							+		+									
P. nodosus	Potamogetonaceae			+			+	+		+			+			+			+
Hydrilla	Hydrocharitaceae			+				+	+	+									

resulting in increase of the bicarbonates ($HCO3^-$) and carbonates ($CO3^-$) shifting the equilibrium towards alkaline side (Khan et al 2017). The lower values of dissolved oxygen (3.6 mg/l) found at site VI during the pre-monsoon months were due to the rise in temperature. The increasing water temperature renders the oxygen to flee from the water medium because of a diminished affinity of water for oxygen (Pandiarajan 2019). The rate of decomposition of organic compounds also increases by increasing temperature, which further leads to the reduction in DO level and accumulation of nutrients. Upadhyay et al (2012) reported the DO concentration in Upper lake water ranged between 3.4-10.8 mg/l. The higher values of chloride (59.99 mg/l and 69.99 mg/l) were observed in the pre-monsoon season at site IV and V which clearly indicates that these sites were influenced by urban run-off and sewage effluents. The presence of chloride in natural water is due to dissolution of salt deposits (e.g. gallite, sylvite) so, any increase in the concentration of

Table 2. Seasonal variations in physico- chemical properties of Bhoj wetland

Parameters	Season	S-I	S-II	S-III	S-IV	S-V	S-VI
		Behta village	Christian cementry	Kamla park	Hamidia college	MVM college	Lilly talkies
pH	PRM	8.6	8.0	8.1	8.7	7.8	8.9
	M	7.9	8.1	7.9	8.0	7.9	8.4
	POM	7.5	7.8	7.2	8.4	8.1	7.6
Water temperature ˚C	PRM	27	35	35	32	31	33
	M	24.4	27.0	25.6	25.5	27.2	27.2
	POM	22.7	20.7	21.2	25.3	20.7	26
Air temperature ˚C	PRM	32	37	38	37	33	38
	M	28.4	27.4	30	28.6	28.5	30.2
	POM	26.9	24.4	24.7	28.3	24.7	29
DO mg/l	PRM	7.1	6.9	6.9	7.3	7.0	3.6
	M	7.9	4.8	7.2	8.2	8.1	6.8
	POM	8.7	9.0	9.6	8.2	8.4	8.1
Cl^- mg/l	PRM	43.99	45.99	41.99	59.99	61.99	49.99
	M	16.99	43.99	15.99	34.99	39.99	37.99
	POM	26.9	28.994	16.99	31.99	38.98	34.98
TH mg/l	PRM	180	122	160	180	220	180
	M	92	160	80	140	140	158
	POM	140	160	110	178	170	180
Ca^{++} mg/l	PRM	52.5	71.5	88.2	109.2	115.5	123.9
	M	31.11	47.09	26.91	48.77	50.46	50.46
	POM	26.9	42.05	20.1	47.0	49.6	51.3
Turbidity	PRM	14.9	22	20	28	14.9	20
NTU	M	28	25	22.8	20.4	21.2	22.3
	POM	11.0	8.1	14.7	22	27	29
TDS mg/l	PRM	183	112	120	215	233	237
	M	110	198	160	184	194	202
	POM	80	70	60	110	110	100
$PO4^{3-}$ mg/l	PRM	0.184	0.463	0.186	0.440	0.442	0.481
	M	0.175	0.515	0.113	0.437	0.467	0.546
	POM	0.045	0.063	0.042	0.056	0.467	0.53
$NO3^-$ mg/l	PRM	0.354	0.283	0.195	0.241	0.268	0.231
	M	0.082	0.121	0.103	0.094	0.095	0.095
	POM	0.049	0.052	0.047	0.212	0.174	0.250

chloride can be an indication of human induced pollution (Cl^- ranging from 50-100 mg/l is common in septic tank effluents) (Fact sheets, University of Massachusetts Amherst 2016)

The higher values of total hardness and calcium were recorded in pre-monsoon season may be due to the decreases in water cover because of evaporation which - concentrates the Ca^{++} and Mg^{2+} salts. The excessive dilution by heavy rains in the monsoon season is responsible for lowering the hardness of water. Potasznik and Szymcznyk (2015) stated the calcium concentration can be shaped by various other factors, mostly the geological structure of a catchment area, soil type, plant cover, weather conditions (precipitation, evaporation, seasonal variations) and intensity of water supply (surface runoffs, groundwater inflows and sewage). Talwar et al (2013) analyzed water samples of Upper Lake and found the hardness to vary in between 67 and 315 mg/l. In the monsoon season, higher turbidity values were observed because of the coloured dissolved organic matter or humic stains (CDOM) and suspended particles, such as silt, clay, etc. coming from nearby areas after heavy rains that stirred up the bottom sediments (EPA 2009).

Higher values of TDS were during pre-monsoon season due to the elevated water temperatures which lead to the increase in rate of evaporation as well as increase in dissolved salts (Ca^{2+}, Mg^{2+}, Na^+, K, Cl^-, $SO4^{2-}$) in water. Gupta et al (2017) analyzed the water samples of Narmada River and found the TDS to range between 108-233 mg/l. As per the standards of USEPA the average concentration of nitrates in surface water must be lower than 1 mg/l, so the nitrate concentration was within the limits. Higher concentrations of nitrate were recorded in pre-monsoon at site I and site II due to different reasons. Site I was a slum area so waste discharges containing nitrogenous content enter the catchment area while site II being possibly polluted with fertilizers due to agricultural activities. Other sources of nitrates were decaying vegetation, domestic and industrial effluents and atmospheric fall. Sharma (2006) reported the minimum range of nitrate at surface of Upper lake is 0.048 - 0.315 mg/l. The higher orthophosphate values were during pre-monsoon season because bacteria in the sediments at the bottom of the lake break down organic content of dead plants and animals creating anoxic conditions. These conditions help in the formation of ferrous-phosphate complex $Fe3^{2+}(PO4)2$ which releases soluble phosphates into the water (Wetzel 2001). Gupta et al (2017) found phosphates in Narmada river ranging between 0.01- 0.52 mg/l. Lacaoul and Freedmann (2006) also supported this studies that five major environmental variables (surface water temperature, TDS, bicarbonate and carbonates, and dissolved phosphorus) were mainly responsible for differences in the relations between the species and the environment. The deplorable water quality was observed in all sites except site III which was clearly evidenced by the colonization of submerged vegetation. The Site V of the Lower lake i.e. Hamidia College had more clay, silt content and coarse material due to the construction of bridge which catastrophically affected the distribution and abundance of aquatic plants. The abundance of free-floating invasive species in other sites together with high TDS and turbidity and low DO clearly showed that these sites have poor water quality.

CONCLUSION

Total twelve species of macrophytes were recorded during the study period from both the lakes. The present study reveals that the site Site V, VI of the lower lake were highly disturbed in pre-monsoon season due to the various activities of local inhabitants. These activities have not only decreased the diversity, distribution, density and productivity of aquatic plant communities but also the overall health of the lake ecosystem. So, it is very important to conserve the natural ecosystems that are deteriorating at an alarming rate otherwise the remnants will significantly lose their ability to sustain the present biological diversity.

REFERENCES

Adoni AD, Joshi G, Ghosh K, Chourasia SK, Vaishya AK, Yadav M and Verma HG 1985. *Workbook on Limnology*, Pratibha Publications, Sagar, 216

APHA (American Public Health Association) 1998. *Standard methods for the examination of water and waste water*. 20th Edition, New York.

Biswal A 2019. *Macrophytes of Bhoj wetland: A Pictorial guide*. Madhya Pradesh State Biodiversity Board.

Bradley JJ 2005. *Hydrogeomorphic Wetland Profiling: An Approach to Landscape and Cumulative Impacts Analysis*, Colorado State University, EPA/620/R-05/001.

Chouhan S, Shukla G, Mulchandani V, Sharma VK and Mehrotra NN 2009. Physico-chemical characteristics of certain water bodies of Bhopal, India. *Current World Environment* **33**: 55-62.

Environmental Protection Agency Ireland 2009. *Turbidity in Drinking Water*. Drinking Water Advice Note No. 5: 2009.

Gupta N and Hussain J 2017. Effect of Physico-chemical and biological parameters on the quality of river water of Narmada, M.P. India. *Water Science* **31**: 11-23.

Khan AA, Shammi QJ, Dar SH and Nabi, N 2015. Seasonal variations in physico-chemical parameters in Upper lake of Bhopal M.P. *International Journal of Applied and Universal Research* **2**(2): 1-7.

Nabi NG, Dar SH, Rashid A, Teli AR and Bashir M 2017 Seasonal variations of physico-chemical parameters in Lower Lake of Bhopal. *The Pharma Innovation Journal* **6**(11): 710-714.

Pandiarajan S, Thambiratnam S, Rajasekaran I and Sivaruban B 2019. Bio-monitoring and detection of water quality using *Ephemeroptera, Plecoptera* and *Trichoptera* (EPT) complex in Karanthamalai stream of Eastern Ghats. *Indian Journal of Ecology* **46**(4): 818-822.

Potasznik A and Szymcznyk S 2015. Magnesium and calcium concentration in the surface water and bottom deposits of a river-lake system. *Journal of Elementolology* **20**(3): 677-692.

Sarkar P, Das T and Mandal R 2019. Assessing Human Dependency on the Provisioning Ecosystem Services of Chatla Floodplain Wetland of Barak Valley, Assam, Northeast India. *Indian Journal of Ecology* **46**(3): 516-520

Sethu R, Kalidoss R, Anand S, and Rajaram R 2019. Influence of physicochemical water quality on aquatic macrophyte diversity in seasonal wetlands. *Applied Water Science* **13**:9-12.

Tamot S and Sharma P 2006. Physico-chemical status of Upper Lake (Bhopal, India) water quality with special reference to Phosphate and Nitrate concentration and their impact on Lake ecosystem. *Asian Journal Experimental Science* **20**(1): 151-158.

Received 24 June, 2020; Accepted 26 August, 2020

Singh M and Parikh P 2020. Freshwater diatoms as bio-indicators in urban wetlands of Central Gujarat, India. *Indian Journal of Ecology* **47**(1): 7-11.

Talwar R, Bajpai A, and Malik S 2013. Study of seasonal variations in Upper lake, Bhopal with special reference to impact of monsoon season. *International Journal of Environmental Sciences* **3**:3

Upadhyay R, Pandey AK, Upadhyay SK, Bassin JK, and Mishra SM 2012. Limnochemistry and nutrient dynamics in Upper Lake, Bhopal, India. *Environment Monitoring Assessment Journal* **184**: 7065-7077.

USEPA (United States Environmental Protection Agency) 2012. Water Monitoring and Assessment.

Valk AG 2006. *The Biology of Freshwater Wetlands*, 2nd eds, Oxford University Press Inc, New York, p1-12.

Indian Journal of Ecology (2020) 47(3): 769-774

Manuscript Number: 3082
NAAS Rating: 4.96

Seasonal Aggregate Effects of Water Bird Populations on Tropical Rural Lake

M. Saravanaraja, P.S. Aruna Devi and K. Nagarajan

PG and Research Department of Zoology
Sri Vasavi College, Erode-638 316, India
E-mail: drmsrsvc333@gmail.com

Abstract: The present study indented to find the cumulative summer effects on the water bird communities of Vellode Lake. Ornithological studies tinted the presence of 38 species of water birds. Exclusively presence of vulnerable *Pelecanus crispus*, near threatened *Mycteria leucocephala*, *Threskironis melanocephalus* and *Anhinga melanogaster* were noteworthy recordings of the bird survey. Limnological studies uttered that the fluctuations of water level and nutrient release alters the chemical quality of the lake water especially dissolved oxygen, pH and total nitrogen and sequential modifications among biological oxygen demand and chlorophyll-a. Present study enlighten the superfluous difficulties of the lake ecosystem and refurbishing strategies. Expounded observations and suggestions of the study should help the lake managers and policy makers to retain the naturalistic features of the lake.

Keywords: Water birds, Water level fluctuations, Nutrient release, Sequential modifications

Birds are both visually and acoustically conspicuous components of ecosystem. Over long period of the time, they are the best studied class of organisms and exhibit the most diverse range of ecological functions among vertebrates. As member of ecosystems, birds play many important roles such as seed dispersers, scavengers, nutrient depositors, insectivores, pollinators, raptors and ecosystem engineers (Parrish 2001, Croll 2006) and are considered useful biological indicator because they are ecologically versatile and live in all kinds of habitats as herbivores, carnivores and omnivores. Biological monitoring by using birds to detects unpredictable environmental changes and their cumulative effect on biological organisms. The role of birds on hydrology has rarely been studied in freshwater ecosystems. Some interesting studies on the effects of bird aggregation on the physiochemical conditions of lake water and vice versa have been published (Hanson 2003, Longcore et al 2006, Unkless and Makrewicz 2007, Roy et al 2011). The A dominant trend of bird count exercises undertaken in India has been focus on endangered birds, wetland birds, heronries and bird found be conservational significant (Urfi et al 2012). However, only a less attention is given to seasonal impacts over specific bird communities.

MATERIAL AND METHODS

Study area: Vellode lake of Erode district, South India was the study area, which is situated 12764 ft. In the total area of 75.935 ha, only 35 ha has water throughout the year i.e., the eastern region of the lake. Remaining area has moist deciduous forest with *Acacia nilotica indica* trees as main vegetation inter-spread with other trees like *Palmyra*, *Prosobis julifora* and *Euclyptus* etc. The water level of the lake is very high during rainy and winter seasons and it will set decreased in early summer until the late summer up to 50 % of water. Vellode Lake provides space for wide range of avifaunal diversity. The bird communities of the sanctuary depend on the lake water for their current activities like feeding, nesting, resting and excreting. The present study envisioned to elucidate the role of limnological characteristics of the lake on water bird populations through incorporating the results of ornithological studies and limnological studies.

The methods followed for the bird counting were point counting, direct counting method, look down method, line transects method, nest searching method, interview with locals, sky watching method and canopy watching method. Birds were identified by the help of standard field guides of Ali (1996) and Ali and Dillon Ripley (1987). Few species were identified with help of internet sources. During the study period from 2015 to 2019, every month water samples were collected at the depth of about one foot from four sampling points of the lake. All the parameters were analyzed as per the procedure of American Public Health Association (APHA 1998, 2005). Based on the results of analysis water quality indices were calculated. For the calculation water quality index consumer support group online calculators software was used.

RESULTS AND DISCUSSION

Diversity of water birds: The Vellode lake supports wide

range of avifaunal diversity. The present studies exclusively focus on water birds alone. In the bird survey nine migratory, twelve local migratory (Table 1) and seventeen residential water birds (Table 2) were recorded and identified as 11 pelecaniiformes, 2 charadiiformes, 6 ciconiiformes, 1 passeriformes, 8 anseriformes, 1 podichiformes, 5 gruiformes and 4 corachiiformes (Fig. 1). Among the water bird communities one vulnerable (*Pelecanus crispus*), three near threatened (*Mycteria leucocephala*. *Threskironis melanochephalus* and *Anhinga melanogaster*) and 34 least concern species were identified with the reference of IUCN (2013). Usually the lake supports wide range of migratory birds during winter season. However, based on water quality, availability of food and temperature extend their population in the lake. During summer months of 2013, the diversity of water bird population was highly reduced and annual the bird population also. Species richness of the water bird populations were presented in Figure 2.

Water quality monitoring: During the study period of five years, water quality of the lake was estimated (Table 3). Depletion of water quality was recorded during 2016 and 2017. In particular, dissolved oxygen, total dissolved solids, turbidity and chlorophyll-a were not within the permissible level of WHO (2005). Water quality index clearly elucidate poor status of the lake during summer. The correlation between physicochemical parameters of Vellode Lake water and diversity of water bird communities are presented in Table 4.

Increased temperature, high amount of algal growth increased rate of organic decomposition and increased coliforms bacterial populations were collectively responsible for depletion of DO level. Reduced water volume and increased water temperature were collectively reduced the dissolving rate of atmospheric oxygen in the lake water (Islam 2007, Rajkumar et al 2011). Depletion of DO of the lake water during summer may also be due to 'red drop', the process in which the photosynthesis is inhibited at higher temperature resulting in a negligible release of oxygen. The

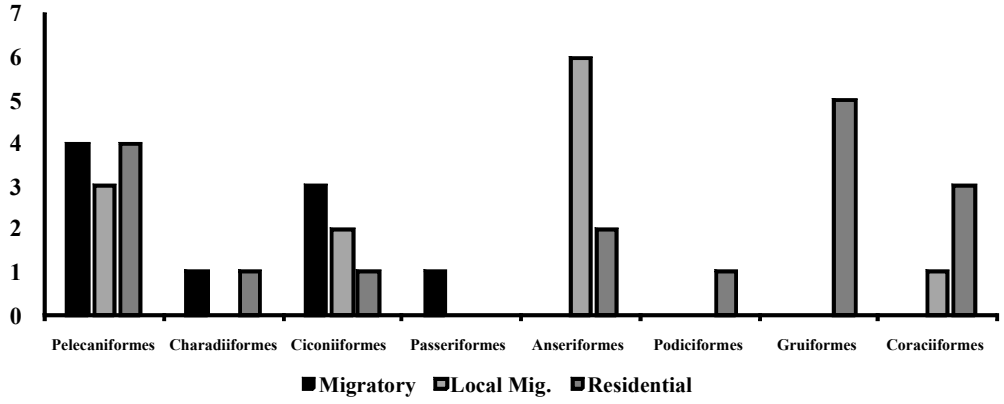


Fig. 1. Diversity of water bird communities in Vellode Lake

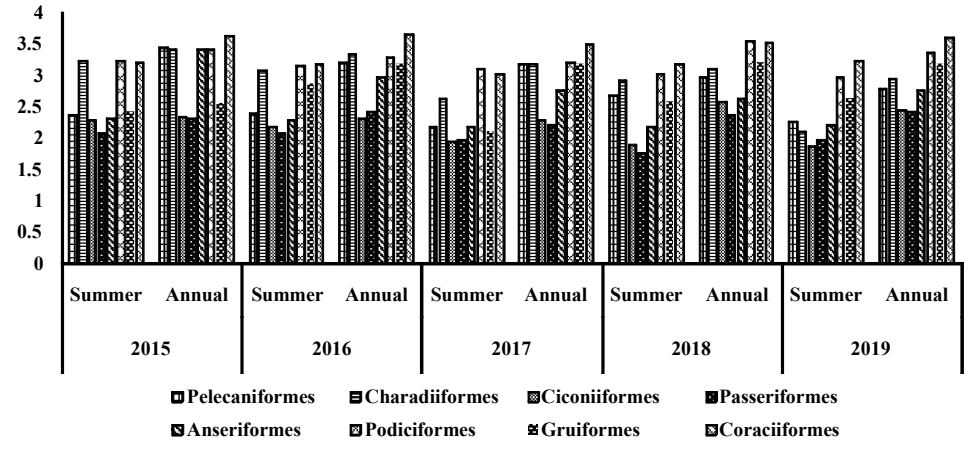


Fig. 2. Species richness of water bird communities in Vellode Lake

Table 1. Taxonomic details of recorded migratory and local migratory avifaunal diversity of Vellode Lake

Scientific name & species authority	Common name	IUCN category	Family	Order
Tachybaptus ruficollis (Pallas 1764)	Little grebe	LC	Podicipididae	Podiciformes
Microcarbo niger (Vieillot 1817)	Little cormorant	LC	Phalacrocoracidae	Pelecaniformes
Anhinga melanogaster (Lin. 1766)	Darter or Snake bird	NT	Anhingidae	Anseriformes
Aredea cinerea (Lin. 1758)	Gray heron	LC	Ardeidae	Pelecaniformes
Ardea purpurea (Lin. 1766)	Purple heron	LC	Ardeidae	Pelecaniformes
Butorides striatus (Lin. 1758)	Little green heron	LC	Ciconiidae	Ciconiiformes
Nycticorax nycticorax (Lin. 1758)	Black crowned night heron	LC	Ardeidae	Pelecaniformes
Anas poecilorhyncha (Foster 1781)	Spot billed duck	LC	Anatidae	Anseriformes
Amournis phoenicurus (Pennant 1769)	White breasted water hen	LC	Rallidae	Gruiformes
Gallicrex cinerea (Gmelin 1789)	Water cock	LC	Rallidae	Gruiformes
Gallinula chloropus (Lin. 1758)	Common moorhen	LC	Rallidae	Gruiformes
Porphyrio porphyrio (Lin. 1758)	Purple moorhen	LC	Rallidae	Gruiformes
Fulica atra (Lin. 1758)	Common coot	LC	Rallidae	Gruiformes
Sterna aurantia (Gray 1831)	River tern	LC	Sternidae	Charadriiformes
Ceryle rudis (Lin. 1758)	Lesser pied king fisher	LC	Cerylidae	Coraciiformes
Halcyon capensis (Lin. 1766)	Stork billed kingfisher	LC	Halcyonidae	Coraciiformes
Halcyon smyrnensis (Lin. 1758)	Whitebreasted kingfisher	LC	Halcyonidae	Coraciiformes

Table 2. Taxonomic details of recorded residential avifaunal diversity of Vellode Lake

Scientific name & species authority	Common name	IUCN category	Family	Order
Migratory				
Pelecanus crispus (Bruch 1832)	Dalmatian pelican	VL	Pelecanidae	Pelecaniformes
Phalacrocorax carbo (Lin. 1758)	Great cormorant	LC	Phalacrocoracidae	Charadiiformes
Mycteria leucocephala (Pennant 1769)	Painted stork	NT	Ciconiidae	Ciconiiformes
Anastomus oscitans (Boddaert 1783)	Asian open bill stork	LC	Ciconiidae	Ciconiiformes
Ciconia ciconia (Lin. 1758)	European white stork	LC	Ciconiidae	Ciconiiformes
Threskiornis melanocephalus (Latham 1790)	Oriental white ibis	NT	Threskiornithidae	Passeriformes
Pelecanus onocrotalus (Lin. 1758)	Great white pelican	LC	Pelecanidae	Pelecaniformes
Anas Penelope (Lin. 1758)	Eurasian wigeon	LC	Anatinae	Pelecaniformes
Tringa nebularia (Lin. 1758)	Common green	LC	Scopacidae	Pelecaniformes
Local Migratory				
Casmerodius albus (Sibely 1990)	Large egret	LC	Ciconiidae	Ciconiiformes
Ardeola grayii (Sykes 1832)	Indian pond heron	LC	Ardeidae	Pelecaniformes
Bubulcus ibis (Lin. 1758)	Cattle egret	LC	Ardeidae	Pelecaniformes
Mesophoyx intermedia (Wagler 1827)	Median egret	LC	Ardeidae	Pelecaniformes
Egretta garzetta (Lin. 1758)	Little egret	LC	Ciconiidae	Ciconiiformes
Nettapus coromandelianus (Gmelin 1789)	Cotton teal	LC	Anatidae	Anseriformes
Alcedo atthis (Lin. 1758)	Small blue king fisher	LC	Alcedinidae	Coraciiformes
Anas crecca (Lin. 1758)	Common teal	LC	Anatinae	Anseriformes
Anas ferina (Lin. 1758)	Common pochard	LC	Anatinae	Anseriformes
Anas acuta (Lin. 1758)	Northern pintail	LC	Anatinae	Anseriformes
Anas clypeata (Lin. 1758)	Northern shoveler	LC	Anatinae	Anseriformes
Anas gibberifrons (Lin. 1758)	Sunda teal	LC	Anatinae	Anseriformes

red drop phenomenon was also reported by Satpathy et al (2007). During winter, more than 20,000 birds were resides in the lake and which may results on deposition of the high amount of organic matter. Reduced water volume and high wind actions during the post summer season favor the high rate of microbial activity in the lake bottom. This process may also be the responsible for the depletion of the DO levels in the lake water during post summer season. The fact was supported by increased biological oxygen demand and enhanced population of the coliforms. The sediment of the lakes may be in direct contact with the photic zone during the summer season that together with a higher sediment surface per volume of water as water depth decreases which increased the importance of sediment-water interactions. Therefore, exchange of P between water and sediment was influenced by biological (bacterial activity, mineralization process, and bioturbation), chemical (Redox conditions, pH, nitrate availability) and physical (resuspension, sediment mixing) factors (Sondergaard et al 2001). Addition of bird droppings and dead aquatic biota were the major factors for the enrichment of nutrients like nitrogen and potassium of the lake sediment (Olson et al 2005). During summer, these factors in their abundance level exchange their fractions with water column of the lake. Thus, the availability of these primary nutrients enhanced the algae bloom (Rasmussen and Ceballos 2009).

During the study period, the lake received only less than 20 cm of average annual rainfall. Due to less record of North-East monsoon, the release of LBP canal water from Lower Bhavani dam was also mostly delayed to late September, where it usually opened in mid- August. In addition, absence of separate sluice delays the lake to retain the water level. High fluctuations in the water level affected the physicochemical and biological characteristics of the lake water. In particular, release of nutrients from sediment to water column, reduced rate of photosynthesis, changes in the composition of planktons and other aquatic biota and high level of human interventions to the core area where the birds prefer to nesting were highly notable observations. The present investigation also found that fall of water level to the very less quantity caused the high degree of problems for the lake to attain its high level. The problems included increased permanent plant coverage on the way of seepage water, formation of new land masses, blockings in outlets and damages to the boundaries. The monthly bird survey during the period from 2015 to 2019 revealed that the population of resident birds were steadily increased from late monsoon and attains maximum during mid-winter season. In most part of summer months the populations of resident, local migratory and migratory birds were very much reduced due to low water level and less availability of food sources. The correlation between physicochemical quality and water bird population expounded that every parameters have their own kind of relationship with different orders of water birds. Ultimately, it is proved that common management strategies with single factor concept like depletion of dissolved oxygen are not precisely fitted to the lake ecosystem.

Periodic removal of ever growing aquatic weeds like *Eichhornia* and *Azolla* through manual operations would help to maintain the aesthetic value of the lake ecosystem. Adoption of the bio-manipulation of the aquatic organisms like fishes, shrimps and other suitable organisms could improve the process of the ecosystem. Proactive public education and association of scientists and researchers with broader training are needed for maintenance of the aquatic ecosystem.

Table 3. Water quality of Vellode Lake during the period from 2015 to 2019 (All are mean values)

Parameter	Unit	2015		2016		2017		2018		2019	
		Summer	Annual	Summer	Annual	Summer	Annual	Summer	Annual	Summer	Annual
Atmp. temperature	^{0}C	33.6	26.8	33.5	27	35.5	26.5	34.2	27.4	36.5	27.7
Water temperature	^{0}C	29.5	23.5	29.8	23.3	30.2	24.5	29.2	24.2	30.1	25
Ph	-	7.92	7.4	8.23	7.5	8.4	7.8	7.9	7.48	8.19	7.62
Turbidity	NTU	3.5	3.1	6.2	5.6	10.7	6.9	8.7	6.7	7.6	6.9
Total dissolved solids	mg/l	318	290	325	305	418	385	393	374	402	380
Dissolved oxygen	mg/l	4.3	5.2	4.3	5.3	4.1	4.9	4.7	5.5	4.5	5.3
BOD	mg/l	23	19	29	19	38	26	34	24	29	26
Total kjeldhal nitrogen	mg/l	5.3	4.8	5.6	4.8	5.9	5.2	4.9	4.6	5.6	5.2
Chlorophyll – a	µg/l	18.6	8.5	19.5	9.1	29.5	11.7	21.8	11.3	19.9	9.3
Water quality index	-	43	46	40	46	42	45	46	56	44	53

Note: Summer values are mean of March, April, May and June; Annual values are mean of from January to December

Table 4. Correlation between physicochemical parameters of Vellode Lake water and diversity of water bird communities

Parameter	Pelecani.		Charadrii.		Ciconii.		Passeri.		Anseri.		Podichi.		Grui.		Corachi.	
	Summer	Annual	Summer	Annual	Summer	Annual	Summer	Annual	Summer	Annual	Summer	Annual	Summer	Annual	Summer	Annual
Atmp. temperature	-0.36	-0.81	-0.98	-0.69	-0.76	0.75	-0.23	0.81	-0.65	-0.42	-0.75	0.56	-0.33	0.42	-0.07	0.14
Water temperature	-0.86	-0.79	-0.64	-0.92	-0.22	0.35	0.41	-0.12	-0.18	-0.67	-0.22	-0.06	-0.29	0.52	-0.37	-0.53
Ph	-0.77	-0.33	-0.46	-0.47	-0.22	-0.33	0.29	-0.57	-0.27	-0.56	-0.18	-0.71	-0.25	0.52	-0.59	-0.58
Turbidity	-0.1	-0.82	-0.56	-0.83	-0.84	0.32	-0.66	0.02	-0.94	-0.98	-0.68	-0.19	-0.52	0.96	-0.63	-0.64
Total dissolved solids	-0.09	-0.77	-0.76	-0.88	-0.93	0.41	-0.66	-0.22	-0.95	-0.88	-0.81	-0.06	-0.5	0.73	-0.41	-0.8
Dissolved oxygen	-0.92	-0.4	-0.14	-0.21	-0.45	0.8	-0.69	0.83	-0.33	-0.18	-0.55	0.83	0.48	0.19	0.65	0.2
BOD	-0.07	-0.78	-0.34	-0.88	-0.69	0.32	-0.61	-0.28	-0.86	-0.79	-0.53	-0.13	-0.44	0.63	-0.75	-0.73
Total kjeldhal nitrogen	-0.93	-0.28	-0.39	-0.43	0.02	-0.46	0.56	-0.35	0	-0.19	0.04	-0.73	-0.31	0.2	-0.49	-0.11
Chlorophyll – a	-0.46	-0.36	-0.25	-0.42	-0.44	0.26	-0.29	-0.54	-0.62	-0.75	-0.21	-0.07	-0.77	0.59	-0.94	-0.98
Water quality index	-0.33	-0.78	-0.59	-0.72	-0.2	0.97	0.12	0.52	-0.02	-0.69	-0.21	0.75	-0.37	0.47	0.29	-0.31

CONCLUSION

Populations of water bird communities of the lake ecosystem are considerably scratched by the cumulative summer effects. The cumulative effects are enhanced by fluctuations of water level and abundance of bottom sediment. Consequently the alteration in the physicochemical features of lake water leads to less availability of the food in the lake area for water birds. High level of turbidity made that the lake water as an unfit to even swimming of the birds. Expounded observations and suggestions of the study should help the lake managers and policy makers to retain the naturalistic features of the lake.

REFERENCES

Ali S 1996. *The book of Indian Birds*, 12th Ed., Bombay Natural History Society.

Ali S and Ripley D 1987. *Hand Book of the birds of India and Pakistan*. Compact Ed., OUP, Bombay.

APHA: American Public Health Association 1998. *Standard methods for examination of water and waste water*. 20th Ed., New York, USA.

APHA: American Public Health Association 2005. *Standard methods for examination of water and waste water.* 21st Ed., New York, USA.

Croll DA, Maron JL, Estes JA, Danner EM and Byrd GV 2005. Introduced predators transform subarctic islands from grassland to tundra. *Science* **307:** 1959-1961.

Hanson AR 2003. Chemical limnology and water bird community of an urban constructed wetland. In: Proceedings of the 4th Conference: *Aquatic birds working group of Societas Internationalis Limnologiae (SIL)*. Sackville, Canada, 26.

Islam SN 2007. Physico-chemical condition and occurrence of some zooplankton in a pond of Rajshahi University. *Bangladesh Journal of Fisheries and Hydrobiology* **2**: 21-25.

IUCN: International Union for Conservation and Nature 1996. *Pan African symposium on sustainable use of natural resources and community participation*, Harare, Zimbabwe. June, 24-27.

IUCN: International Union for Conservation of Nature 2003. *Guidelines for the application of IUCN Red list Criteria at regional levels*. Ver.3. IUCN Species survival commission, Gland, Switzerland and Cambridge, UK.

IUCN: International Union for Conservation of Nature 2004. *Assessing Northern area progress towards sustainability Baseline Report.* IUCN, Northern Areas Programme. Jutial, Gilgit.

Longcore JR, McAuley DG, Pendelton GW, Bennatti CR, Mingo TM and Stromborg KL 2006. Macro invertebrate abundance, water chemistry and wetland characteristics affect use of wetlands by avian species in Maine. *Hydrobiology* **567**: 143-167.

Olson MH, Hage MM, Binkley MD and Binder JR 2005. Impact of migratory snow geese on nitrogen and phosphorus dynamics in a freshwater reservoir. *Freshwater Biology* **50**: 882-890.

Parrish JK 2001. Direct and indirect effects: interactions between Bald eagles and Common murres. *Ecological Applications* **11:** 1858-1869.

Rasmussen and Ceballos 2009. The effects of sediment removal on internal nutrient cycling and eutrophication in lake Allatoona. In: *Proceedings of the Georgia Water Resources Conference*, 2009, The University of Georgia.

Roy US, Goswami AR, Anulipi A and Mukhopadhyay S 2011. Changes in densities of water bird species in Santragachi lake, India: Potential Effects on limnological variables. *Zoological Studies* **50**(1)**:** 76-84.

Satpathy KK, Mohanty AK, Sahu G, Prasad MVR, Venkatesan R, Natesan U and Rajan M 2007. On the occurrence of *Trichodesmium erythraeum* (Ehr.) bloom in the coastal waters of Kalpakkam, east coast of India. *Indian Journal of Science of Technology* **1**(2): 1-9.

Sondergaard M, Jensen JP and Jeppesen E 2001. Retention and internal loading of phosphorus in shallow; Eutrophic lakes. *The Scientific World* **1:** 427-442.

Unckless RL and Makarewikz JC 2007. The impact of nutrient loading from Canada Geese (Branta canadensis) on water quality, a mesocosm approach. *Hydrobiology* **586**: 393-401.

Urfi AJ, Sen M, Kalam A and Meganathan T 2012. Counting binds in India. Methodologies and trends. *Current Science* **89**(12)**:** 1997-2003.

Received 22 June, 2020; Accepted 19 August, 2020

Indian Journal of Ecology (2020) 47(3): 775-781

Manuscript Number: 3083
NAAS Rating: 4.96

Issues and Problems of Small-Scale Fishing (SSF) Communities in South Asia: A Comprehensive Overview

Mohammed Mamun Rashid, Azlinda Azman*, Paramjit Singh Jamir Singh and Md Isahaque Ali

Social Work Programme, School of Social Sciences, Universiti Sains Malaysia, 11800, Penang, Malaysia
**E-mail: azlindaa@usm.my*

Abstract: Fishing and aquaculture activities have become the main suppliers of food and nutrition all around the world. These two activities are also the source of livelihood for many people across the globe. Almost 90% of the global fish production takes place in Asia, specifically in South Asian countries. However, issues like over-fishing, lack of governance, and sustainability have started to threaten SSF communities around the region. This conceptual paper aims to examine issues and problems plaguing SSF communities in South Asian countries. The data reveal that the adverse effects of climate change has seriously impended lives and livelihoods of fishing communities. In this regard, ethnic fishing communities are more vulnerable to globalization, emergence of capital penetration, poverty-stricken conditions and being entrapped in high debt. Communities of SSF have partial set of skills and resources for coping with the ever-changing internal and external elements, including shocks and vulnerabilities. This paper also presents recommendations for policy changes, including livelihood diversification, policy inclusion and capacity development to improve lives and livelihoods of these economically and socially downtrodden people.

Keywords: South Asia, Issues, Challenges, Fisheries communities

Fishing is a form of traditional occupations and people have been fishing for food since the beginning of mankind. The important role and contribution of SSF have been historically articulated and conventionally recognized in several areas like social and economic development, food security and employment. Human consumption of fish has doubled (3.2%) in comparison to population growth (1.11%) in the past five decades, resulting in the increase in the normal per capita obtainability of fish beyond 20 kilograms (Food and Agriculture Organization (FAO), 2018). At the global level, 171.1 million tons of fish are produced annually from fisheries and aquaculture activities. Subsequently, fish has highly contributed to food and nutrition security. Fish accounts to nearly 17% animal protein consumption worldwide, and up to 72% of animal protein consumption in some South Asian countries. Almost 90% of the global fish production takes place in Asia, specifically in South Asian countries like India and Bangladesh, which are ranked as the 2nd and 5th biggest fish producers in the world. Mass consumption, habitat destruction, unfair uses of resources and exploitation have put a strain on the natural environment and major depletion of natural resources around the world. This has created serious concern over sustainability. As a result, humans are experiencing negative effects in a variety of ways, procedures and complex responses (Mozumder et al 2019). The supply of fish has become more fragile globally due to excessive fishing and mismanagement and this has brought negative impacts to the world's economy (World Bank 2014). Giri (2018) highlighted the emerging problems of overfishing and lack of sustainability in the SSF in Nepal due to reckless human actions, corrupted market policies and practices. The similar deteriorating trend is also evident in the supply of Tuna Fish in Sri Lanka. Other countries like Korea, Japan and Taiwan have also experienced the decrease in fish supply due to several economic causes and lack of enforcement to control exploitation. Similarly, Pakistan is also suffering from the over-exploiting of its fisheries. Many commercial fish species are facing substantial overfishing and some areas have already exhausted their fish supplies. In this light, Pakistan's maritime areas are largely open and could be accessed by everyone, which exposed this area to exploitation. In addition, the government has limited fishing to control inputs, such as granting fishing licenses or controlling output through the provision of a sharing system.

Islam and Chuenpagdee (2013) found that fishing communities are economically and socially vulnerable. They are highly exposed to natural disasters, accidents at sea, pirate attacks, loan sharks, insecurity of food, and drinking water problems, illness and health problems, manipulation as well as social exclusion. Rahman and Schmidlin (2019) stated that fishermen fishing at sea face dangers due to the hostile marine environment, instable boat-based activities, faulty gears, loneliness, and fatigue, which subsequently lead to a high rate of fatality among fishermen. The death of

the fishermen, who were the major breadwinner could have negative impact for the family well-being and will cause them to slip into hardcore poverty. Thus, vulnerabilities of these households could decrease by increasing boat operations safely, networking among respective families, controlling of criminal activities at sea, providing financial support to lessen debt, communication, information and learning regarding entrance to markets for selling fishes. The female-led households are usually more susceptible to food insecurity compared to male-led households. Consequently, these households have lower adaptation capacities as they have little access to schooling and have limited set of skills and income capabilities (Hossain et al 2016, Ali et al 2016). Based on the discussion above, the aim of this paper is to examine issues and problems of SSF communities in South Asia, predominantly in Bangladesh, India, Pakistan, Sri Lanka and Nepal. Hence, this study addresses the effects of climate change, poverty and debt cycle, jolts and vulnerability, adaptation mechanism, flexibility and living conditions from the South Asia perspectives.

Fishing situation in the globe: Fishing has become the main source of income and livelihood for many people. In 2016, approximately 59.6 million individuals were involved in fishing and aquaculture activities (FAO 2018). Cheung et al (2016) observed that the supply of fish and marine produce is forecasted to reduce by up to 30% by 2050 due to global warming and changes in main production. This scenario is largely due to the lack of management by national governments and this could have detrimental effect on socio-environmental aspects. In this regard, there are still huge knowledge gaps about contribution and feature of SSF. The agricultural and food industries are significant to achieve targets of Sustainable Development Goals (SDGs) by 2030. A majority of SDGs are directly link to aquaculture and fisheries, particularly SDG 14. FAO (2018) indicated that

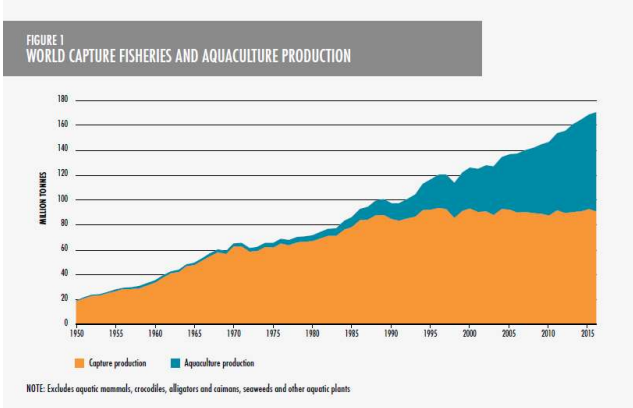


Fig. 1. World capture fisheries and aquaculture production (source: FAO, 2018)

while the yield of wildly caught fish has relatively been static since the late 1980s, aquaculture has been deemed as the step forward in the continuing development in providing sufficient amount of fish to cater to the world's population.

The total marine catch around the world was 81.2 million tons during 2015. However, the number decreased to 79.3 million in 2016, which is two million tons lesser than the previous year. China is the world's main producer of marine products, in which for 2016, it recorded a yield of 4.6 million. The fishery industry in the rest of Asia generated a yield of 3.5 million, which comprises of 75% of the world fish yield (FAO, 2018). The FAO Code of Conduct was introduced in 1995 to establish a global ethics of behavior for good practices to ensure real preservation, administration and optimizing the existing marine resources, including their ecosystem and biodiversity. Hosch (2009) critiqued that the Code of International Standards was not followed by users and respective stakeholders. For instance, in India, fish stock calculation conducted on 52 species of coastal and marine lives based on ecology data composed from arrival stations across peninsular India during 2012-2016 (Central Marine Fisheries Institute 2017). It is also indicated that stocks of 55.77% of fish species are below the physically maintainable layers due to over-harvesting from fish stocks, and yet to reach Maximum Sustainable Yield (MSY) (Giri 2018).

Issues and Challenges Faced by Fishing Communities in South Asia

Issues and challenges faced by poor fishing communities affecting the security of food, livelihoods and fishing environments in developing countries, especially in South and Southeast Asian countries are discussed below.

Climate change and fishing communities: Living cycle, migration shape, feeding, reproduction and behavioral patterns of fish have changed rapidly due to adverse effect of climate change. It has negative effect on biological and physical characteristics of fish (Hossain et al 2016, Ali et al 2014). The synthesis from Report of the Intergovernmental Panel on Climate Change (Intergovernmental Panel on Climate Change 2014) shows that since the pre-industrialization era, the average global sea surface temperature on land and on the ocean surface increased by 0.85°C (0.65°C to 1.06°C). The livelihood of SSF is also threatened by the increase in incidence of natural disasters as a result of climate change. In this regard, climate change can have multifaceted impact on the livelihood and economic well-being of SSF due to its impact on the productivity and distribution of fishery reserves, as well as the supply of fisheries (Ali et al 2019).

One of the countries facing the serious impact of climate change is Bangladesh. Climate change has been linked to

complex problems like food and income security, as well as health and development in different areas of Bangladesh. It is predicted that the climate change will lead to more frequent natural disasters like tropical cyclones, flood, storm surge and drought to the region. South Asia will be experiencing with heavier rain falls during the monsoon season in the nearer future. This could make people living in low laying parts of the Bangladeshi coastal areas to lose their home. It is projected that 30 million people living in coastal communities will move to urban settlements for search of livelihoods by 2050 (Intergovernmental Panel on Climate Change 2014).

In India, climate change causes major disruption in marine ecologies due to the heating and acidification of seawater, salinity variations, eutrophication and changes of current near the shore. The preliminary productivity of marine ecologies depends on the biophysical and chemical interactions in the marine environment. Environmental variables, such as sea surface temperature (SST), wind, currents, rainfall, Sea Level Anomaly (SLA) and chlorophyll will extremely impact the fishery resources and yield of fish from coastal waters.

In Nepal, the climate change affects the socio-economic condition of fishermen and related communities. Decreasing lakes area and water flows in river due to sudden extreme weather events and scarcity of water. This has changed the dimension of the fishery and aquaculture sector. The increasing temperature affects the water quality in lakes and reservoirs, which subsequently altered the feeding and growth pattern of aquatic species. The changes in temperature also affect the migration of species and reduce water quality which could also affect the health of people and animals.

In Pakistan, there are multifaceted pathways which climate change influences the productivity and distribution of fish reserves, which then has serious economical implication. While climate change effects on biological variables are anticipated, its relative impact on fisheries sub-sectors and the level of disturbance on the fishing industry is still unclear.

In Sri Lanka, oceanic currents from the regional oceanic circulation around the continental shelf create seasonal changes in winds and temperature patterns. On the east coast, the currents are strongest during the northeast monsoon when they show an easterly trend, while on the west coast, they are strongest during the southwest monsoon with a westerly trend.

Meanwhile, in Bhutan, fish supplies are relatively unstable and the weather conditions particularly can differ significantly over time due to cyclical unpredictability. For instance, temperature of water and flows recurrent variations affect the fish population in terms of their growing rates, habitat, and yield. Such changes could disturb the obtainability of fish resources and create a need for different fishing equipment. This will affect the productivity of the fishing industry and change in how fishery scientist interpret catch and catch rate information.

Climate change has many adverse effects such as coastal and riverbank erosion, salinity, tidal surges, seal level rise, temperature as well as rainfall variations. According to IPCC AR5, SSF communities of South Asia are at risk due to their low capacity for adaptation with hostile effects of climate change. Hasan and Nursey-Bray (2018) reported that ethnic fishermen living in the coastal areas of South Asia are susceptible to deaths due to extreme weather. They also face physical-setting, socio-economic and institutional obstacles for coping with lives in the coastal fishing populations.

Poverty and Debt Cycle of Small-Scale Fisheries

South Asian fishing communities struggle for living and working in dangerous surroundings. They have very poor representation and inclusion in the existing policy. They lived in poverty and in unproductive situations or environment that is beyond their control (FAO 2010, Jentoft et al 2011, Pomeroy and Andrew 2011). Poverty-stricken fishing communities are exposed to starvation and lack of adequate shelter. Children from these households are also exposed to sickness and malnutrition due to the inadequate access to clean water and lack of access to quality healthcare. Most of the time, these children are not able to go to school, have limited or no reading and writing skills and are not able to speak properly. Poverty leads to the lack of employment opportunities except fishing at surrounding areas and the absence of representation and social position. SSF communities are plagued with issues pertaining income and consumption, environmental risk, power structure, social positioning, access to legal rights, human rights situation, control over natural resources and influence relationship in the society.

Marine fishermen can be categorized into three groups that is those who go for deep-sea fishing for 15–20 days, near-shore fishermen who go and come back to shore daily, and fishermen who fish in the estuary. Within these clusters, the most powerful group is the boat owners who usually organize large-scale fishing expeditions (Hasan & Nursey-Bray 2018). In South Asia, several commercial standards (fish catches, housing, land ownership, capital investments, household loan liability, etc.), control of income, diverse shared characteristics (such as literacy, access to education, health and other basic services) as well as social manifestations of poverty (such as power relatives) have been included in poverty discussion. Poverty among fishermen is not a one-dimensional phenomenon, and lack of

income is just one of the myriads of factors. Poverty is attributed by a number of other factors like 'capabilities', (i.e. nutrition, health and education etc.), weaknesses, and political influences. There are four categories of discrimination, namely class discrimination, economic exclusion, community disregarding, and disempowerment. These injustices restrict persons' or groups' command over assets or capitals that, in turn, significantly lead to poverty (Islam 2011).

Islam (2011) argued that formal education is very important to empower fishing communities. Basic education is one of the important pillars to tackle adverse situations and to be resilient during and after disaster. Fishermen with some basic education prove to be more resilient in times of disaster by having more capability to make livelihood choices. When their possessions are demolished, SSF have to reconstruct their livings, but deprivation from entitlement and capability, limited access to alternative skills than fishing force them to be dependent on natural resources. To increase their income, some fishermen use destructive equipment or aiming endangered species which put a burden on the marine and coastal ecosystem.

Fishermen in the coastal areas of South Asia are living in poverty-stricken condition. Their earnings are seasonal and the yearly income of fishing communities varies significantly. Wealthy boat owners often manipulate fishermen as under paid workers. Some fishermen also gradually turn to bonded labor due to unpaid loans to moneylenders. In general, moneylenders control fishing grounds in coastal area as a majority of fishermen depend on them for loans. This 'debt trap' creates negative impacts to the fishery industry South Asia. SSF communities of South Asia are also highly vulnerable due to depletion of fish catches in their fishing grounds. Income reduction is a big issue and it has become difficult for majority of fishermen to maintain their families using their income.

Shocks and Vulnerability

Vulnerability and poverty are connected but are not the same (Béné 2009, Jentoft and Eide 2011). Vulnerability is reflected by the options available to families and individuals to make a living, the challenges they face and their capability to overcome these challenges. Vulnerability also refers to the lack of “defensive security” (Jentoft and Midré 2011). Meanwhile, poverty concerns deficiency. Vulnerability and poverty among SSF are inter-connected to the lack of access to natural resources, dishonesty and wrongly enforced rules with affect their livelihood. Singh et al (2019) stated that existing laws and policies related to SSF management does not necessarily enforced to the best interest to those living in poverty, including SSF. Some policies have also been deemed to threaten the livelihood of fishing communities as they lead to resource depletion and income reduction.

Fishermen are also concerned about safety at sea as they are vulnerable to pirate attacks. Thus, consolidation of fishing rights and security improvement could help increase their well-being (Allison et al 2011). Islam (2011) mentioned that, in several cases, fishermen are defenseless against mistreatment by middlemen or administrative bureaucrats who are incapable to deliver “protective security”. Islam (2013) also revealed that vulnerability not only varies between communities of fishermen in South Asia, but also between different household clusters within a community, based on fishermen experience, compassion and adaptive capacity. Fishing communities face various restrictions and obstacles to fishing operations caused by natural disasters. Limitations include physical features of climate and sea, such as higher incidence of natural disasters. Obstacles include poor maintained fishing vessels, inaccurate weather predictions, weak radio signals, lack of access to low interest loans, limited income, underestimation of cyclone incidence, boat-owners pressure, limited access to education, limited livelihood alternatives, unfair loan arrangements, absence of enforcement of fishing and maritime laws, and entrance for marketing of fishes.

Faster fishing trips during rough weather, adaption with natural disasters at sea, safe return from fishing grounds by good vessels, on time responses to cyclones and livelihood variations are evolving elements in safeguarding of SSF communities of South Asia. Cyclones and floods have an overwhelming effect on the lives and properties, i.e. the overall capital system. Fishermen in South Asia are at frontline of such negative effects and facing these characteristics periodically. Many fishermen are missing frequently due to rough weather at sea. Unfortunately, the government of these countries do not keep proper records of the missing or dead. Roads, transport links, different physical assets and fishing gears are wiped out. They have minimum access to health and basic services, and rehabilitation schemes after natural disasters. These make them more vulnerable in the community (Ali, Hatta and Azman 2014).

Coping, Social Resilience and Livelihoods

Islam and Chuenpagdee (2013) mentioned that fishing communities in South Asia employ a number of adaptation strategies, including lessening and alteration of meal patterns, income discrepancy through releasing labor and changing instrument, fishing illegally, and drawing from mutual insurance and social network. The capacity of a family to adapt with the effects of astonishment exposure depends on the family's productive capacity (e.g. capitals, endowments and labor), and family features (dependency

ratios), entree to social networks, power, and other factors. Population increase, climate change, as well as rapid suburbanization have put burdens on marine resources. In this condition, a majority of SSF households in South Asia are facing the similar problems (e.g. depleting resources in fisheries sector) that place a strain on sustainability. The SSF also face social and economic exclusion as they face rejection from entering a shared property for fishing. Subsequently, the helpless and poorest fishers often have to give up their rights to fish due to bureaucracy and corruption culture where influential elites will be promised in the administrative arrangement (Islam 2011).

A sufficient and stable low of income and food security are crucial to safeguard the livelihood of SSF. Fishermen are forced to stop fishing because of bad weather and high tidal waves during time of rainy season. Furthermore, fishermen are susceptible to pirate attacks and other criminal activities at sea which have made fishing activities dangerous. This seasonality or disruption in fishing activities disrupt fishing operations and consequently, threatens their earning and food security. On the other hand, in some cases, fishermen are accountable for their reckless conditions such as alcoholism which create a further financial strain for them (Salas et al 2011, Bavinck 2011). The lack of centralized support and poor welfare management has created further discrimination to the poor. In this regard, fishermen are often exploited or victimized by the authorities and middlemen (Jentoft et al 2011). Fish is a highly valued product compared to other agricultural products in South Asia. SSF communities are often disadvantaged because they are not getting a reasonable share of their fish yield due to bureaucracy from the authority and debt slavery which forced them to sell their fish at lower price to the middleman.

Moreover, as fishing is broadly a seasonal profession, SSF often have limited fishing rights and limited choice of fishing grounds. This has made fishing a short-term way to gain an income. SSF families often face food shortages and experience hidden starvation or pseudo-famine. Thus, the government, NGOs and development partners need to consider steps like allocating fish grounds for small scale fishermen, adaptive management for preservation of fishery resources, providing and skill development training for professional diversity, undertaking socio-economic and political empowerment programs for institutional improvement, providing micro loan, allocation of land, and building of safer homes that could withstand natural disasters like cyclones (Deb and Haque 2011).

CONCLUSION

The livelihood of SSF communities in South Asia is very vulnerable. Myriad institutional and policy initiatives should be taken to ensure socio-economic improvement of fishing communities in South Asia. Thus, this paper supports the comprehensive DFID's livelihood model for improving well-being of SSF communities in South Asia. The Sustainable Livelihood Approach (SLA) is people-centered and provides an integrated interpretation about people's livelihoods within social, institutional, political, economic and environmental contexts (Department for International Development [DFID] 2000) in which the SLA has the most powers. The framework distinguishes or determines: (i) the diversification nature of livelihoods; (ii) institutionalized difficulties in improving livelihoods; (iii) the social and economic landscapes of livelihood strategies; (iv) the main aspects that reduce or increase vulnerability; and (v) the micro-macro or macro-micro linkages that bridge livelihoods to policies. All these identifications, in order, will help to recognize the appropriate access facts to support the livelihood of people (DFID 2000).

The livelihoods of the fishing community depend on earning, well-being, food security, sustainable usage of natural resources and reducing vulnerability. Livelihoods diversification is strongly recommended for sustainable development of fishing communities in South Asia, as discussed below:

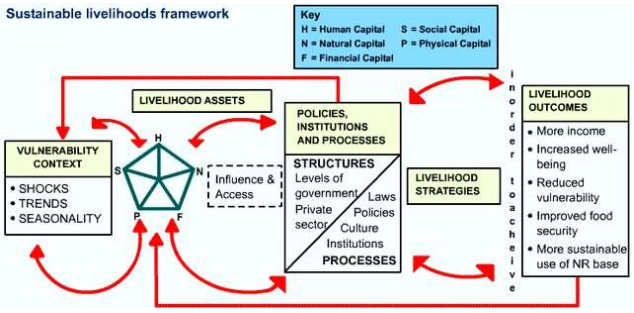


Fig. 2. The DFID's sustainable livelihood framework (Source: DFID's, 2000)

Livelihood: SSF should use different gears for different fish species, season, weather and tidal elevation. In this light, introducing different gears could bring maximum benefit for fishermen. Furthermore, fishermen should be provided with technical training that will maximize the efficiency of the fishing industry and to safeguard the economic and social implication of fishing to the national economy. Another significant issue is the lack of security of fishing grounds, especially for small-scale fishermen. It is necessary to ensure strong law enforcement to safeguard the security at fishing grounds. To protect fishermen from pirates, there is a need for authorities like the Coast Guard, Navy, Forest Guard and Police to conduct joint security operation. Moreover, the

Coast Guard could intensify their regular operation at night to prevent pirate attacks at night time. Government should also establish interest-free credit facilities for fishermen and their family members to avoid dependency on middlemen for loans at higher interest rates. The government should also encourage SSF to find alternate livelihood options for SSF. The depleting fish resources has placed restriction for fisherman to catch fish. Thus, alternative livelihood, particularly off- season farming activities should be arranged for them. The change of policy is an important element for socio-economic development of fishing communities from the South Asian perspectives. Multi-sectorial policies have been established to secure the well-being of fishing communities and fisheries sector.

Policy initiatives: Multidisciplinary approaches involving the public sector, private sector, fisherman communities and NGOs will help recognize the complex problems in managing SSF. The implementation of effective management systems is necessary to prevent over exploitation of fishery resources. The government should ban foreign trawling in their own territory. Sophisticated fishing gears should be banned to reduce over exploitation. Legal frameworks for community level management and decision-making must be further strengthen. Policy makers should ensure the active participation of representatives from fishing communities so that issues and concerns of SSF communities could be considered during policy formulation and execution. The increases of women's participation in decision-making in the community and other organizations, as well as capacity building of fishing communities and respective stakeholders are recommended to further develop South Asian fishing communities.

Capacity development: Empowering stakeholders through capacity development (via training, education, exchange and exposure visit, collaborative programs) and institutional strengthening through active institutional linkages and better communication between South Asian member states and their international partners, strengthening the fisheries departments and ensuring strong coordination with other service are beneficial for the growth of fisheries in the region.

REFERENCES

Allison E H, Ratner B D, Åsgård B, Willmann R, Pomeroy R and Kurien J 2011. Rights based fisheries governance: From fishing rights to human rights. *Fish and Fisheries* **13**(1): 14-19.

Ali I, Rameeja S, Maruthi A Y, Azman A, Singh P, Bala J, Ahmad A, Rafatullah M, Ismail N and Hossain K 2019. Impacts of climate change on disadvantaged coastal communities, pp. 42-59. In: Karmaoui A (ed). *Decision Support Methods for Assessing Flood Risk and Vulnerability.* IGI Global, USA.

Ali I, Hatta Z, Azman A, Islam S, Mazumder AH and Hossain K 2016. Community participation in disaster management: A case study of Bangladesh. *Indian Journal of Ecology* **43**(2): 463−472.

Ali I, Hatta Z and Azman A 2014. Transforming the local capacity on natural disaster risk reduction in Bangladeshi communities: A social work perspective. *Asian Social Work and Policy Review* **8**(1): 34−42.

Béné C 2009. Are fishers poor or vulnerable? assessing economic vulnerability in small-scale fishing communities. *Journal of Development Studies* **45**(6): 911-933.

Bavinck M 2011.Wealth, poverty, and immigration: the role of institutions in the fisheries of Tamil Nadu, India, pp 172-19. In: Jentoft S and Eide A (eds.), *Poverty Mosaics: Realities and Prospects In Small-Scale Fisheries.* Dordrecht, Springer Science+Business Media BV.

Central Marine Fisheries Institute 2017. *Annual Report 2016-17.* Kerala, India.

Cheung W, Jones M, Reygondeau G, Stock C, Lam V and Frohlicher 2016. Structural uncertainty in projecting global fisheries catches under climate change. *Ecology Model* **325:** 57-66.

Deb AK and Haque CE 2011. Sufferings start from the mothers' womb': vulnerabilities and livelihood war of the small-scale fishers of Bangladesh. *Sustainability* **3**(12): 2500-2527.

Department for International Development 2000. Sustainable livelihoods guidance sheets. Retrieved from http://www.livelihoods.org/info /info_guidancesheets.html.

Food and Agriculture Organization 2010. *The State of World Fisheries and Aquaculture*. Fisheries and Aquaculture Department. Rome, Food and Agricultural Organization of the United Nations.

Food and Agriculture Organization 2018. *The State of World Fisheries and Aquaculture 2018-Meeting the Sustainable Development Goals*. Rome, Italy.

Giri SS 2018. *Small-Scale Fisheries in South Asia*. SAARC Agriculture Centre, Dhaka- 1215, Bangladesh.

Hossain K, Quaik S, Ismail N, Rafatullah M, Ali I, Hatta Z, Avasn M, Pant G and Rameeja S 2016. Climate change-perceived impacts on agriculture, vulnerability and response strategies for improving adaptation practice in developing countries (South Asian Region). *International Journal of Agricultural Research* **11**(1): 1-12.

Hasan Z and Nursey-Bray M 2018. Artisan fishers' perception of climate change and disasters in coastal Bangladesh. *Journal of Environmental Planning and Management* **61**(7): 1204-1223.

Hosch G 2009. *Analysis of the Implementation and Impact of the Fao Code of Conduct for Responsible Fisheries since 1995.* FAO Fisheries and Aquaculture Circular, (C1038), I.

Intergovernmental Panel on Climate Change 2014. *Climate Change: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects*. In Working Group II to the Fifth Assessment Report of the IPCC, Cambridge, U.K. and New York, Cambridge University Press.

Islam T, Azman A, Singh P J S, Ali I, Akhtar T, Rafatullah M, Ismail N and Hossain K 2019. Socio-economic vulnerability of riverbank erosion of displaces: case study of coastal villages in Bangladesh. *Indian Journal of Ecology* **46**(1): 34−38.

Islam MM 2011. *Living on the Margin: The Poverty-Vulnerability Nexus in the Small-Scale Fisheries of Bangladesh*. Springer, Dordrecht.

Islam MM 2013. *Vulnerability and Adaptation of Fishing Communities to the Impacts of Climate Variability and Change: Insights from Coastal Bangladesh*. University of Leeds.

Islam MM and Chuenpagdee R 2013. Negotiating risk and poverty in mangrove fishing communities of the Bangladesh Sundarbans. *Maritime Studies* **12**(1): 7.

Jentoft S, Eide A, Bavinck M, Chuenpagdee R and Raakjær J 2011. A better future: prospects for small-scale fishing people. In: Jentoft S and Eide A (eds) *Poverty Mosaics: Realities and Prospects In Small-Scale Fisheries*. Dordrecht, Springer Science+Business Media BV.

Jentoft S and Eide A 2011. Setting the Stage. In: Jentoft S and Eide A

(eds). *Poverty Mosaics: Realities and Prospects in Small-Scale Fisheries*. Dordrecht, Springer Science+Business Media B V.

Jentoft S and Midré G 2011. The Meaning of Poverty: Conceptual issues in small-scale fisheries research, pp. 43-68. In: Jentoft S and Eide A (eds). *Poverty Mosaics: Realities and Prospects in Small-Scale Fisheries.* Dordrecht, Springer Science+Business Media BV.

Mozumder M, Wahab M, Sarkki S, Schneider P and Islam M 2018. Enhancing social resilience of the coastal fishing communities: A case study of Hilsa (*Tenualosa ilisha* H.) Fishery in Bangladesh. *Sustainability* **10**(10): 3501.

Pomeroy RS and Andrew NL 2011. *Small-Scale Fisheries Management: Frameworks and Approaches for the Developing World*. Cambridge, MA, CAB International.

Received 20 May, 2020; Accepted 26 August, 2020

Rahman MK and Schmidlin TW 2019. The plight of some of the poorest of the poor: Vulnerabilities of fishing families on Kutubdia Island, Bangladesh. *Environmental Hazards* **18**(5): 1-13.

Salas S, Bjorkan M, Bobdilla F and Cabrera MA 2011. Coping strategies of fishing communities in Yucatan, Mexico, pp. 195-220. I In: Jentoft S and Eide A (eds). *Poverty Mosaics: Realities and Prospects in Small-Scale Fisheries*. Dordrecht, Springer Science+ Business Media BV.

Singh PJS, Rashid MM, Azman A and Ali I. 2019. Fishery policies and acts in present context-experiences from coastal Bangladesh. *Indian Journal of Ecology* **46**(4): 857-861.

World Bank 2014. *Strategic Vision for Fisheries and Aquaculture*. The Global Program on Fisheries, WB.

Indian Journal of Ecology (2020) 47(3): 782-787

Manuscript Number: 3084
NAAS Rating: 4.96

Study of Environmental Conditions, Morphometric and Meristic of Mudskipper (*Periophthalmus*) from Ambon Island Coastal Waters, Indonesia

D. Rumahlatu, K. Sangur, A.P. Leuwol, Y.N. Apituley, S.I.A Salmanu and I. Arini

Study Program of Biology Education, Faculty of Teacher Training and Education
Pattimura University, Ambon 97233, Indonesia
E-mail: dominggus_amq@yahoo.co.id

Abstract: The aim of this study was to determine the condition of the aquatic environment, morphometric and meristic of mudskippers from the coastal waters of Ambon Island. The environmental conditions were measured using the in-situ method, while the morphometric and meristic characters of mudskippers were quantitatively measured. The results of this study indicated some variations in the morphometric and meristic measurements of the three species of mudskippers (*Periophthalmus argentilineatus*, *P. kalolo* and *P. minutus*). In addition, the temperature, salinity, pH, and substrate of the waters are very suitable for mudskipper life.

***Keywords*:** Environmental conditions, Morphometric, Meristic, Mudskipper

Mudskipper (*Periophthalmus*) is a group of amphibian fish belonging to the family Gobiidae, the order Perciformes (Murdy 1989, Ansari et al 2014) and inhabiting the coast, river mouths, and mangrove ecosystems (Gosal et al 2013, Bidawi et al 2017), with the distribution of several sub-families *ca*. 2,000 species (Murdy 1989). Recent research has found numerous variations of mudskipper species in various aquatic ecosystems. Seven species were found in Singapore waters; *P. schlosseri, P. argentilineatus, P. chrysospilos, P. gracilis, P. malaccensis, P. novemradiatus, P. variabilis, P. walailakae* (Larson et al 2016). Ten species were documented in Selangor waters, Malaysia (Khaironizam and Norma-Rashid 2002), four species in the waters of Brunai Darusalam, namely *P. malaccensis, P. gracilis, P. vulgaris* and *P. schlosseri* (Polgar 2016). Research on mudskipper in Indonesian coastal waters has also been widely reported. One of them is *P. schlosseri* which found in the Barito estuary, South Kalimantan. The protein of this organism was used as a biomarker for heavy metal contamination (Hidayaturrahmah et al 2019). *Boleophthalmus boddarti, P. chrysospilos, P. gracilis* and *P. schlosseri* were found in the mangrove areas of the coast of Bali, North Sumatra (Muhtadi et al 2016). Murdy and Takita (1999) observed *P. spilotus* from Sumatra *B. pectinirostris, B. boddarti, Scartelaos* sp, *P. takita, P. schlosseri* in Payumb beach, Merauke (Sunarni and Maturbongs 2016). *P. pusing* and *P. gracilis* in habited the Lesser Sunda Islands (Jaafar et al 2016). However, only few researches on mudskipper in the coastal waters of the Ambon Island, Indonesia was carried out. To our knowledge, only the WoRMS (2015) reports the distribution and taxonomy of mudskipper. However, those researchers did not report the morphometrics and meristic of the mudskipper.

Morphometric characteristic of mudskipper refer to a measurable structure, such as fin length, head length, eye diameter, or the ratio between the measurements, while the meristic characters include almost all countable structures, including number of fins, scales, and gills (Safi et al 2014). Brraich and Akhter (2015) explain that morphometric and meristic characters are considered as isometric growth, and both characters are influenced by environmental factors. Previously, Vatandoust et al (2014) and Lawson (2010) explained that morphometric and meristic character measurements are for taxonomic importance and morphological variation. Several morphometric and meristic research on mudskipper has been reported, which morphometric and meristic measurements were carried out on *Scartelaos tenuis* and *P. waltoni* (Maryam et al 2015), *P. papilio* (Lawson 2010), and *B. boddarti* (Daud et al 2005). Therefore, the results of this study will provide knowledge about the three species of mudskippers.

MATERIAL AND METHODS

Study sites: This study was conducted in the mangrove area (August - October 2019) on the coastal waters of Ambon Island, Indonesia (Fig. 1). The locations of tis research were Poka beach (3°38'40.0"S, 128°11'36.3"E), Waai beach (3°34'36.1"S, 128°19'33.6"E), and the Rutong beach (3°42'12.9"S, 128°16'17.2"E. The observation station was

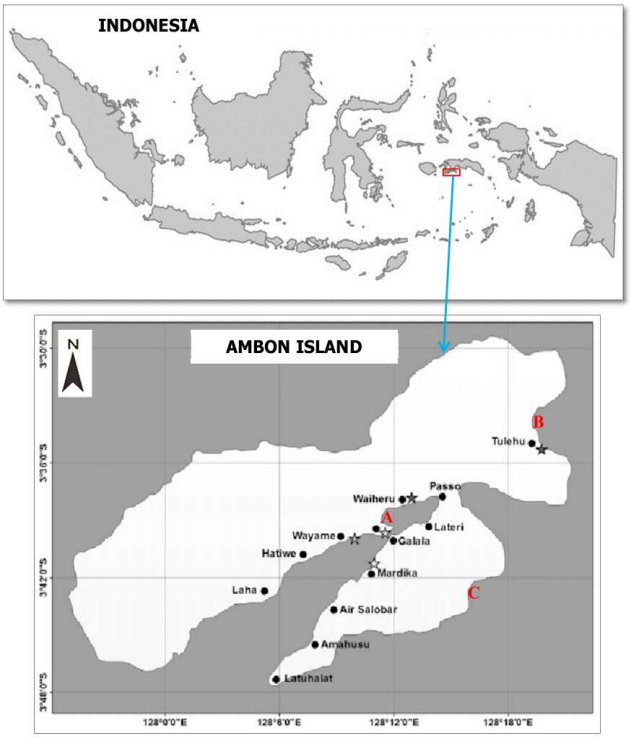


Fig. 1. Mudskipper sampling area. A: Poka beach, B: Waai beach, C: Rutong beach

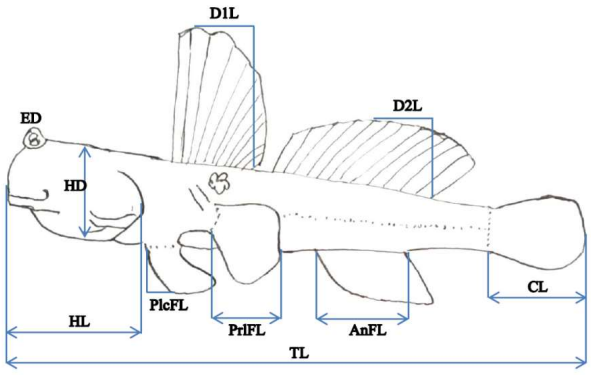


Fig. 2. Morphometric and meristic measurements of mudskipper [Modified line art Lawson (2010)]

determined by using purposive sampling method and was based on the initial observation of the mudskipper, because mudskippers are not living in all Ambon beaches.

Sampling procedure and sample collection: The data of the water environmental parameters (substrate, pH, salinity, and temperature) were collected using in-situ method. Furthermore, the mudskipper samples were sampled from each beach. Each observation area was divided into 2 stations (6 observation stations in total). Mudskipper samples were sampled using a mesh size of 1.75 inches and were then put into ethylene plastic and labelled (sample coding). The specimen was put in an ice box and were taken to the laboratory for identification, morphometric and meristic measurements.

Identification, morphometric and meristic measurement of mudskipper: The mudskipper specimens were identified by referring to WoRMS (2015) and Fishbase (2019). The morphometric and meristic characters of mudskipper were observed and measured quantitatevely (Lawson 2010), which included eye diameter (ED), head diameter (HD), total length (TL), head length (HL), body weight (BW), pelvic fin length (PlcFL), pectoral fin length (PrlFL), anal fin length (AnFL), caudal length (CL), first dorsal fin length (D1L), and second dorsal fin length (D2L) (Fig. 2). The meristic characteristics measured were the number of the first dorsal fin (D1F), the number of the second dorsal fin (D2F), the number of pelvic fins (PlcF), the number of pectoral fins (PrlF), number of anal fins (AF), number of caudal fins (CF), and the number of caudal thorns (CT).

Data analysis: The quantitative descriptive data analysis was carried out to describe the results of environmental measurements, morphometric and meristic characters of mudskipper from the coastal waters of Ambon Islands.

RESULTS AND DISCUSSION

Physical-chemical parameters of the environment: The physical-chemical factors of the aquatic environment at each station were not significantly different, where the pH of the sea water ranged between 7.7-7.9, the salinity ranged from 27-28 $_{0/00}$, sea water temperature ranged from 26-27°C, and the various substrate constituents (Table 1). Mahadevan and Ravi (2015) reported that temperature, salinity, and pH of sea water suitable for mudskipper life were in the range of 23.5-35.3°C (temperature), 24.4-34.4 psu (salinity), and 7.67-8.8-17 (pH). Elviana et al (2019) also reported that environmental conditions for mudskipper life in the estuary waters of Merauke regency were seawater temperature 26.5-27.5°C, salinity 24-28 psu, and pH 7.6. Akinrotimi et al (2019) also showed that various environmental conditions were temperature range 29.97-30.12 °C, salinity 10.01-14.88 psu, and pH 6.33-6.52 suitable for the growth of *Periophthalmus barbarous* mudskipper. This means that the environmental parameters of Ambon Island waters are very suitable for mudskipper life. The physical-chemical conditions of the aquatic environment are important variables for the distribution of various species of fish and aquatic biota (Yagci et al 2016, Kumar and Nautiyal 2019) as well as to its growth (Akbulut 2009). Jaafar et al (2004) explained that environmental parameters have a large influence on the mudskipper presence in sea waters.

Species of mudskipper: Based on the identification of the samples, there are three species of mudskippers were found in the coastal waters of the Ambon Islands. *Periophthalmus argentilineatus* at Poka and Rutong beaches, *Periophthalmus kalolo* at Waai beach, and *Periophthalmus minutus* at Poka beach, with a total of 45 individuals (Table 2 and Fig. 3).

The morphology mudskippers at Rutong beach have the main difference in the skin color. The skin of mudskipper *P. argentilineatus* at station 1 is browner than that of same mudskipper species at station 2 (Fig. 3). Different skin colors are influenced by environment which is substrate in the mangrove ecosystem. Pavlidis et al (2008) explained that environmental factors such as water temperature, light intensity, and color of the substrate have a significant influence on the brightness of the skin especially the back skin. Leclercq et al (2010) also reported that the carotenoid pigments of brook trout that lives on a bright substrate will turn from the skin to become flesh. This is in accordance with the condition of the substrate in the mangrove area of station 1 which is composed of sand and mud, while at station 2 the substrate is sand and gravel. Jiang et al (2015) showed that the color of the substrate had a significant effect on the growth and body color of red *Apostichopus japonicus*. Moreover, Enot et al (2015) confirmed that the mudskipper *P. argentilineatus* lives in the mangrove area has a characteristic of black line below the edge of the first dorsal fin and white spots. In addition, *P. kalolo* was also found at Waai beach. It has a characteristic of black line on the edge of D1, and there are white spots on the base of the body. *P. minutus* was found on Poka beach with characteristics of almost similar to the other two species, but differ in the dorsal part which has six black spots (Enot et al 2015). Pormansyah et al (2019) reported that there were 8 species of mudskipper fish in Maluku waters, *B. boddarti*, *P. freycineti*, *P. schlosseri*, *P. argentilineatus*, *P. gracilis*, *P. kalolo*, *P. malaccensis*, and *S. histophorus*. Meanwhile, Hui et al (2019) reported that the genus *Periophthalmus* was abundant as much as 50% and consisted of species *P. chrysospilos*, *P. gracilis*, *P. argentilineatus*, *P. walaikakae* and *P. variabilis* in Tanjung

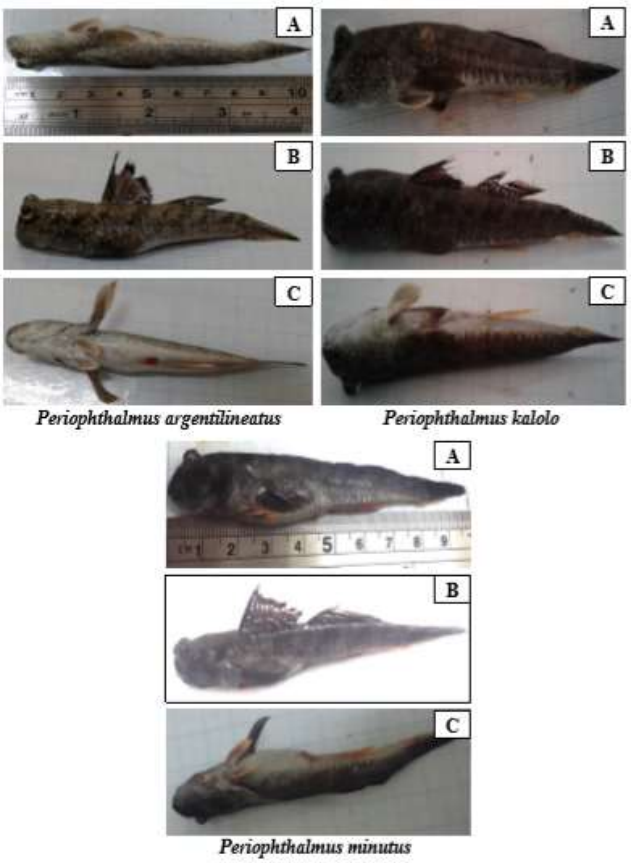


Fig. 3. Mudskipper from the coastal waters of Ambon Islands. (A) side view, (B) dorsal appearance, (C) ventral appearance

Table 2. Mudskipper in coastal waters of Ambon Islands

Mudskipper	Area						Total
	P1	P2	W1	W2	R1	R2	
Periophthalmus argentilineatus (Valenciennes 1837)	-	+	-	-	+	+	25
Periophthalmus kalolo (Lesson 1831)	-	-	+	+	-	-	11
Periophthalmus minutus (Eggert 1935)	+	-	-	-	-	-	9

See Table 1 for details

Table 1. Environmental conditions of mangrove area

Area		Width of the area (m^2)	Environmental conditions			
			Substrate	pH	Salinity ($_{0/00}$)	Temperature ($^{\circ}$C)
Poka	P1	9.800	Black sand and mud	7.7	28	26
	P2	3.150	Black sand and mud	7.7	28	26
Waai	W1	1.600	Sand and gravel stones	7.7	27	25
	W2	6.975	Sand and mud	7.7	27	26
Rutong	R1	4.675	Sand and mud	7.9	27	27
	R2	3.575	Sand and gravel stones	7.9	27	27

[Description: Poka-station 1 (P1), Poka-station 2 (Poka-station 2 (P2), Waai-station 1 (W1), Waai-station 2 (W2), Rutong-station 1 (R1), Rutong-station 2 (R2)]

Piai, Pontian, Johor.

Morphometric and meristic of mudskipper: The results of the morphometric measurements of the three types of mudskipper are shown some variations in eye diameter (ED), head diameter (HD), total length (TL), head length (HL), body weight (BW), pelvic fin length (PlcfL), pectoral fin length (PrlfL), anal fin length (AnfL), Caudal length (CL), first dorsal fin length (D1L), and second dorsal fin length (D2L) (Table 3). In addition, the meristic measurements of the three types of mudskipper showed some variations in the number of the first dorsal fin (D1F), second dorsal fin (D2F), pelvic fins (PlcF), pectoral fins (PrlF), anal fins (AF), caudal fins (CF), and caudal thorns (CT) (Table 4).

The morphological adaptation of mudskipper species causes variations in morphometric and meristic measurements (Nugroho et al 2016). Gangan et al (2016) add that meristic characters such as pre and post hip scutes, branching pectoral fins, pelvic fins, rectal fins, chest filaments, dorsal and anal fins are characters that can distinguish species in the genus *Setipinna*. In addition, other factors that influence differences in fish morphology are food availability, environmental conditions, and fish maturity stages (Daud et al 2005). In this study, it was revealed that the morphometrics and meristic of *P. minutus, P. argentilineatus,* and *P. kalolo* have the variation in measurements (Table 3 and 4). Many researchers have

Table 3. Average results of morphometric measurement of mudskipper

Morphometric characters	Morphometric measurement results								
	P. minutes (N= 9)			*P. argentilineatus* (N= 25)			*P. kalolo* (N= 11)		
	Range		Mean ± SD	Range		Mean ± SD	Range		Mean ± SD
	Minimum	Maximum		Minimum	Maximum		Minimum	Maximum	
Eye diameter (ED) (mm)	1.38	5.04	3.98±2.00	2.02	6.6	3.60±1.89	2.1	4.6	3.31±1.82
Head diameter (HD) (mm)	7.04	9.04	7.60±2.76	6.04	15.9	8.47±2.90	3.25	11.3	8.07±2.83
Head length (HL) (cm)	1.1	2.4	1.80±1.33	1	2.5	1.60±1.26	0.9	2.5	1.45±1.19
Total length (TL) (cm)	8.1	14.3	9.70±3.11	6.8	12.8	8.20±2.86	5.4	12.9	2.75±2.77
Body weight (g)	4	8	8.44±2.91	2	16.8	4.97±2.22	0.9	15.5	4.56±2.04
Caudal Length (CL) (cm)	1.5	2.5	1.74±1.32	1	2.7	1.59±1.25	1	2.3	1.52±1.23
Pelvic Fin Length (PlcFL) (cm)	0.9	1.7	0.97±0.98	0.6	1.4	1.00±0.99	0.4	1.3	0.87±0.93
Pectoral Fin Length (PrlFL) (cm)	1.3	2	1.53±1.24	0.8	1.9	1.38±1.17	0.8	2.1	1.37±1.16
Anal Fin Length (AnFL) (cm)	1	2.1	1.46±1.21	0.7	1.8	1.13±1.07	0.7	1.8	1.08±1.04
Dorsal 1 Length (D1L) (cm)	1.5	2.5	1.93±1.39	1.2	2.2	1.58±1.25	0.8	2.4	1.37±1.17
Dorsal 1 Length (D2L) (cm)	1.4	2.7	1.80±1.36	0.9	1.9	1.40±1.17	0.6	2.1	1.15±1.07

Table 4. Average results of meristic measurements of mudskipper

Meristic characters	Meristic measurement results								
	P. minutes (N= 9)			*P. argentilineatus* (N= 25)			*P. kalolo* (N= 11)		
	Range		Mean ± SD	Range		Mean ± SD	Range		Mean ± SD
	Minimum	Maximum		Minimum	Maximum		Minimum	Maximum	
Dorsal 1 Fins (D1F)	13	14	14.33±3.79	11	17	14.04±3.75	10	17	13.00±3.60
Dorsal 1 Thorns (D1T)	3	11	6.56±2.56	2	13	7.75±2.74	7	17	10.60±3.25
Dorsal 2 Fins (D2F)	12	14	12.89±3.59	10	19	13.24±3.64	11	19	13.04±3.61
Dorsal 2 Thorns (D2T)	6	22	15.44±3.93	6	20	11.21±3.33	7	18	11.44±3.38
Pelvic Fin (PlcF)	11	16	13.78±3.71	7	18	13.02±3.59	11	17	12.95±3.60
Pectoral Fin (PrlF)	13	22	16.33±4.04	10	20	14.38±3.79	10	16	12.80±3.58
Anal Fin (AF)	10	13	11.22±3.35	9	13	11.18±3.35	10	12	11.24±3.36
Caudal Fins (CF)	13	20	17.44±4.18	13	19	16.18±4.02	13	21	16.14±4.02
Caudal Thorns (CT)	9	18	13.00±3.56	3	20	10.72±3.27	8	15	11.99±3.46

reported varying morphometric and meristic measurement results from different types of mudskippers. Lawson (2010) reported the morphometric measurements of *P. papilio*, ED varied from 4-8mm, HD; 20-34mm, HL; 22-43mm, BD; 15-33mm and TL; 140-190mm. For meristic measurements found 10-13 D1F, 11-14 D2F and 10 AF. Maryam et al (2015) observed TL; 134.4 and BW; 11.17 for *S. tenuis*, while TL; 107.8 and BW 11.93 for *P. waltoni*. Fish length and weight data are very important to study because they provided information for fish monitoring and management (Özpiçak et al 2018; Balık and Öztaş 2019). Researchers have also discovered new mudskipper species based on morphometric and meristic measurements. Jaafar et al (2016) describe the *P. pusing* from the Lesser Sunda Islands which was previously identified as *P. gracilis* and Jaafar and Larson (2008) a new species of *P. takita* (Gobiidae: Oxudercinae) from northern Australia, which was previously identified as *P. novaeguineaensis*. Takitta et al (2011) reported that male *P. minutus* is longer than females, *P. minutus* male is 55 mm, while female *P. minutus* is 53 mm. Meanwhile Ansari et al (2014) reported that *P. argentilineatus* can extend to a size of 9.5 cm to 15 cm. Dinh (2017), conclude that environment provides food and conditions suitable for mudskipper life so that it affects the growth and development of fish. The influence of environmental factors together with genes can influence phenotype expression so that there are differences in morphometric and meristic measurements a population (Ujjainia and Kohli 2011, Soliman et al 2018, Sartimbul et al 2018). Tajbakhsh et al (2018) also observed that environmental factors such as salinity and seasonal temperature can affect physiologically, then can affect the morphology of *Ponticola bathybius* in the long run.

CONCLUSIONS

Based on the results of the study, it can be concluded that environmental conditions can support the life and activities of mudskipper in Ambon Island waters. Morphometrics and meristics of *P. argentilineatus*, *P. minutus*, and *P. kalolo* had some variations. Morphological characters in morphometric measurements are total length, body weight, and head diameter. Prominent morphological characters in meristic measurements are caudal fins, pectoral fins, and dorsal 2 thorns. This morphometric and meristic study can be used as information for the use of mudskipper as a bioindicator.

ACKNOWLEDGEMENTS

This study is supported by a grant (Competitive Research) from the Faculty of Teacher Training and Education, Pattimura University (Contract Number: 701/UN13/SK/2019). Authors' acknowledge the contributions of D.R., K.S., A.P.L., Y.N.P., S.I.A.S., I.A.

REFERENCES

Akbulut B 2009. Explorations on temperature, oxygen, nutrients and habitat demands of fish species found in river Çoruh. *Artvin Çoruh Üniversitesi Orman Fakültesi Dergisi* **10**(1): 29-36.

Akinrotimi OA, Amachree D and Azunna CG 2019. Length-weight relationship of mudskipper, *Periophthalmus barbarus* (Bloch and Schneider 1801), from Buguma creek, Rivers State. *International Journal of Fisheries and Aquatic Research* **4**(1): 75-79.

Ansari AA, Trivedi S, Saggu S and Rehman H 2014. Mudskipper: A biological indicator for environmental monitoring and assessment of coastal waters. *Journal of Entomology and Zoological Studies* **2**(6): 22-33.

Balık İ and Öztaş M 2019. Comparison of length-weight relationships for whiting, *Merlangius merlangus* (Linnaeus, 1758) caught from three different areas of the south-eastern Black Sea. *Ege Journal of Fisheries and Aquatic Sciences* **36**(1): 57-63.

Bidawi BM, Desrita and Yunasfi 2017. Hubungan panjang berat dan faktor kondisi ikan belodok (Famili: Gobiidae) pada ekosistem mangrove di Desa Pulau Sembilan Kabupaten Langkat Provinsi Sumatera Utara [The correlation between length weight and condition factors of mudskipper fish (Famili: Gobiidae) in mangrove ecosystem in Pulau Ssembilan village, Langkat District, North Sumatra Province]. *Depik* **6**(3): 228-234. (in Indonesian).

Brraich OS and Akhter S 2014. Morphometric characters and meristic Counts of a Fish, *Crossocheilus latius latius* (Hamilton-Buchanan) from Ranjit Sagar Wetland, India. *International Journal of Fisheries and Aquatic Studies* **2**(5): 260-265.

Daud SK, Mohammadi M, Siraj SS and Zakaria MP 2005. Morphometric analysis of Malaysian Oxudercine Goby, *Boleophthalmus boddarti* (Pallas, 1770). *Pertanika Journal of Tropical Agricultural Science* **28**(2): 121-134.

Dinh QM 2017. Morphometric, growth and condition factor variations of *Boleophthalmus boddarti* in the Mekong delta, Vietnam. *Iranian Journal of Fisheries Sciences* **16**(2): 822-831.

Elviana S, Sunarni S, Maturbongs MR, Sajriawati and Fakhriyyah S 2019. Mudskipper diversity and its relationship to an environmental condition in estuary. *IOP Conference Series: Earth and Environmental Science* **343**: 1-5.

Enot WS, Fahri and Annawaty 2015. Periophthalmus spp. (Gobiidae: Oxudercinae) di habitat mangrove Kabupaten Banggai, Sulawesi Tengah Tengah [*Periopthalmus* spp. (Gobiidae: Oxudercinae) in Mangrove habitat at Banggai District, Central Sulawesi]. *Proceeding Seminar Nasional Biologi,* pp.117-120. (in Indonesian).

Fishbase 2019. Fish Identification: Find Species. Retrieved from https://www.fishbase.se/identification/SpeciesList.php?genus=Periophthalmus

Gangan SS, Kumar R, Ramteke KK, Kumar AP, and Jaiswar AK 2016. Study of morphological variation discernible by multivariate analysis between the species of genus Setipinna (Teleostei: Clupeiformes). *Ecology, Environment and Conservation* **22**: 11-16.

Gosal LM, Katili DY, Singkoh MF and Tamanampo JE 2013. Kebiasaan Makanan Ikan Gelodok (*Periophthalmus* sp.) di Kawasan Mangrove Pantai Meras, Kecamatan Bunaken, Kota Manado, Sulawesi Utara [The Food Habit of Mudskipper Fish, *Periophthalmus* sp. in Mangrove Areas of Meras Beach, Bunaken District, Manado City, North Sulawesi]. *Jurnal Bios Logos* **3**(2): 44-49. (in Indonesian).

Hidayaturrahmah, Mabrur, Santoso HB, Sasmita R, Rahmy USA and Badruzsaufari 2019. Short communication: Protein profiles of giant mudskipper and its potential use as biomarker candidate for heavy metal contamination in Barito Estuary, Indonesia.

Biodiversitas **20**(3): 745-753.

Hui Y, Mohamed M, Othman MNA and Tokiman L 2019. Diversity and behaviour of mudskippers of Tanjung Piai, Pontian, Johor. *IOP Conference Series: Earth and Environmental Science* **269**: 1-15.

Jaafar Z, Hajisamae S, Chou LM and Yatiman Y 2004. Community structure of coastal fishes in relation to heavily impacted human modified habitats. *Hydrobiologia* **511**: 113-123.

Jaafar Z and Larson HK 2008. A New Species of Mudskipper, *Periophthalmus takita* (Teleostei: Gobiidae: Oxudercinae), from Australia, with a Key to the Genus. *Zoological Science* **25**(9): 946-952.

Jaafar Z, Polgar G and Zamroni Y 2016. Description of a new species of Periophthalmus (Teleostei: Gobiidae) from the Lesser Sunda Islands. *Raffles Bulletin of Zoology* **64**: 278-283.

Jiang S, Dong S, Gao Q, Ren Y and Wang F 2015. Effects of water depth and substrate color on the growth and body color of the red sea cucumber, *Apostichopus japonicas*. *Chinese Journal of Oceanology and Limnology* **33**(3): 616-623.

Khaironizam MZ and Norma-Rashid Y 2002. Length-weight relationship of mudskippers (Gobiidae: Oxudercinae) in the coastal areas of Selangor, Malaysia. *Naga WorldFish Center Quarterly* **25**(3 & 4): 20-22.

Kumar S and Nautiyal P 2019. State of benthic macroinvertebrate community in Bhagirathi River ecosystem impacted by hydroelectric projects. *Indian Journal of Ecology* **46**(4): 760-767

Larson HK, Jaafar Z and Lim KKP 2016. An updated checklist of the gobioid fishes of Singapore. *Raffles Bulletin of Zoology* **34**: 744-757.

Lawson EO 2010. Morphometric measurements and meristic counts in mudskipper (*Periophthalmus papilio*) from mangrove swamps of Lagos lagoon, Nigeria. *Journal of Applied Biosciences* **34**: 2166-2172.

Leclercq E, Taylor JF and Migaud H 2010. Morphological skin colour changes in teleosts. *Fish and Fisheries* **11**(2): 159-193.

Mahadevan G and Ravi V 2015. Distribution of mudskippers in the mudflats of Muthupet, Southeast coast of India. *International Journal of Fisheries and Aquatic Studies* **3**(2): 268-272.

Maryam A, Saeid EP and Hosein R 2015. Partial morphometrics and meristic evaluation of the two species mudskippers: *Scartelaos tenuis* (Day, 1876) and *Periophthalmus waltoni* (Koumans, 1941) from the Persian Gulf, Bushehr, Iran. *International Journal of Fisheries and Aquatic Studies* **2**(5): 353-358.

Muhtadi A, Ramadhani SF and Yunasfi 2016. Identifikasi dan Tipe Habitat Ikan Gelodok (Famili: Gobiidae) di Pantai Bali Kabupaten Batu Bara Provinsi Sumatera Utara [Identification and habitat type of Mudskipper (Family: Gobiidae) at the Bali Beach, district of Batu Bara, North Sumatra Province]. *Biospecies* **9**(2): 1-6 (Indonesian).

Murdy E and Takita T 1999. *Periophthalmus spilotus*, a new species of mudskipper from Sumatra (Gobiidae: Oxudercinae). *Ichthyological Research* **46**(4): 367-370.

Murdy EO 1989. A taxonomic revision and cladistic analysis of the oxudercine gobies (Gobiidae: Oxudercinae). *Records of the Australian Museum, Supplement* **11**: 1-93.

Nugroho ED, Ibrahim, Rahayu DA and Rupa D 2016. Studi morfologi ikan mudskippers (Gobhidae: Oxudercinae) sebagai upaya karakterisasi biodiversitas lokal Pulau Tarakan [Morphological Study of Mudskippers (Gobiidae: Oxudercinae) as characterization effors of Local Biodiversity of Tarakan Island]. *Jurnal Harpodon Borneo* **9**(1): 46-57. (in Indonesian)

Received 31 May, 2020; Accepted 26 August, 2020

Özpiçak M, Saygın S, Hançer E, Aydın A, Yılmaz S and Polat N 2018. Length-weight and length-length relationships of chub (*Squalius cephalus*, L., 1758) in habiting a few inland waters of the Middle Black Sea Region. *Ege Journal of Fisheries and Aquatic Sciences* **35**(2): 175-179.

Pavlidis M, Karkana M, Fanouraki E and Papandroulakis N 2008. Environmental control of skin colour in the red porgy, *Pagrus pagrus*. *Aquaculture Research* **39**: 837-849.

Polgar G 2016. First record and conservation value of *Periophthalmus malaccensis* Eggert from Borneo, with ecological notes on other mudskippers (Teleostei : Gobiidae) in Brunei. *Scientia Bruneiana* **15**: 48-57.

Pormansyah, Iqbal M, Setiawan A, Yustian I and Zulkifli H 2019. A review of recent status on mudskippers (Oxudercine Gobies) in Indonesian waters. *Oceanography and Fisheries Open Access Journal* **9**(4): 1-4.

Safi A, Khan MA and Khan MZ 2014. Study of some morphometric and meristic characters of striped piggy fish, *Pomadasys stridens* (Forsskal, 1775) from Karachi Coast, Pakistan. *The Journal of Zoology Studies* **2**(2): 38-42.

Sartimbul A, Rohadi E, Ikhsani SN and Listiyaningsih D 2018. Morphometric and meristic variations among five populations of Sardinella lemuru Bleeker, 1853 from waters of Bali Strait, northern and southerneast Java and their relation to the environment. *Aquaculture, Aquarium, Conservation & Legislation Bioflux* **11**(3): 744-752.

Soliman FM, Mehanna SF, Soliman HA and Baker TS 2018. Meristic and morphometric characteristics of five-lined snapper, *Lutjanus quinquelineatus* (Bloch, 1790) from the Red Sea, Egypt. *Egyptian Journal of Aquatic Biology & Fisheries Zoology* **22**(1): 4-48.

Sunarni S and Maturbongs MR 2016. Biodiversitas dan kelimpahan ikan Gelodok (Mudskipper) di daerah intertidal pantai Payumb, Merauke [Biodiversity and abundance of mudskippers in intertidal zone of Payumb Beach, Merauke]. *Prosiding Seminar Nasional Kemaritiman Dan Sumberdaya Pulau-Pulau Kecil* **1**(1): 125-131. (in Indonesian).

Tajbakhsh F, Abdoli A, Stepien C and Tabatabei N 2018. Geometric morphometric and meristic analysis of the deepwater goby, *Ponticola bathybius* (Kessler, 1877) (Teleostei: Gobiidae) in the Iranian waters of the Caspian Sea. *Iranian Journal of Ichthyology* **5**(1): 64-73.

Takita T, Larson HK and Ishimatsu A 2011. The natural history of mudskippers in northern Australia, with field identification characters. *The Beagle, Records of the Museums and Art Galleries of the Northern Territory* **27**: 189-204.

Ujjainia NC and Kohli MPS 2011. Landmark-based morphometric analysis for selected species of Indian major carp (*Catla catla*, Ham. 1822). *International Journal of Food, Agriculture and Veterinary Sciences* **1**: 64-74.

Vatandoust S, Abdoli A, Anvarifar H and Mousavi-sabet H 2014. Morphometric and meristic characteristics and morphological differentiation among five populations of Brown Trout Salmo trutta fario (Pisces: Salmonidae) along the southern Caspian Sea basin. *European Journal of Zoological Research* **3**(2): 56-65.

WoRMS 2015. *World Register of Marine Species*. Retrieved from http://www.marinespecies.org/aphia.php?p=taxdetails&id=205192

Yagci A, Apaydin YM, Bilgin F and Erbatur I 2016. The effects of physicochemical parameters on fish distribution in Egirdir Lake, Turkey. *Iranian Journal of Fisheries Sciences* **15**(2): 846-857.

Indian Journal of Ecology (2020) 47(3): 788-791

Manuscript Number: 3085
NAAS Rating: 4.96

Comparison of Performance of Trimedlure and Enriched Ginger Root Oil (*Zingiber officinalis*) in Attracting Males of Mediterranean Fruit Fly (*Ceratitis capitata*)

Jamal Ben Yazid, Zouheir Chafik[1], Imane Bibi and Ez-Zahra Kharmach

Laboratory of Biochemistry and Biotechnologies
[1]Laboratory of Plants and Microorganisms Biology, Mohamed first University, Faculty of Sciences, Oujda, Morocco
E-mail: benyazidjamal@yahoo.fr

Abstract: In Moulouya perimeter, North-east of Morocco, citrus industry is of great economic importance with 22.000 ha of surface area and a production exceeding 300.000 tons per year. The Mediterranean fruit fly (Medfly) *(Ceratitis capitata)* is one of the pest insects threatening this crop because of the direct yield losses it inflicts and the quarantine restrictions imposed by citrus importing countries. The phytosanitary management of *C.capitata* is of considerable strategic importance for the farmers of the region. This management is conducted based on the monitoring and detection of Medfly males before the start of pesticides spray. Successful surveillance programme depends on the choice of an adapted attractant. The study was carried out in Moulouya Perimeter in 2018 and 2019 years. The main objective of this work is to compare the performance of two para-pheromones used in monitoring for the capture of Medfly males, namely trimedlure and enriched ginger root oil. The finding showed that both trimedlure and enriched ginger root oil were selective towards Medfly. The trimedlure had a higher attractive performance than enriched ginger root oil. Furthermore, trimedlure kept its attractiveness performance up to eight weeks while the enriched ginger root oil lost its performance from three weeks after capsules opening.

Keywords: Attractant, *Ceratitis capitata*, Ginger oil, Medfly, Para-pheromone, Trimedlure

In Moulouya Perimeter, the citrus fruits are one of the largest fruit crops that play a very important socio-economic role with acreage of 22.000 ha and a yearly production exceeding 300.000 tons (ORMVAM 2020). In this region, decision-making regarding the control of the Mediterranean fruit fly (hereafter Medfly) in host fruits orchards is made based on the results of monitoring trap captures of Medfly males. Thus, the success of any form of control strategy depends on the effectiveness of the trapping system set up and the performance of the attractants used in the traps. The trimedlure (TML) has been proven to be one of the most widely used attractants for monitoring Medfly males since the 1960s (Manoukis 2016) and, it is reported in several studies that essential oils from certain plant species are used to act as trapping attractants for Tephritidae. Among the essential oils that have been tested and that have shown encouraging performances is essential ginger oil (*Zingiber officinalis*) called "Enriched Ginger Root Oil" (EGRO) (Shelly and Pahio 2002). The effectiveness of EGRO has been outlined in some studies and has been subject to several controversies. According to certain studies, α-copaene (the active ingredient in ginger oil) is 2 to 5 times more effective than trimedlure (Flath et al 2005, Epsky and Niogret 2017). Other studies have reported opposite results, showing that trimedlure is more effective than EGRO (Shelly and Pahio 2002). The present study aims to assess, under experimental conditions in Moulouya perimeter, northeastern Morocco, the effectiveness of trimedlure and EGRO in the monitoring and detection programmes for adult males of *C. capitata* in citrus orchards.

MATERIAL AND METHODS

Attractants: The trimedlure is a para-pheromone widely utilized in Morocco for the monitoring and detection of male *C. capitata* purpose in fruit orchards at a rate of two traps per hectare. The Enriched Ginger Root Oil "EGRO", used was in the form of capsules imported for experimentation in this study. The concentration of α-copaene (the active ingredient in EGRO) in each capsule is 8% with a liquid content of 2 ml. This concentration has been used in studies in other parts of the world mainly USA (Shelly and Pahio 2002, Shelly 2013). The traps used for both para-pherormones are of the "Maghreb Med" type. These traps are baited separately by trimedlure or EGRO. They are cylindrical opaque plastic traps perforated laterally and hung at a hight of 1.5 m above the ground on the south-east side of the trees in the monitored orchards. Within each trap, the capsule of one of the two attractants and a tablet of insecticide dichlorvos were placed as toxicant. To assess the temporal loss of bait attractant due to the time elapsed after opening the capsules

(age of the attractant), male captures were compared between traps baited with trimedlure and traps baited with EGRO using attractants that were three weeks old before use.

Study site and experimental orchards: The Moulouya perimeter was chosen for this study (Fig. 1) because it presents technical problems related to decision making in Medfly control and a lack of mastery of the monitoring techniques before launching chemical spray (Ben yazid et al 2020). The region is also known for the presence of Medfly throughout the year and the presence of host plants throughout the seasons (Ben yazid et al 2020). These parameters allow the Mediterranean fruit fly to complete its cycle and constitute a threat to citrus orchards, especially the local variety "Fina Berkane" known for its brand image in the main citrus markets (especially the United States and Russia). The study area is located on the southern coast of the Mediterranean Sea, at an altitude varying between 100 and 300 m above sea level. The climate is characterized by a hot summer with an average temperature of about 29C° and January is the coldest month with an average of about 12,9 C°. The average rainfall is about 329 mm (ORMVAM 2020).

The selected orchards were citrus orchards of the Clementine variety "Fina Berkane" which have not undergone any chemical treatment in the localities of Chouihia (latitude 34°52'17.7"N, longitude 2°37'3.6"W) and Aklim (latitude 34°53'10.1"N, longitude 2°30'53.4"W) known by the high occurrence of Medfly. This decision was made to avoid interference and modification of the natural dynamics of the Mediterranean fruit fly population that could result from the chemical spray. For the trial to compare the effect of capsule age on the loss of para-pheromone attractiveness, the attractants were placed in “Maghreb Med” traps hung in two different orchards from those of the other trial and which are far from the study area and located in Reggada location (latitude 34°56'3.9"N, longitude 2°13'47.3"W).



Fig. 1. Location of the study area in the Moulouya Perimeter on the map of Morocco

Data analysis: The captures of all the traps monitored were statistically analyzed using a generalized linear model (GLM) to study the difference between the performance of the two attractants in terms of captures of Medfly males, taking into account the factors of location and year. For the evaluation of the temporal loss of performance, the GLM test was used followed by a HSD (Honestly Significant Difference) Tukey test for the separation of the means (α=0,05). The data were synthesized and statistically analyzed using IBM-SPSS version 25 software.

RESULTS AND DISCUSSION

Sex selectivity of para-pheromones: Both the two para-pheromones showed high selectivity towards the males of Medfly. In all the traps set up, there were only males and (no females captured) during our trial. Thus, neither trimedlure nor EGRO are attractive to females of Medfly under the climatic and experimental conditions of our study. That result complies with the results reported by Niogret et al (2017) Shelly and Pahio (2002) and Hafsi et al (2016) confirming that trimedlure is selective towards males of Medfly. For EGRO, Hafsi et al (2019) found apparent selectivity of this para-pheromone towards males of Medfly. However, Manrakhan et al (2017) showed that traps baited by para-pheromones EGRO and TML separately, attracted both males and females of Medfly, but with very few captures of females. This result means that both para-pheromones can be useful to monitor the flights of the male Medfly for surveillance and detection purposes.

Attractive performance of para-pheromones to males of medfly: The mean captures for the two types of traps were significantly different (Fig. 2). The test of the general linear model (GLM) highlighted this significant difference following the analysis of data on total captures for the two attractants independently of year and orchard. The same test found that the factors, Year and Orchard did not have significant effects on total captures during the study period (Fig. 3 and Fig. 4). The mean number of male captures for all traps baited by trimedlure was 482,76 /trap, whereas the in traps baited by "EGRO" ginger root oil was 365, 20 flies/trap. This showed that trimedlure had higher performances, in the captures of Medfly males than those obtained by EGRO. These results are highly similar to those documented in other studies. The studies conducted to evaluate the attractiveness performance of trimedlure to attract Medfly males, have

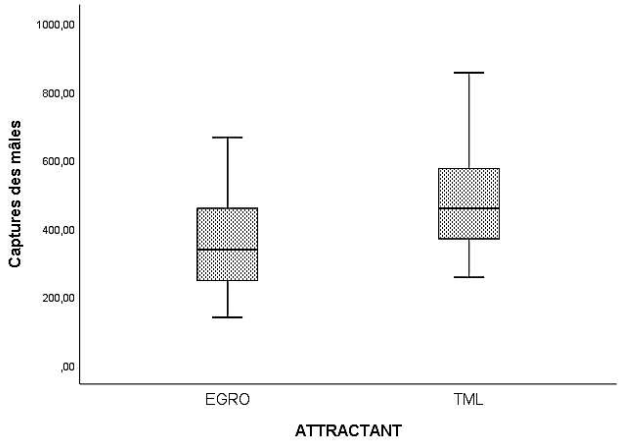


Fig. 2. Average male captures recorded per trap for the two para-pheromones (EGRO and TML) during the study period

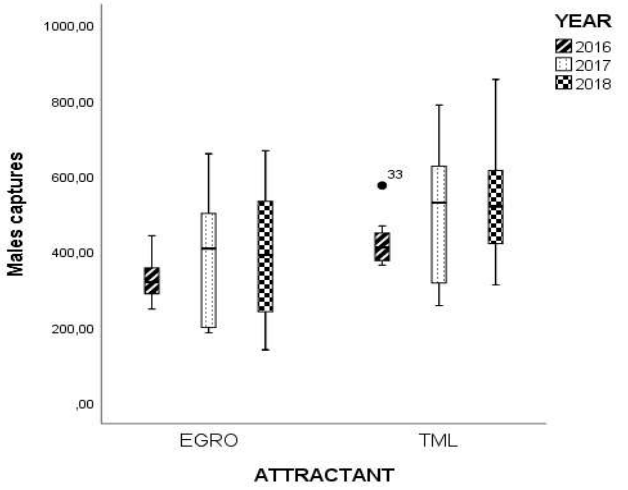


Fig. 3. Average male captures in EGRO and TML baited traps per year

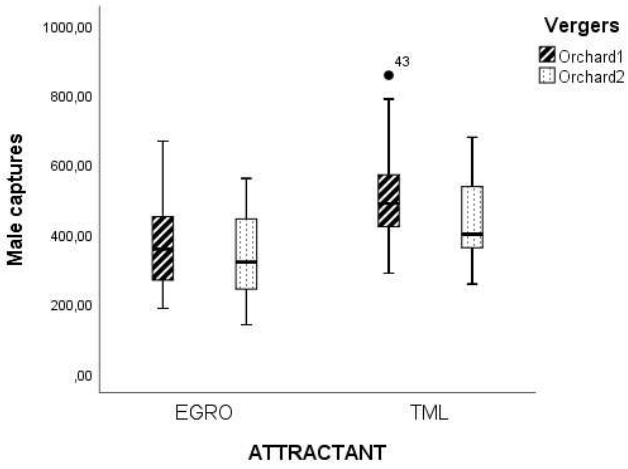


Fig. 4. Average male captures in EGRO and TML baited traps by orchard during the study period

shown a higher efficacy of this para-pheromone compared to EGRO used at the same concentration (Shelly and Pahio 2002, Shelly 2013). However, Mwatawala (2013) showed similar performances of the two para-pheromones for the capture of Medfly males by using a higher concentration of EGRO, which explained this increase in capture performance that equalized the performance of trimedlure under the experimental conditions of the reported study.

Effect of Para-pheromone's age on the attractiveness performance: The evolution of the performance of the two para-pheromones according to the date of their opening (duration after opening), the study found that the performance gap widens further after the third week of the traps set up. Thus, the trimedlure maintained its performance up to eight weeks, whereas from the third week; The EGRO lost its performance and attraction and captures decreased very noticeably and during the last weeks of monitoring, a decrease in the number of flies caught was noted, which can be explained by the loss of efficiency over time in the traps baited by the EGRO (Fig. 5 and Fig. 6). Comparison of the performance of the 3-week-old capsules with the immediately opened and used "Age 0" capsules revealed three distinct groups. Trimedlure's 3-week-old capsules showed similar performance by belonging to the same

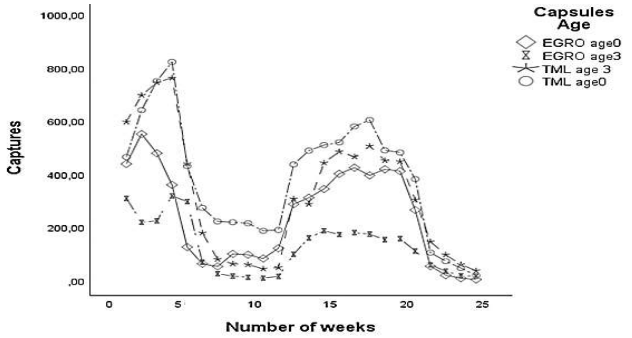


Fig. 5. Evolution of captures as a function of the age of EGRO and trimedlure capsules during the study period

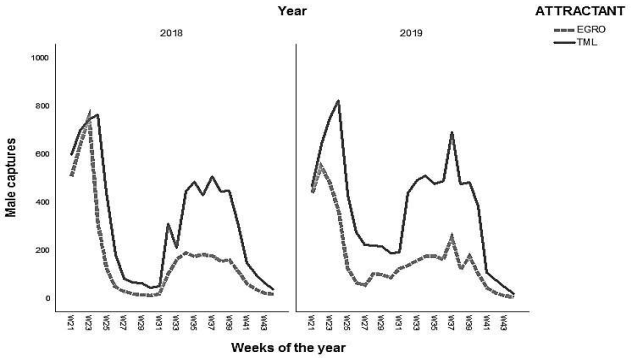


Fig. 6. Evolution of captures as a function of age of EGRO and TML capsules (2018 and 2019)

Table 1. Comparison of the attractiveness performance of open and immediately used para-pheromone capsules with those at 3 weeks of age

Captures significant difference from Tukey[a,b]				
Age of the attractant capsules	N	Sub-assembly		
		1	2	3
EGRO (3 weeks)	24	127,6083		
EGRO (0 weeks)	24		243,1688	
TML (3 weeks)	24			323,5833
TML (0 weeks)	24			381,7917
Significance		1,000	1,000	0,100

The error term is Mean Square (Error) = 7466.210. Uses harmonic mean sample size =24,000. α=0,05

subset. EGRO capsules with the age of three weeks showed significantly lower attraction performance compared to capsules with "Age 0" (Table 1). Some studies showed that the effectiveness of EGRO capsules decreases over time from the date they were opened (with age). Capsules lost attractiveness performance after the 3rd to 4th week from the capsule opening (Shelly and Pahio 2002).

CONCLUSION

The study leads to conclude that trimedlure remains one of the most efficient para-pheromones used to capture males of the Mediterranean fruit fly for monitoring and detection purposes. This para-pheromone showed high selectivity towards males. The trimedlure maintains its attractiveness to adult males for more than six weeks. EGRO also had a significant attractive effect on males of the Medfly. However, this para-pheromone has shown limitations, particularly concerning the loss of performance three weeks after opening the EGRO capsules. This loss of attractiveness may lead to an under-estimation of captures and thus to an under-estimation of actual Mediterranean fruit fly populations, which constitutes a high risk of punctures and fruit infestation. To bait traps with the EGRO, in a monitoring programme, it is recommended to change in regularly basis capsules every three weeks to ensure the stability of the effectiveness of the attractiveness of this para-pheromone for males of the Medfly.

ACKNOWLEDGEMENTS

The authors express their deep gratitude to MORTADA Abdelkhalek, Agronomist of Regional Office of Agricultural investment of Moulouya, for his help in field and laboratory work and data analysis. Many thanks for the growers who authorized us to set up traps in their orchards.

Received 24 June, 2020; Accepted 25 August, 2020

REFERENCES

Ben yazid J, Chafik Z, Bousamid A, Bibi I and Kharmach E 2020. Population Dynamics and Seasonal Occurrence of Mediterranean Fruit Fly (*Ceratitis capitata* Wiedemann, 1824) in Moulouya Perimeter North East of Morocco. *Indian Journal of Ecology* **47**(2): 564-569.

Epsky NF, Niogret J 2017. Short range attraction of *Ceratitis capitata* (Diptera: Tephritidae) sterile males to six commercially available plant essential oils. *National Volatiles Essential Oils* **4**: 1-7.

Flath RA, Cunningham RT, Mon TR and John JO 2005. Additional male mediterranean fruitfly (*Ceratitis capitata* Wied.) Attractants from Angelica seed oil (*Angelica archangelica* L.). *Journal of Chemical Ecology* **20**: 1969-1984.

Hafsi A, Abbes K, Harbi A, Duyck PF and Chermiti B 2016. Attract-and-kill systems efficiency against *Ceratitis capitata* (Diptera: Tephritidae) and effects on non-target insects in peach orchards. *Journal of Applied Entomology* **140**(1-2): 28-36.

Hafsi A, Rahmouni R and Chermiti B 2019. Detection of *Ceratitis capitata* Wiedemann (Diptera: Tephritidae) using trimedlure versus enriched ginger oil in citrus orchards, *International Journal of Pest Management* **66**(4): 378-384.

Manoukis NC 2016. To catch a fly: landing and capture of *Ceratitis capitata* in a Jackson trap with and without an Insecticide. *PloS ONE* **11**(2): 1-10.

Manrakhan A, Daneel JH, Beck R, Virgilio M, Meganck K and De Meyer M 2017. Efficacy of trapping systems for monitoring of Afrotropical fruit flies. *Journal of Applied Entomology* **141**(10): 825-840.

Mwatawala M, Virgilio M, Quilici S, Dominic M and De Meyer M 2013. Field evaluation of the relative attractiveness of enriched ginger root oil (EGO) lure and trimedlure for African *Ceratitis* species (Diptera: Tephritidae). *Journal of Applied Entomology* **137**(5): 392-397.

Niogret J, Gill MA, Espinoza HR, Kendra PE and Epsky ND 2017. Attraction and electroantennogram responses of male Mediterranean fruit fly (Diptera: Tephritidae) to six plant essential oils. *Journal of Entomology and Zoology Studies* **5**: 958-964.

ORMVAM 2020. (Office Régional de la mise en Valeur Agricole de Moulouya) in Fiche synthétique sur les agrumes dans le Périmètre de la Moulouya. Available in http://ormvam.co.ma/wp-content/uploads/2017/10/Fiche-agrumes-SIAM-2017-actualis%C3%A9e-pour-BAE-Copie-pour-site-ORMVAM.pdf. Consulted in June 24th. 2020.

Shelly TE 2013. Detection of male Mediterranean fruit flies (Diptera: Tephritidae): performance of trimedlure relative to capilure and enriched ginger root oil. *Proceedings of the Hawaiian Entomological Society* **45**: 1-7.

Shelly TE and Pahio E 2002. Relative attractiveness of enriched ginger root oil and trimedlure to male Mediterranean fruit flies (Diptera: Tephritidae). *Journal of Florida Entomology* **85**(4): 545-551.

Indian Journal of Ecology (2020) 47(3): 792-798

Manuscript Number: 3086
NAAS Rating: 4.96

Litter Mass Loss Rate Changes as Function of Soil Microbial Diversity and Litter Chemical Quality in Tropical and Sub-Tropical Forest of Mizoram: A Microcosm Study

Ngangbam Somen Singh and S.K. Tripathi*

Ecosystem Lab, Department of Forestry
School of Earth Sciences and Natural Resources Management, Mizoram University, Aizawl-796 004, India
**E-mail: sk_tripathi@rediffmail.com*

Abstract: Soil microbes (populations of fungi, actinomycetes and bacteria) and C/N ratio are among important factors influencing the process of litter decomposition in variety of ecosystems. The present study aimed to assess changes in soil microbial populations and C/N ratio in decomposition of mixed litters of tropical (~100 m) and subtropical (~1450 m amsl altitude) forests under laboratory microcosm experiment. Microcosms were made of PVC pipe fitted with a screw lid with a sealed bottom. Microcosms consist of mixture of mineral soil and surface organic horizon (3: 1) collected from the two contrasting forests of Mizoram. Mixed senesced litters collected from two forests were air dried and 5g of air-dried litter samples were placed in replicated laboratory microcosm. The samples were moistened regularly at every third day. Five replicated samples were recovered periodically up to 180 days after experimental setup. Mass loss was rapid in initial stages (up to 40 days) which decrease at the end of the retrieval period. Mass loss rates in sub-tropical forest litter changes as function of soil and litter N, whereas the same in tropical forest was regulated by fungi, actinomycetes and litter C/N ratio.

Keywords: Decay constant, Mass loss, Soil microbes, Litter nitrogen, Litter carbon

In forest ecosystem, two-third of the C and nutrients return to the soil through litter decomposition (Cebrian 1999) which is regulated by microbial action. Litter nutrient transfer to forest soil represent a major pathway of nutrient cycling in forest ecosystem (Pandey et al 2007, Gavazov et al 2014). Litter decomposition in forest ecosystem is affected by factors such as climatic, edaphic and microbes (Cornwell et al 2008, Tripathi and Singh 1992a, García-Palacios et al 2013, Tripathi and Singh 1992b, Gavazov et al 2014). Among the various abiotic factors, temperature, precipitation and soil moisture significantly affect litter decay through activated microbial activities that helps in decomposition (Boyero et al 2014, Purahong et al 2014, Lalnunzira and Tripathi 2018). In addition, litter quality and soil property have also been found to strongly influence the rate of litter decomposition (Liu et al 2009). Litter quality such as carbon, nitrogen and C/N ratio helps in providing energy for microbes during different stages of decomposition (Zhang et al 2013, Lalnunzira and Tripathi 2018). Generally, litter containing higher nitrogen in warm and humid condition shows higher decomposition rate than litter with less nitrogen content in cold sites (Schuur et al 2001, Sun et al 2004).

In forests, litter decomposition takes place in a composite litter samples which decomposes faster compared to individual species litter (Gartner and Cardon 2004). Organic carbon is the primary source of energy for decomposers and N serves as an important component of microbial metabolism. Therefore, the proportion of carbon and nitrogen present in litter affects the process of decomposition (Zhang et al 2013). The C/N ratio in litter often regulates activities of decomposer (microorganism). Lower C/N ratio shows faster decomposition while higher C/N ratio exhibit tendency of immobilization and slower the rates of litter decay (Taylor and Middleton 2004, Gul et al 2012). Apart from nutrients availability in soil and litters, soil microbes are often associated with nutrients in decomposition. Among the soil microbes, bacteria and fungi break down the complex litter compound. At the initial stages certain enzyme were excreted by microbes to break large and complex litter substrate and utilize carbon for their energy (Talbot et al 2008, Hobbie et al 2013). Thus, the amounts of soil microbes present in soil as well as litter are important in studying litter decomposition processes. Variation in litter quality often reflected by colonization of different microbes in litter, for example, fungi dominates in organic matter with low nutrients than actinomycetes and bacteria (Hodge et al 2000, Hieber and Gessner 2002, Cross et al 2005).

There are several reports on the role of abiotic and biotic factors in litter decomposition in field experiment. However, the role of microbes and litter quality on litter decomposition in microcosm experiments are still extremely less. This study showed the impact of soil microbial activities and changes in litter quality (C, N and C/N ratio) during mixed tree leaf (*Melocanna baccifera, Tectona grandis, Quercus floribunda, Drypetes indica* and *Castanopsis* species) litter decomposition in two forest litters at same temperature and

soil moisture under control environment in microcosm. Further, mass loss rates of two forest litters in microcosm have been correlated with changes in microbial population and litter quality.

MATERIAL AND METHODS

Soil sampling and litter used in the experiments: The soils were randomly collected from two forest sites of Mizoram, India which have different climatic variation during monsoon onset in July 2016. First site was selected from sub-tropical semi-evergreen forest (STF) at Hmuifang reserve forest (23°27'25.8"N 92°45'20.6"E, 1481m amsl) which characterize by mildly cold temperature while another site was selected from lower altitude with hot and humid type of climatic condition from tropical deciduous forest (TF) type in Sairang (23°49'19.9"N 92°39'34.8"E, 101m asl). Soils used for experiment were collected from surface organic horizon (top soil layer without humus) upper 10cm in depth from each site. Soil collected from each sites were mixed thoroughly and sieved (2.5mm mesh) before setup in microcosm. Leaf litters used in this experiment were collected from both forest sites during February 2016.

Design of microcosm experiment: The microcosm experiment was setup at forestry department, MZU (23º44'13.93" N latitude and 92º39'39.88" E, 758 m asl) modified after Taylor et al (1989) (Fig. 1). Microcosms made from polyvinyl chloride (PVC) pipe (12 cm in diameter and 16cm in height) fitted with a screw lid and a sealed bottom and a bottom pierced with l-cm diameter hole allowing excess water to be drained off. Soil mixture consisting of mineral soil collected from MZU campus and surface organic horizon (top soil layer without humus) at ratio 3: 1. About 5g of air dried yellowish senescent mixed leaves litter rewetted for 1hr in distilled water before placing in microcosm. Then hand held mist sprayer was used for maintaining soil moisture. The replicated samples were recovered on 40, 75, 120 and 180 days after experimental setup.

Analysis of carbon and nitrogen in soil and litter: After litter recovery from microcosm, soil samples dried in hot air oven at105^0 C for 5 hrs then ground and sieved (0.5mm). The litter samples were carefully brushed off, washed and dried in oven at 60^{0}C until constant weight. Finally, litter samples were ground and sieved (1 mm). Carbon and nitrogen contents in soil and litter samples were analyst at Central Instrumentation Laboratory, MZU (CHNS/O Elemental Analyzer with auto sampler and TCD detector –Euro Vector, Model: EuroEA3000).

Soil microbial counts: For colony forming units (CFUs), experiment was based on Dilution Plate Method (Waksman 1922). Different agar media were prepared separately for fungi, actinomycetes and bacteria. For fungi, potato dextrose agar (PTA) added with antibiotic 0.08% of penicillin and chloramphenicol at the time of preparing. Starch casein agar (SCA) mixed with nystatin (0.08%) used for isolation of actinomycetes. For bacterial counts, media prepare from nutrient agar added with around 0.08 per cent of nystatin and actidione. Serial dilution of soil prepares from 1g of fresh soil added to 10 ml of distilled water. Dilution of 10^{-3} to 10^{-5} use for isolation of fungi, 10^{-4} to 10^{-6} actinomycetes and 10^{-5} to 10^{-7} were used for bacterial isolation. 1ml of each dilution was added into petri-plates containing solid media (triplicates). Then media plates were incubated at 28±1^{0}C for fungal growth and 25±1^{0}C for both actinomycetec and bacterial growth.

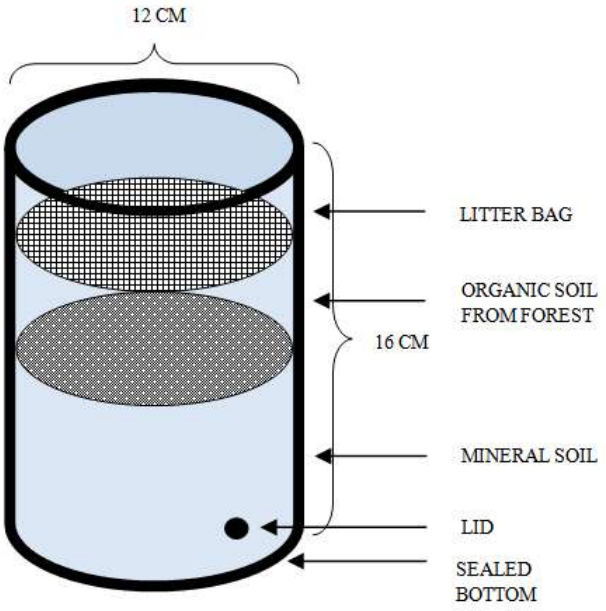


Fig. 1. Microcosm based on Taylor et al (1989) method

Decay constant (k): Negative exponential decay model of Olson (1963) was applied to find annual decay constant (k) of leaf litter components. It was expressed as

$$x^t/x^0 = \exp^{(-kt)},$$

Where,

x^0-initial mass oflitter,

x^t- amount of litter remaining after time t,

t –time (year) and

k -decomposition rate (year^{-1}).

Time required for 50 and 95 per cent mass loss was calculated as $t_{50} = 0.693/k$ and $t_{95}=3/k$ respectively.

Statistical analysis: One-way analysis of variance was used to find least significant different (LSD, $p \leq 0.05$) between number of days (i.e. 0, 40, 75, 120 and 180 days) and nutrients (C, N and C/N ratio) concentration along with microbial counts (fungi, actinomycetes and bacteria) in soil.

For litter LSD at $p \leq 0.05$ was applied for comparison mean (5 replication) of nutrient with numbers of decomposition days. Pearson correlation used to examine relationship of decay constants among sites. The statistics were performing using MS (7)-excel. Fit regression model coefficients were carried out using minitab-18 software to evaluate various variable factors (soil microbes and various nutrients of soil and litter) effecting mass loss.

RESULTS AND DISCUSSION

Litter decay constant: Decomposition of leaf litter showed rapid decay in initial stages (up to 40 days) then slowly decreases at the end of the retrieval period. Similar trends have been reported in various studies on *Tephrosia species* litter (Güsewell and Gessner 2009, Munthali et al 2013, Wapongnungsang et al 2018). Rapid mass loss at the initial stage may be due to presence of high amount of labile substance such as amino acid, sugar and soluble phenolic (Wang et al 2004) which are easily degraded by microbes mainly bacteria. After initial stage, in the second phase of decay mainly cellulose decomposes at relatively lower rate that the initial one and during the third phase of decomposition was reported to be very slow because of the dominance of recalcitrant substances like lignin, pectin, polyphenols and waxes (Pandey et al 2007). Litter mass remaining over time has been shown in Figure 3. Mass remaining followed a simple linear trend in two forest litter. However, the decomposition was slightly faster in TF (R^2 = 0.947) as compare to STF (R^2 = 0.938). At the end of the experiment, mass remaining was 61.74 in STF and 55.98 in TF. Mean annual organic decay constant $K_{(org)}$ value for two sites were 1.9 and 1.7 in TF and STF, respectively. The annual decay constant $K_{(org)}$ value (1.7– 1.9) was higher as compare to reports from field sites by Loría-Naranjo et al 2018(0.012), Jampanin 2004 (0.07–0.11; 0.03–0.07), Torreta and Takeda 1999 (0.99–1.05) but lower compare to the one reported by Wapongnungsang and Tripathi 2017 (2.32 – 2.88). Projected mass loss for 50% decay would require 148 days in STF and 129 days in TF. For 95 per cent mass loss predicted days for two forest litters were 641 in STF and 558 in TF (Table 1). Changes in mass loss rate was strongly positively correlated with time of litter decomposition in days (R = 0.98, R^2 = 0.94). Soil temperature and moisture were significantly important during decomposition, higher soil temperature with low moisture content usually lower litter decomposition (Martius et al 2004, Hobbie et al 2010, Paudel et al 2015).

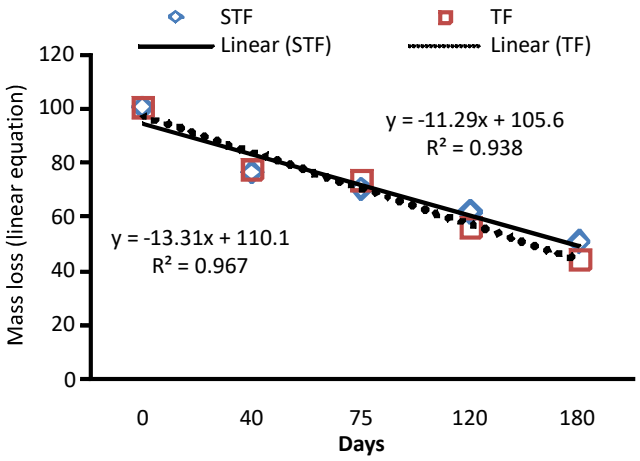


Fig. 3. Litter mass loss express in simple linear equation with R^2 value from two forests. Trend lines shows slightly difference in two forest types, TF was somewhat faster than STF

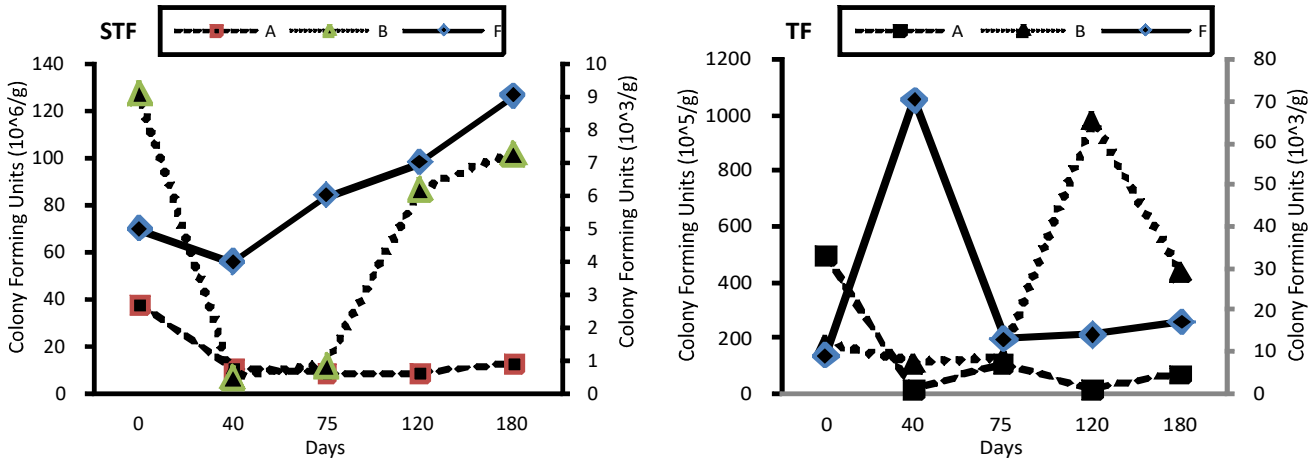


Fig. 2. Colony forming units (CFUs) of soil microbes (F=Fungi, A= Actinomycetes and B= Bacteria) from two forest (STF & TF) was observed in STF but no significance difference in TF site (p=0.2, df=16)

Concentration of nitrogen, carbon and C/N ratio in soil and litter: The soil Ncontent ranged from 0.18 – 0.5 in STF and 0.19 – 0.31 in TF during entire period of the experiment (Fig. 4). Variations in soil N, C and C/N ratio were significant between the two sites. In both sites, initially the amount of soil N and C decreases till 75 days of litter placement followed by their gradual increase later as decomposition progressed (Table 2). Litter N content ranged between 1.21 and 1.5 in STF site and 1.44 and 1.5 in TF sites (Fig. 5). Decreased N in both soil and litter comparing to initial nutrients contents reveals that these nutrients may be used by microbes for faster decomposition later N increases with lower decay rate at later stages. According to Albers et al (2004) initial low litter N content have significant effect on litter decay as it regulates activities of various during decomposition. Changes in litter N and C/N ratio during the course of decomposition were significant, whereas, the variations in litter C was not significant (Fig. 5). Litter C/N ratio ranged from 31.78 – 37.82 and 29.24 – 32.03 in STF and TF sites, respectively. Maximum C/N ratio observed in STF during 75 day (37.82) and minimum in TF on 40 days retrieval (29.24) (Fig. 4). The

Table 1. Annual decay constants (k) value for both forest sites along with the times require for t_{50} (50%) and t_{95} (95%) mass loss

Site	$K_{(org)}$	t_{50}	t_{95}
STF	1.7	148.2	641.7
TF	1.9	129.0	558.4

Table 2. Nitrogen and carbon proportion in soil as well as in leaf litter during decomposition

Nutrients	Site	Decomposition days				
		0	40	75	120	180
Soil						
Nitrogen	STF	1	0.68	0.35	0.38	0.42
	TF	1	1.01	0.90	1.27	1.67
Carbon	STF	1	0.58	0.32	0.38	0.41
	TF	1	1.03	1.07	1.39	1.87
Litter						
Nitrogen	STF	1	0.94	0.81	0.88	0.97
	TF	1	1.00	0.96	0.99	1.10
Carbon	STF	1	0.94	0.95	0.91	1.03
	TF	1	0.91	0.90	0.92	1.04

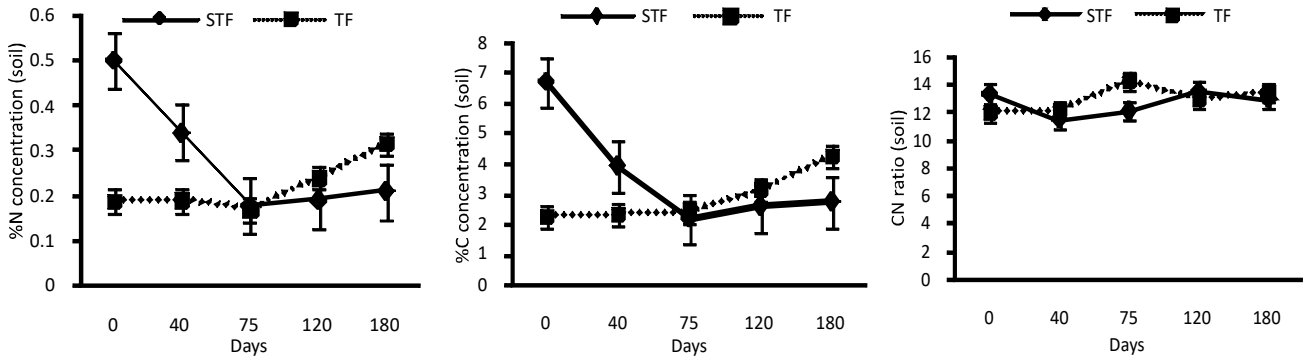


Fig. 4. Percentages of soil nitrogen, carbon and C/N ratio during mixed litter decomposition. In STF site, both N and C shows higher in initial days while in TF site, both N and C increases with decomposition days. C/N ratio shows irregular trend in both forest sites

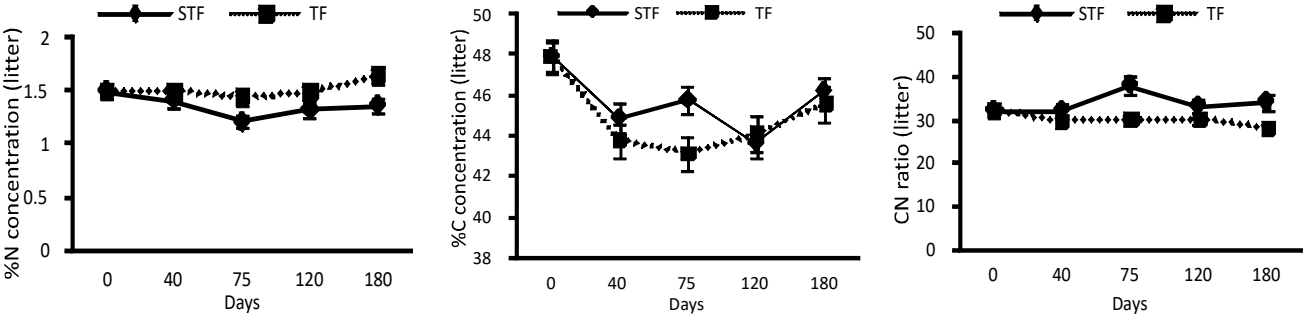


Fig. 5. In leaf litter, nitrogen content was always higher in TF than STF site. Decrease in carbon content was observed up to 75 days than increases gradually at the end in TF. In litter C/N ratio shows STF site compare to TF site

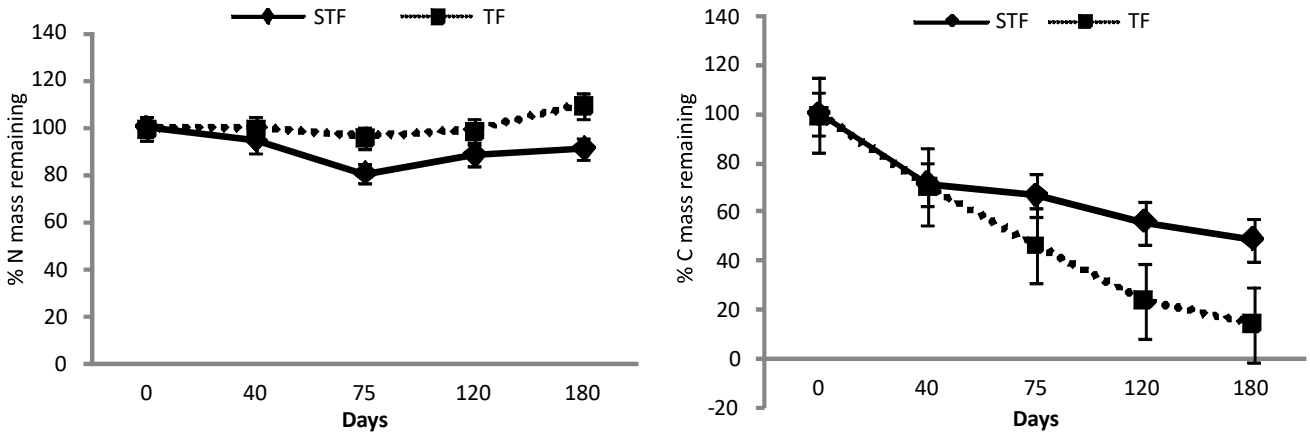


Fig. 6. Representing nitrogen (%) and carbon (%) mass remaining in litter. In TF site shows significantly higher N remains than STF while in case of C, STF shows significantly higher mass remaining than TF

percentage N mass remaining was 91.17 per cent (STF) and 109.82% (TF) whereas litter C was 49 per cent (STF) and 14.32 per cent (TF) (Fig. 6).

Soil microbial population during mixed litter decomposition: Most of the soil microbial counts were decreased in the initial stage, which could be the results of changes in temperature and moisture from natural forest floor and that of microcosm. As the soil microbes require certain temperature and moisture for their activities (Pandey et al 2007). Microbial activity considerably increases in forest soil with constant soil moisture and temperature (Austin and Vitousek 2000; Xuluc-Tolosa et al 2003). Soil microbial population (fungi, actinomycetes and bacteria) changes significantly (during decomposition in STF, but no significant noticed in TF site. Maximum CFUs of fungi was observed in TF site during 40 days retrieval period and minimum in STF during 40 days retrieval days (Fig. 2). In both sites, actinomycetes show rapid decreases in initial 40 days followed by almost constant population till final retrieval (Fig. 2). Bacterial counts decrease from initial to 40 days then increase gradually at the end of retrieval period in STF. The overall result of soil microbial population count (i.e. CFUs) reveals that microbial population was in order: bacterial >actinomycetes> fungi during the study (Fig. 2). In STF, most of the microbial dynamic are more in initial and at final stage. During decomposition, soil microbial count varied depending on C/N ratio of litter. Higher bacterial count was noticed in the litter higher with low litter C/N and higher fungi dominance was recorded in litter having high C/N ratio (Hodge et al 2000) due to variations in bacterial and fungal metabolism. Bacterial CFUs were numerously higher with high litter C/N ratio, same trend was revealing on the study of litter in microcosm (Güsewell and Gessner 2009).

Correlation between mass loss with soil microbes and nutrients (soil and litter): In a variety of forest ecosystems, there are reports that litter decomposition process is strongly affected by factors such as biotic, abiotic, litter substrate quality (Pandey et al 2007, Zhang et al 2008, Zhou et al 2008, Paudel et al 2015). The main decomposer activities are depending upon the availability of litter and soil moisture contents with optimum temperature and the quantity and quality litter present on the forest floor. To assess effect of abiotic variables (soil microbes, soil nutrients and litter nutrients) on litter mass loss, best fit regression model was applied to predict litter mass rate. In STF site, N in both soil and litter accounted for about 95.97 per cent variability in mass loss. In TF site, soil microbes (fungi and actinomycetes) along with litter C/N ratio were selected as stronger predictor variables accounting 99.84 per cent variability in mass loss rates. Equations are as follows:

Sub-tropical forest (STF), mass loss rate (%)

$= 10.76 + 10.94\ (N_{soil}) - 7.71\ (N_{litter})$

$R^2 = 95.97\ \%$

Tropical forest (TF), mass loss rate (%)

$= -27.26 + 0.8361\ (F) + 0.2886\ (A) + 0.6018\ (C/N_{litter}\ ratio)$

$R^2 = 99.84\ \%$

CONCLUSION

This study assesses the effect of changing pattern of litter quality and decomposer organisms on the mass loss rates in two forest litter types under controlled abiotic factors. The study suggests mass loss was rapid in initial stages (up to 40 days) which decrease at the end of the retrieval period. Mass loss rates in sub-tropical forest litter changes as function of soil and litter N, whereas the same in tropical forest was regulated by fungi, actinomycetes and litter C/N ratio. Changes in microbial population bacteria and fungi during the different stages of decomposition and their role in

litter decomposition has significant potential in regulating the soil carbon stock in tropical forest ecosystems. Tropical forests are known to act as source and sink of carbon. Further studies would be required to strengthen the results that can be useful in developing policies related to regulating carbon sequestration in tropical forests.

REFERENCES

Albers D, Migge S, Schaefer M and Scheu S 2004. Decomposition of beech leaves (Fagussylvatica) and spruce needles (*Picea abies*) in pure and mixed stands of beech and spruce. *Soil Biology and Biochemistry* **36**(1): 155-164.

Austin AT and Vitousek PM 2000. Precipitation, decomposition and litter decomposability of *Metrosideros polymorpha* in native forests on Hawai'i. *Journal of Ecology* **88**(1): 129-138.

Boyero L, Cardinale BJ, Bastian M and Pearson RG 2014. Biotic vs. abiotic control of decomposition: a comparison of the effects of simulated extinctions and changes in temperature. *PLoS One* **9**(1): 87426.

Cebrián J and Williams M 1998. Accumulation on autotrophic nutrient content in ecosystems. *Ecology Letters* **1**: 165-170.

Cornwell WK, Cornelissen JH, Amatangelo K, Dorrepaal E, Eviner VT, Godoy O and Quested HM 2008. Plant species traits are the predominant control on litter decomposition rates within biomes worldwide. *Ecology Letters* **11**(10): 1065-1071.

Cross WF, Benstead JP, Frost PC and Thomas SA 2005. Ecological stoichiometry in freshwater benthic systems: Recent progress and perspectives. *Freshwater Biology* **50**(11): 1895-1912.

Garcia-Palacios P, Maestre FT, Kattge J and Wall DH 2013. Climate and litter quality differently modulate the effects of soil fauna on litter decomposition across biomes. *Ecology Letters* **16**(8): 1045-1053.

Gartner TB and Cardon ZG 2004. Decomposition dynamics in mixed-species leaf litter. *Oikos* **104**(2): 230-246.

Gavazov K, Mills R, Spiegelberger T, Lenglet J and Buttler A 2014. Biotic and abiotic constraints on the decomposition of Fagussylvatica leaf litter along an altitudinal gradient in contrasting land-use types. *Ecosystems* **17**(8): 1326-1337.

Gul S, Whalen JK, Ellis BE and Grayston SJ 2012. Plant residue chemistry impacts soil processes and microbial community structure: A study with Arabidopsis thaliana cell wall mutants. *Applied Soil Ecology* **60:** 84-91.

Güsewell S and Gessner MO 2009. N: P ratios influence litter decomposition and colonization by fungi and bacteria in microcosms. *Functional Ecology* **23**(1): 211-219.

Hieber M and Gessner MO 2002.Contribution of stream detrivores, fungi, and bacteria to leaf breakdown based on biomass estimates. *Ecology* **83**(4): 1026-1038.

Hobbie EA, Ouimette AP, Schuur EA, Kierstead D, Trappe JM, Bendiksen K and Ohenoja E 2013. Radiocarbon evidence for the mining of organic nitrogen from soil by mycorrhizal fungi. *Biogeochemistry* **114**(1-3): 381-389.

Hobbie SE, Oleksyn J, Eissenstat DM and Reich PB 2010. Fine root decomposition rates do not mirror those of leaf litter among temperate tree species. *Oecologia* **162**(2): 505-513.

Hodge A, Robinson D and Fitter A 2000. Are microorganisms more effective than plants at competing for nitrogen? *Trends in Plant Science* **5**(7): 304-308.

Jampanin S 2004. *Comparison of Litter Production and Litter Decomposition for Carbon Sequestration Assessment in Forest Ecosystems at KaengKrachan National Park, Thailand*. M.Sc. Thesis (Zoology).

Lalnunzira C and Tripathi SK 2018. Leaf and root production, decomposition and carbon and nitrogen fluxes during stand development in tropical moist forests, north-east India. *Soil Research* **56**(3): 306-317.

Liu L, King JS, Booker FL, Giardina CP, Lee Allen H and Hu S 2009. Enhanced litter input rather than changes in litter chemistry drive soil carbon and nitrogen cycles under elevated CO2: a microcosm study. *Global Change Biology* **15**(2): 441-453.

Loría-Naranjo M, Sibaja-Cordero JA and Cortés J 2018. Mangrove leaf litter decomposition in a seasonal tropical environment. *Journal of Coastal Research*.

Martius C, Höfer H, Garcia MV, Römbke J and Hanagarth W 2004. Litter fall, litter stocks and decomposition rates in rainforest and agroforestry sites in central Amazonia. *Nutrient Cycling in Agroecosystems* **68**(2): 137-154.

Munthali MG, Gachene CKK, Karanja NK and Sileshi GW 2013. Decomposition rates and nutrient release patterns of *Tephrosia vogelii* and *Tephrosia candida* residues in Malawi. In *Joint Proceedings of the 27th Soil Science Society of East Africa and the 6th African Soil Science Society Conference*.

Olson JS 1963. Energy storage and the balance of producers and decomposers in ecological systems. *Ecology* **44**(2): 322-331.

Pandey RR, Sharma G, Tripathi SK and Singh AK 2007.Litterfall, litter decomposition and nutrient dynamics in a subtropical natural oak forest and managed plantation in northeastern India. *Forest Ecology and Management* **240**(1-3): 96-104.

Paudel E, Dossa GG, de Blécourt M, Beckschäfer P, Xu J and Harrison RD 2015. Quantifying the factors affecting leaf litter decomposition across a tropical forest disturbance gradient. *Ecosphere* **6**(12): 1-20.

Purahong W, Schloter M, Pecyna MJ, Kapturska D, Däumlich V, Mital S and Krüger D 2014. Uncoupling of microbial community structure and function in decomposing litter across beech forest ecosystems in Central Europe. *Scientific reports* **4**: 7014.

Read DJ and Perez-Moreno J 2003. Mycorrhizas and nutrient cycling in ecosystems–A journey towards relevance? *New Phytologist* **157**(3): 475-492.

Saviozzi A, Levi-Minzi R, Riffaldi R and Vanni G 1997. Role of chemical constituents of wheat straw and pig slurry on their decomposition in soil. *Biology and Fertility of Soils* **25**(4): 401-406.

Schuur EA, Chadwick OA and Matson PA 2001. Carbon cycling and soil carbon storage in mesic to wet Hawaiian montane forests. *Ecology* **82**(11): 3182-3196.

Sun OJ, Campbell J, Law BE and Wolf V 2004. Dynamics of carbon stocks in soils and detritus across chronosequences of different forest types in the Pacific Northwest, USA. *Global Change Biology* **10**(9): 1470-1481.

Swift MJ, Heal OW and Anderson JM 1979. Decomposition in Terrestrial Ecosystems–Blackwell Scientific.

Talbot JM, Allison SD and Treseder KK 2008. Decomposers in disguise: mycorrhizal fungi as regulators of soil C dynamics in ecosystems under global change. *Functional ecology* **22**(6): 955-963.

Taylor BR, Parkinson D and Parsons WF 1989. Nitrogen and lignin content as predictors of litter decay rates: A microcosm test. *Ecology* **70**(1): 97-104.

Taylor J and Middleton BA 2004. Comparison of litter decomposition in a natural versus coal-slurry pond reclaimed as a wetland. *Land Degradation and Development* **15**(4): 439-446.

Torreta NK and Takeda H 1999. Carbon and nitrogen dynamics of decomposing leaf litter in a tropical hill evergreen forest. *European Journal of Soil Biology* **35**(2): 57-63.

Tripathi SK and Singh KP 1992a. Abiotic and litter quality control during the decomposition of different plant parts in dry tropical bamboo savanna in India. *Pedobiologia* **36**: 241-256.

Tripathi SK and Singh KP 1992b. Nutrient immobilization and release patterns during plant decomposition in a dry tropical bamboo savanna, India. *Biology and Fertility of Soils* **14**(3): 191-199.

Waksman SA 1922. A method for counting the number of fungi in the soil. *Journal of Bacteriology* **7**(3): 339.

Wang WJ, Smith CJ and Chen D 2004. Predicting soil nitrogen mineralization dynamics with a modified double exponential model. *Soil Science Society of America Journal* **68**(4): 1256-1265.

Wapongnungsang HR and Tripathi SK 2017. Litter decomposition Vis-a-Vis carbon and nitrogen dynamics of Tephrosia candida components in different fallow periods following shifting cultivation in mizoram. *Indian Journal of Ecology* **44**(4): 791-796.

Wapongnungsang, Hauchhum R and Tripathi SK 2018. Dry matter, carbon and nitrogen inputs from tephrosia candida hedgerows in different fallow lands following shifting cultivation in Mizoram. *Multilogic In Science* **7**(25): 267-271.

Xuluc-Tolosa FJ, Vester HFM, Ramırez-Marcial N, Castellanos-Albores J and Lawrence D 2003 .Leaf litter decomposition of tree species in three successional phases of tropical dry secondary forest in Campeche, Mexico. *Forest Ecology and Management* **174**(1-3): 401-412.

Zhang D, Hui D, Luo Y and Zhou G 2008. Rates of litter decomposition in terrestrial ecosystems: global patterns and controlling factors. *Journal of Plant Ecology* **1**(2): 85-93.

Zhang S, Li Q, Lü Y, Zhang X and Liang W 2013. Contributions of soil biota to C sequestration varied with aggregate fractions under different tillage systems. *Soil Biology and Biochemistry* **62:** 147-156.

Zhou G, Guan L, Wei X, Tang X, Liu S, Liu J and Yan J 2008. Factors influencing leaf litter decomposition: An intersite decomposition experiment across China. *Plant and Soil* **311**(1-2): 61.

Received 29 July, 2019; Accepted 15 October, 2019

Indian Journal of Ecology (2020) 47(3): 799-802

Manuscript Number: 3087
NAAS Rating: 4.96

Delineation of the Major Soil Nutrients in Seabuckthorn (*Hippophae* sp.) Stand and its Comparison to Other Land uses from Extreme Landscape of Trans-Himalaya

Praveen Kumar, Pardeep Kumar*, Munish Sharma, Nagender Pal Butail, Virendra Singh[1] and Arvind Kumar Shukla[2]

Department of Soil Science, CSKHPKV, Palampur-176 062, India
[1]Department of Biology and Environmental Sciences, College of Basic Sciences, CSKHPKV, Palampur-176 062, India
[2]ICAR-Indian Institute of Soil Science, Nabibagh, Berasia Road, Bhopal-462 038, India
E-mail: drpardeep1968@gmail.com

Abstract: Seabuckthorn (*Hippophae* spp. L.) has been recognized as one of the ecologically important indigenous plant species mainly found in the extreme cold arid region of the Indian Himalaya. Besides providing economic benefits and livelihood to the local inhabitants, the plant is considered to improve the fertility of soil. The plant having nitrogen fixation capabilities, however little is known about its potential to induce nitrogen fertilization in the soil and its comparison with different land uses. In the present study the soil samples were collected from a similar landscape with different land uses *viz*., agriculture, horticulture, forest and grassland in Kelad Valley, district Lahaul-Spiti, Himachal Pradesh India. The samples were analyzed for soil pH, organic carbon (OC) and the major soil nutrients *viz*., nitrogen (N), potassium (K) and phosphorus (P). The pH of the soil was acidic to neutral. The organic carbon (OC) content in the soil was high (48.52 g kg^{-1}) in agriculture field, may be due farmer inputs and erosional processes from the surrounding area. However, the available nitrogen (N) was found highest in horticulture land occupied with wild seabuckthorn (*Hippophae rhamnoides* ssp. *turkestanica*) stand indicating addition of nitrogen due to nitrogen fixation ability. The present study also reveals the variation of major soil nutrients under different land uses and soil depths.

Keywords: Nitrogen fixation, Seabuckthorn, Soil nutrient, Trans-Himalaya

The knowledge of the ecological services of the plant species and its impact on microclimate, site conditions and nutrient cycling is very important to understand the long term ecological impacts. The cold arid region of Indian Himalaya is characterized by extreme environmental conditions with the low rain, heavy snowfall and steep slopes. The geobotanical landscape is characterized by fragile plant diversity, where only few indigenous plant species were able to survive. The seabuckthorn (*Hippophae* spp. L.) is one of the indigenous plant species found in cold arid landscape of the higher Himalaya, i.e. Ladakh (Jammu & Kashmir), Upper Chamba, Upper Kullu, Lahaul- Spiti and Kinnaur (Himachal Pradesh), Kumaon Garhwal (Uttarakhand) and North-East region (Sikkim/Arunachal Pradesh) (Acharya et al 2010, Tamchos and Kaul 2016, Husain et al 2018). Seabuckthorn provide various ecological and economic benefits and considered as a multipurpose shrub as used by the local populace for the preparation of various products like syrup, juice, wine, jam and jelly (Singh et al 2012). The presence of higher vitamins and bioactive compound make this plant species a major ingredient in the various health and beauty products (Dhyani et al 2007, Singh and Gupta 2008). The plant species is known to tolerate the extreme xeric conditions and toxic pollutant that adds up its role in protecting the Himalayan ecosystem. The plant species known to conserve soil moisture, avoid soil erosion with extensive root system and add nutrient in the soil for land reclamation of the wasteland. The species have capability to grow in sloppy landscape along the steep slope, bouldary area and waste land (Cifen and Zhao 2003). Some studies have also proved its synergetic role in promoting growth of other plant species and provide the shelter and food for the wildlife in the fragile ecosystem (Lu 1992, Kumar et al 2018). The seabuckthorn (*Hippophae* spp. L.) is a non-leguminous plant species that has unique potential to fix substantial amount of atmospheric nitrogen (Kumar and Sagar 2007, Tamchos and Kaul 2015, Kumar et al 2018). The root nodules provide ability to fix atmospheric nitrogen from the symbiotic association with mycorrhizal fungus *Frankia* sp. (Actinomycetes). There are few studies which try to find out the nutrient status of the soil in general and with the plant community dominated by seabuckthorn (Sharma et al 2006, Charan et al 2013, Sharma and Singh 2017, Kumar et al 2019). Rana et al (2019) also conducted the depth wise nutrient status of the soil under seabuckthorn stand and other plant communities in Lahual valley of Trans-Himalaya, India. However, the

information is lacking for the nutrient status and its comparison under different land uses. A background information for the soil nutrients under similar landscape and parent rock for different land uses are required to understand the nitrogen fixation capability for effective planning and sustainable use. The present study provides an insight to the variation of major nutrients in soil under different land use in soil catena to spotlight the importance of seabuckthorn in conserving Himalayan ecosystem. The term 'catena' describes the top sequence of the soil derived from the parent rock that undergoes similar climatic oscillation with different relief (Barre et al 2017). Moreover the nutrient status also provides insight for the effective decision making under large scale plantation of the indigenous species for the restoration of the fragile Himalayan ecosystem.

MATERIAL AND METHODS

Study site description: The present study was carried in the village Tingrat (Kelad valley) of the district Lahaul-Spiti, Himachal Pradesh, India. The region is characterized by a semi-arid climate which faces heavy snowfall in winter. The study area is located at the longitude 76.78957º and latitude 36.85703º with some sites in the hilly slope viz., forestry, grassland and horticulture and almost flat area under agriculture land (Fig. 1). The study area represents different land uses *viz*., agriculture, grassland, horticulture and forestry; which were selected in the similar soil catena to avoid variation from parent rock and climatic deviation. In agriculture land use the major crops grown were potato (*Solanum* sp.) and cole crops (*Brassica* sp.), while the forest patches were occupied by the Juniper (*Juniperus polycarpos*) tree and wild rose (*Rosa webbiana*) and, the horticulture land use covered with wild seabuckthorn stand. In present study area, the seabuckthorn stand represents a height of 2-4 m with hard woody shrub having small leaves, oval fruit and branches with more spines indicating wild stand of the *Hippophae rhamnoides* ssp. *turkestanica*.

Soil sampling and analysis: The soil sampling was carried out from surface (0-15 cm) and sub-surface (15-30 cm) under different land uses from flat area at the toe of the hill near roadside in agriculture land and the hilly slopes viz., grassland, horticulture and forest (Fig. 1). The samples were collected from the centre and four cardinal directions of the each land uses (Barre et al 2017). Finally, these samples were mixed together depth wise and stored in a polythene bag. Further, these samples were processed and sieved through a 2 mm sieve, oven dried at 60ºC and stored in plastic bottles for further analysis for pH, organic carbon (OC) and the major nutrients viz., nitrogen (N), phosphorus (P) and potassium (K). The pH was measured with 1:2.5 suspension using a pH electrode (Jackson 1973). The available nitrogen was analyzed using alkaline permanganate (Subbiah and Asija 1956), phosphorus with sodium bicarbonate extraction (Olsen et al 1954) and potassium with neutral normal ammonium acetate extraction (Black 1965), respectively. The soil organic carbon (OC) was measured with Walkley-Black rapid titration method (Walkley and Black 1934).

RESULTS AND DISCUSSION

The results of soil parameters pH, OC, N, P and K for different depth level are presented in Figure 2. The pH of the soil increased with increasing soil depth, however the other parameters generally decreases having few exceptions for different land use and depth. The pH of the soil ranged from 5.69 to 6.69. The organic carbon (OC) was highly variable, ranging from 10.66 to 48.52 g kg^{-1}.

The agricultural land showed the highest OC and P soil status among different land uses. The higher content may be observed due to sediment losses from high hill slope (>35º) which trigger erosion from forest, grassland and horticulture to the low land area (i.e. agricultural land) with almost flat surface. The decreasing trend of OC in the soil profile indicating eroded soil, while the sudden increase in OC in deeper strata of the forest soil was correlated with the forest

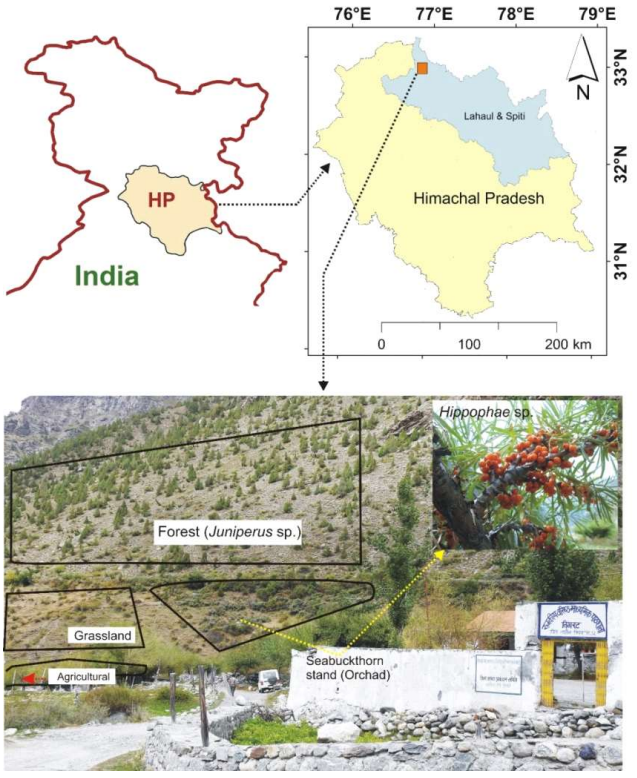


Fig. 1. Location of the study area with respect to India and sites selected under different land uses in similar landscape

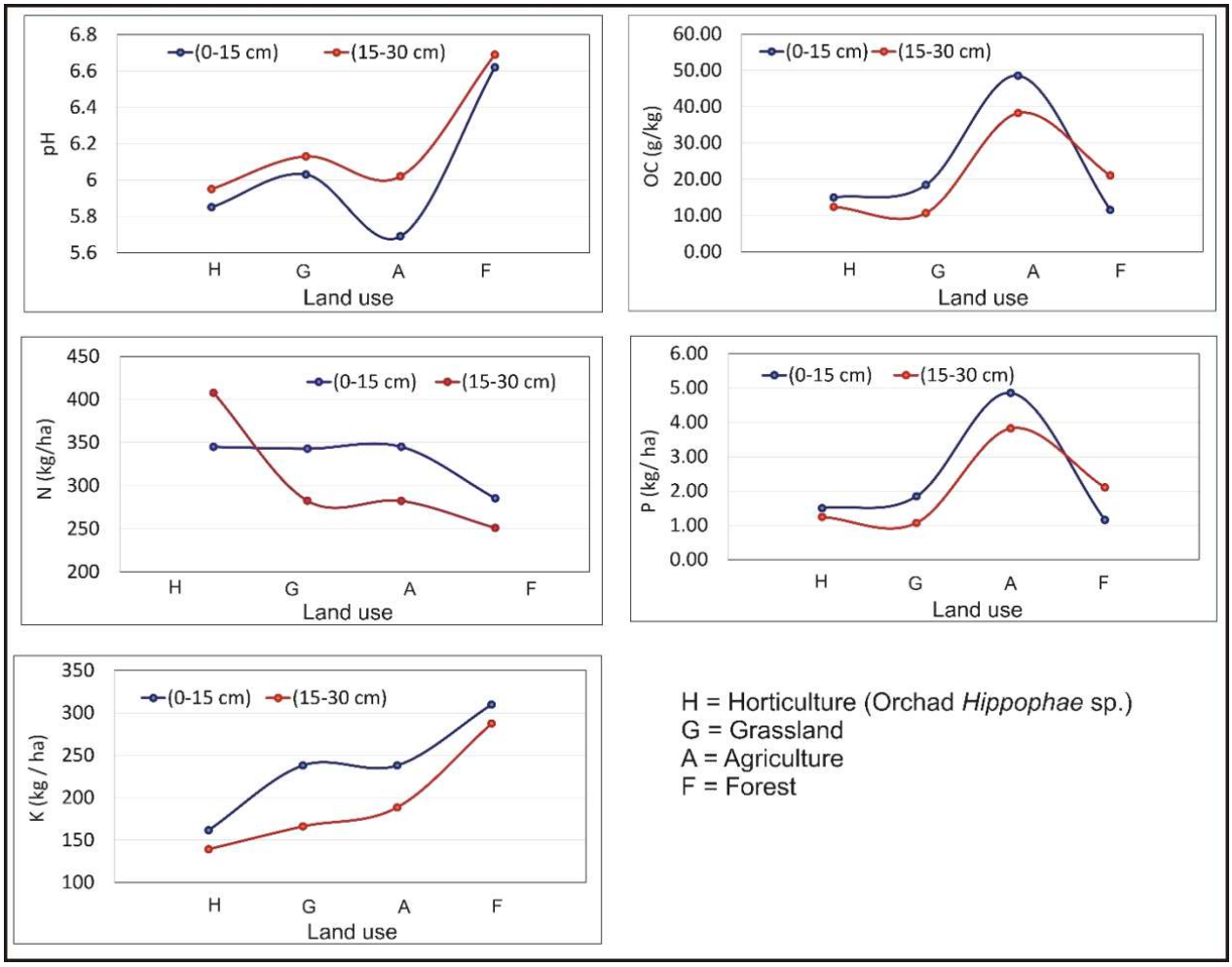


Fig. 2. Variation of soil parameters under different land uses

cover in the past, which might have eroded and the deeper layer still has higher OC. Debasish-Saha et al (2012) also noticed the similar trend of variation in Shiwaliks hills of Lower Himalayas.

The concentration of available phosphorous (P) ranged between 1.07-4.85 kg ha^{-1}. The available phosphorous (P) showed the similar trend with a high concentration in surface samples (0-15 cm), except in the forest community. The concentration of the potassium (K) was lowest in horticulture; however, the available nitrogen (N) was highest among different land uses and surprisingly increases with depth. Rana et al (2019) also noticed the appreciable increase of the available N, P and other micronutrients in the seabuckthorn stands in Lahaul valley, however the low values was observed for the available K in the soil. In the present study the available K was also low in horticulture land in comparison to the different land uses. Generally, the concentration of nitrogen (N) decreases with depth, however the N was highest (407.68 kg ha^{-1}) in the subsurface samples (15-30 cm) in horticulture land. The sudden increase in concentration with depth may be due to nitrogen fixation capabilities of *Frankia* (Actinomycetes) in the horticulture dominated by seabuckthorn (*Hippophae* sp.) communities. Jike and Xiaoming (1992) noticed the ability of seabuckthorn to fix 180 kg N $ha^{-1}year^{-1}$.

CONCLUSION

The Indian Himalayan Region is one of the most vulnerable and fragile ecosystem, where only few indigenous plant species are able to survive. In the present study the soil samples were collected from the seabuckthorn stand was compared with other land uses in the similar landscape. The agricultural land found to have the highest concentration of the OC and P possibly due to farmer input and erosion from high hill to the lowland area. The higher OC in the soil collected from the forest land indicating deforestation and the subsequent erosion. The other soil nutrients showed the comparable results under different land uses and soil depths.

However, the concentration of the available nitrogen was higher in seabuckthorn stand compared to other land uses which exceptionally increases with depth indicating nitrogen fixation in the soil by respective plant species. As the soil samples were collected from the similar landscape and parent rock, so the variation in the soil properties was due to local site conditions, land uses and regional microclimate of the area. Our study also concerns the importance of seabuckthorn for improving soil fertility that will be crucial for management and protecting Himalayan ecosystem.

ACKNOWLEDGEMENT

Authors thank the Department of Soil Science, CSKHPKV Palampur, India for lab facilities. This study was funded by Indian Council of Agricultural Research (ICAR) for financial assistance through the project entitled “AICRP on micro and secondary nutrients and pollutant elements in soils and plants” ICAR-048 (15V).

REFERENCES

Acharya S, Stobdan T and Singh SB 2010. Seabuckthorn (*Hippophae* sp. L.): New crop opportunity for biodiversity conservation in cold arid Trans- Himalaya. *Journal of Soil and Water Conservation* **9**: 201-204.

Barre P, Durand H, Chenu C, Meunier P, Montagne D, Castel G, Billiou D, Soucémarianadin L and Cécillon L 2017. Geological control of soil organic carbon and nitrogen stocks at the landscape scale. *Geoderma* **285**: 50-56.

Black CA 1965. Methods of soil analysis. Part II. Chemical and mineralogical properties. *American Society of Agronomy*, Madison, Wisconsin, USA.

Charan G, Bharti VK, Jadhav SE, Kumar S, Acharya S, Kumar P, Gogoi D and Srivastava RB 2013. Altitudinal variations in soil physico-chemical properties at cold desert high altitude. *Journal of Soil Science and Plant Nutrition* **13**: 267-277.

Cifen B and Zhao G 2003. Stabilization of slopes and watersheds by seabuckthorn (*Hippophae rhamanoides* L.) in arid and semi-arid areas of China. In: *Seabuckthorn: A multipurpose wonder plant.* pp. 409-416.

Debasish-Saha, Kukal SS and Bawa SS 2012. Soil organic carbon stock and fractions in relation to land use and soil depth in the degraded Shiwaliks Hills of Lower Himalayas. *Land Degradation & Development* **25**: 407-416.

Dhyani D, Maikhuri RK, Rao KS, Kumar L, Purohit VK and Sundriyal M 2007. Basic nutritional attributes of *Hippophae rhamnoides* (seabuckthorn) populations from Uttarakhand Himalaya, India. *Current Science* **92**: 1148-1152.

Husain M, Rathore JP, Rasool A, Parrey AA, Vishwakarma DK and Mahendar K 2018. Seabuckthorn: A multipurpose shrubs species in Ladakh cold desert. *Journal of Entomology and Zoology Studies* **6**: 1330-1337.

Jackson ML 1973. *Soil Chemical Analysis*. Prentice Hall of India. Pvt. Ltd., New Delhi. 498.

Jike Z and Xiaoming Z 1992. Progress of study on *Frankia* in nodules of seabuckthorn. *Hippophae* **2**:4-10.

Kumar G, Sharma P, Stobdanand T and Angmo P 2019. Assessment of biomass, carbon stock and rhizospheric properties of seabuckthorn shrub (*Hippophae rhamnoides* L.) in Spituk Village of Leh District, Ladakh. *Annals of Arid Zone* **58**: 91-98.

Kumar P, Singh V and Singh A 2018. Seabuckthorn (*Hippophae* spp.) Conserve plant diversity in the fragile mountain ecosystem of cold desert Himalaya. *Journal of Biodiversity* **9**: 53-68.

Kumar S and Sagar A 2007. Microbial associates of *Hippophae rhamnoides* (Seabuckthorn). *Journal of Plant Pathology* **6**: 299-305.

Lu R 1992. Seabuckthorn-A multipurpose plant for fragile mountains. International Centre for Integrated Mountain Development ICIMOD. Occasional Paper No. 20. Kathmandu, Nepal, 62p.

Olsen RS 1954. *Estimation of available phosphorus in soils by extraction with sodium bicarbonate* (USDA Circular No. 939). Washington, D.C.: U.S. Government Printing Office.

Rana D, Singh V and Gourav 2019. Depth wise assessment of soil fertility in seabuckthorn in comparison to willow and poplar in cold arid Himalayas. *Indian Journal of Ecology* **46**: 104-110.

Sharma A and Singh V 2017. Assessment of micronutrients status under seabuckthorn (*Hippophae rhamnoides* L.) soils in Spiti, Himachal Pradesh. *Indian Journal of Ecology* **44**: 348-351.

Sharma VK, Dwivedi KS, Tripathi D and Ahmed Z 2006. Status of available major and micronutrients in the soils of different blocks of Leh district of cold arid region of Ladakh in relation to soil characteristics. *Journal of the Indian Society of Soil Science* **54**: 248- 250.

Singh A, Butola SJ, Samant SS, Sharma P, Lal M and Marpa S 2012. Indigenous techniques of product development and economic potential of seabuckthorn: A case study of cold desert region of Himachal Pradesh, India. *Proceedings of the National Academy of Sciences* **82**: 391-398.

Singh V and Gupta RK 2008. Micro propagation of seabuckthorn (*Hippophae rhamnoides* L.). In: Singh V, editor. Seabuckthorn (*Hippophae* L.) a multipurpose wonder plant. *Advances in Research and Development*, India, Daya Publishing House, Delhi, **3**: 3-13.

Subbiah BV and Asija GL 1956. A rapid procedure for estimation of available nitrogen in soils. *Current Science* **25**: 259-260.

Tamchos S and Kaul V 2015. Seabuckthorn-the natural soil fertility enhancer. *Current Science* **108**: 5-10.

Tamchos S and Kaul V. 2016. Distributional status of *Hippophae tibetana*: A new report from Changthang valley of Ladakh. *National Academy Science Letters* **39**: 59-62.

Walkley A and Black IA 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science* **37**: 29-38.

Received 26 July, 2020; Accepted 26 August, 2020

Indian Journal of Ecology (2020) 47(3): 803-807

Manuscript Number: 3088
NAAS Rating: 4.96

Impact Analysis of Anacardiaceae family against *Dociostaurus maroccanus* Locust in Inventories of Algeria South-West Region

M. Bereksi Reguig, I. Abdelli[1] and F. Hassani

Ecology and Management of Natural Ecosystems laboratory, Faculty SNV.STU- Tlemcen University
[1]Higher Applied Sciences School-Laboratory (LASNABIO)-Tlemcen-Algeria
E-mail: meryem.bereksireguig@yahoo.fr

Abstract: Orthoptera are considered pests of agricultural production and pastoral. *Dociostaurus maroccanus* is a devastating species, where their distributions extend all around the semi-arid Mediterranean littoral. The phytoprotection method is the goal of this study which is based on essential oils of aromatic plants, taking as an example the Anacardiaceae family. The aim of the present study focuses on the molecular docking approach to inhibition of the enzyme α-amylase which is a digestive enzyme of *D. maroccanus* using phenolics compounds derived from essentials oil of aromatic plants: Elemol, Myrcène, Spathulenol, Terpinen-4-ol, Bornyl acetate. Elemol give the best docking score, its interactions with α-amylase has the lowest energy score compared to the other complexes. Elemol forms strongs one H-donnor interaction and one H-acceptor with residues of actives site of α-amylase. This study revealed for the first time that Elemol from Anacardiacea family is a functional inhibitor of α-amylase activities and it can been used as good bio-insecticide against *D. maroccanus* for the protection of environment and the human health.

Keywords: *Dociostaurs marrocanus*, Bio-pesticides, α-amylase, Essential oils, Anacardiaceae, Molecular modeling methods

The Moroccan locust or *Dociostaurus maroccanus* (Thunberg 1815), is a species known as a pest in Moroccois ranked as the second enemy after the Desert locust *Schistocerca gregaria* (Forskal 1775, Bendjelloun et al 2014). Its existence extends all around the semi-arid Mediterranean littoral, in Europe, the Middle East, North Africa and the majority of Mediterranean islands as well as different Asian regions and is considered as key locust pests because of gregarious nature whose individuals, under the influence of a large group, are able to move from a solitary form harmless to a gregarious form that makes them dreadful considering the important damage they can cause (Louveaux et Benhalima 1987**,** El ghadraoui et al 2018). The economic and ecological impact of locusts on crops and pastures has been known for a long time. Currently, aromatic plants have a considerable advantage thanks to the progressive discovery of the applications of their essential oils in health care as well as their uses in other fields of economic interest. Their many uses mean that they are experiencing a growing demand on world markets. The popularity enjoyed by essential oils and aromatic plants in general for a long time remains linked to their medicinal properties as it is the case of the anti-inflammatory, antiseptic, antiviral, antifungal, bactericidal, antitoxic, insecticidal, toning, stimulating, and calming plants (Ouhererre et Abidat 2018). To do so, with the development of computer tools, molecular modeling and more precisely molecular docking quickly invested the field of biological research. Its main purpose is to predict the most favorable conformation (position and relative orientation) of the ligand within its receptor. In terms of area and bioclimatic diversity, Algeria is known for its richness in aromatic and medicinal plants (Bekkal brikci 2019). The use of aromatic plants has a broad spectrum. The technique involves extracting ligands from the essential oils of these aromatic plants to control these pests.This inhibitory action is made by ligands from a series of plants of the family Anacardiaceae, to produce a bio-insecticide. For this, plant species*: Pistacia lentiscus, P. atlantica, P. terebenthus, P. vera* were evaluated .In present study attempts are mades to identify the most coherent (Enzyme-Ligand) complex (s) that lead to the best inhibitors of the α-amylase enzyme in order to limit the population of *D. maroccanus*. The enzyme chosen for our study is a digestive hydrolase involved in the production of energy in insects. These enzymes are synthetized and secreted by the epithelial cells of the midgut of insects and play an essential role in digestion and their survival. This enzyme was purified from the midgut of *D. maroccanus* (Bahareh et al 2016).

MATERIAL AND METHODS

Ligand and protein preparation: The ligands used in this work are chosen according to the most important yield in each part of the plant (leaf and fruit) (Table 1). The chemical structure of these ligands was obtained from the database

"Pubchem" (Fig. 1), and ligands were drawn from the software "Chemdraw" version 12.0.2.1076; and recorded in format " Mol", and then optimized the ligands with the software "Hypercham" "version 8.0.10 and saved in "Mol" format, for molecular docking with the Molecular Operating Environment" MOE "software. Downloaded enzyme with 1CLV code from "RCSB" or "PDB" (Protein Data Bank) with a resolution of 2A° (Table 3).

Molecular docking protocol: The method is based on molecular modeling. Docking basically consists of two steps:

- Molecular Docking is the step of the selection which consists of placing the ligand in the active site of the protein and sampling the positions, conformations and orientation (poses) possible to have the most stable complex (Mezhoud).
- Scoring is the ranking step, which consists in evaluating the affinity between the ligand and the protein and giving a score to poses obtained during the Docking phase. This score helps us to remember the best pose among all that proposed (Boucherit 2012).

Table 1. Molecules present in the essential oils of the plants

Plants species	Essential oil%	
	Leafs	Fruits
Pistacia lentiscus	- α -pinène 11 - limonène 10.3 - Myrcène 39.2 - Terpinèn .4.ol 29.9 - α -terpinéol 15	- α -pinène 22 - β- myrcène 54
Pistacia atlantica	- α -pinène 10.9 - Delta-3-carène 56 -Spathulenol 22 - Terpinèn-4-ol16 -β-pinène13 - Elemol 20	- Bornyl-acétate 21.5 - Myrcène 34 - Sabinène 19.5
Pistacia terebenthus	- Terpinèn-4-ol 33.7 - α -pinène 16.4	- Limonène 34.2
Pistacia vera	- α -pinène30 -Terpinolène17.6 - Bornyl acétate 11.3	- α -pinène 54.6 - Terpinolène 31.2

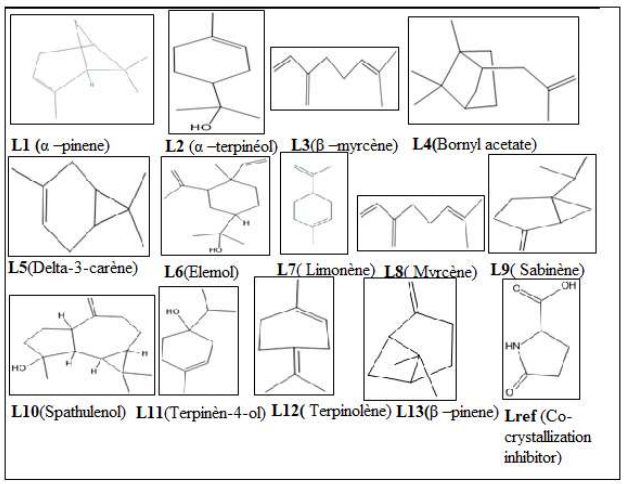


Fig. 1. Ligands structure

RESULTS AND DISCUSSION

Binding affinities of the ligands into α-amylase active site: In order to find the residues forming the largest active amino-acid site of the enzyme to interact with the ligands, used the Site Finder module on the MOE software. It is observed that the enzyme 1CLV contains 20 enzymatic cavities whose largest active site is formed of 21 amino acids which are:

LEU 49-TRP 56-TRP 57-TYR 60-GLN 61-HIS 99-GLY 102-MET 103-LEU150-VAL151 LEU153-ARG183-ASP185-ALA186-GLU222-ILE224-HIS286-ASP287-ARG290-ASN331-ASP332.

After the preparation of the enzyme and the ligands, the next step is the positioning of these inhibitors in the active site of the enzyme 1CLV. For that used the docking module using the "MOE" software. Once the complex ligand receptor is formed (Figures 3-7), and will adapt the most stable

Table 2. Somme properties of tested molecules

Ligands	Weight (g/mol)	TPSA (Å^2)
L1	136,23	0 (0: don, 0: acc)
L2	154,25	20,2 (1:don, 1:acc)
L3	136,23	0 (0: don, 0: acc)
L4	196,29	26,3(0: don, 2: acc)
L5	136,23	0 (0: don, 0: acc)
L6	222,37	20,2(1:don, 1:acc)
L7	136,23	0 (0: don, 0: acc)
L8	136,23	0 (0: don, 0: acc)
L9	136,23	0 (0: don, 0: acc)
L10	220,35	20,2(0: don, 0: acc)
L11	154,25	20,2 (1:don, 1:acc)
L12	136,23	0 (0: don, 0: acc)
L13	136,23	0 (0: don, 0: acc)

Table 3. Some of the α-amylase enzyme properties

Protein	Classification	Method	Resolution	Number of chains	Chain length
1CLV	HYDROLASE	X-Ray diffraction	2 A°	two chains	503

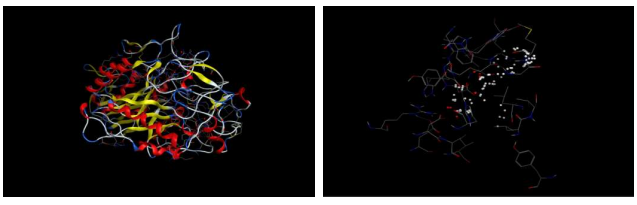


Fig. 2. α-amylase enzyme 3D structure

conformation with the lowest energy level. Once the complex is formed was analyze.In order to compare the stability of the ligands studied in the active site of the enzyme 1CLV, performed a molecular docking between the enzyme and the ligands. The obtained results for each ligand are classified and grouped in Table 4.

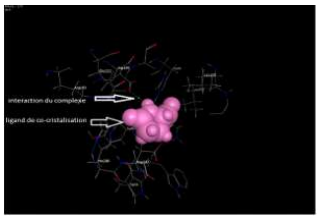


Fig. 3. 1CLV co-cristallisation ligand-complex

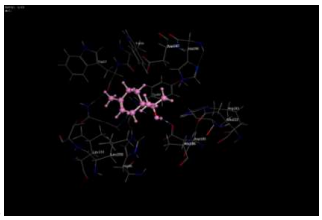


Fig.4. 1CLV complex-L2

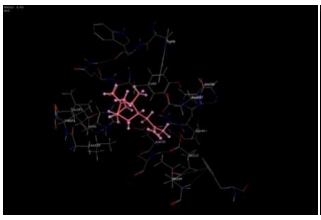


Fig. 5. 1CLV complex-L6

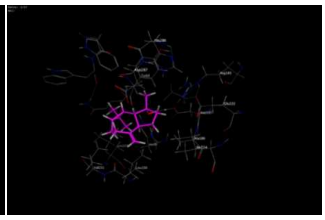


Fig. 6. 1CLV complex-L10

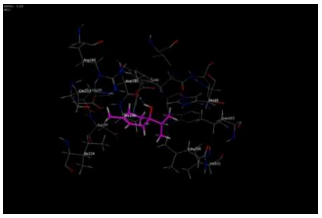


Fig. 7. 1CLV complex-L11

The best score obtained after docking is that of L6 with a score of -4.9763 kcal mol^{-1}, followed by L10 with a score of -4.9324 kcal mol^{-1}, the values other scores of (-4.7707 kcal mol^{-1}) of L8, (-4.6803 kcal mol^{-1}) of L3, (-4.6694 kcal mol^{-1}) of L11, (-4.6049 kcal mol^{-1}) of L4 and (-4.5059 kcal mol^{-1}) of L2 are better compared to the reference ligand with a score of -3.5513 kcal mol^{-1}. According to the results, L6 and L10 are considered to be better inhibitors for 1CLV by the obtained score after docking; moreover, the other ligands L8, L11, L4 and L2 can be considered as good inhibitors of 1CLV.

Enzyme-Ligands Interaction: Interactions between 2.5 Å and 3.1Å are considered strong and those between 3.1Å and 3.55Å are assumed to be average. Interactions greater than 3.55Å are weak or absent (sai, Pintore et al 2006). The interactions present between the ligands and the enzyme are given in Figures 8 to 12. The distances measured between the ligands and the amino-acids of the active site vary between 2.99 ° and 3.26 °.

The average interactions between L6 and the active site of the enzyme α-amylase with a distance of 3.27A °this interaction is considered average because it is between3.1Å and 3.55Å, this interaction is between NE 2 and the amino-acid HIS 286 present in the enzymatic cavity of our enzyme with an energy of -1.6kcal / mol. In addition, interaction between L10 and the active site of the enzyme, with a distance of 3.15A °, was observed and it is between the OD1

Table 4. Docking score and distances bonds of the compounds into α-amylase

Ligands	Score	Interaction with residues	Interaction type	Distance (A°)	Energy
L6	-4,9763	OD1- ASP18 NE2 – HIS286	H- donor H- acceptor	3,03 3,27	-2,1 -1,6
L10	-4,9324	OD1- ASP185	H-donor	3,15	-1,9
L8	-4,7707	/	/	/	/
L3	-4,6807	/	/	/	/
L11	-4,6694	OD1- ASP185	H- donor	3,26	-1,0
L4	-4,6049	/	/	/	/
L2	-4,5059	OD1 – ASP 185	H- donor	2,99	-1,9
L12	-4,4409	/	/	/	/
L7	-4,42	/	/	/	/
L1	-4,1707	/	/	/	/
L13	-4,0883	/	/	/	/
L5	-3,9983	/	/	/	/
Lref	-3,5513	OD1 – ASP185 NE2 - HIS286 ND1 – HIS99 NE2 – HIS99 NE2 - HIS99	H-donor H- acceptor ionic ionic ionic	3,41 3,04 3,87 3,23 3,83	-0,7 -4,4 -0,8 -3,1 -0,9

The ligands are ranked in ascending order, with the lowest score showing a better inhibitor.

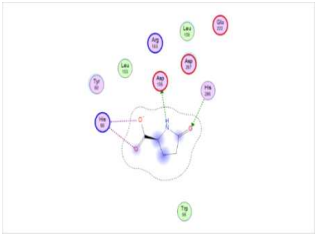


Fig. 8. 1CLV-reference ligand interaction

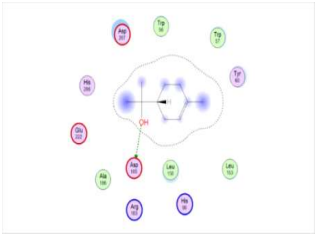


Fig. 9. 1CLV-L2 interaction

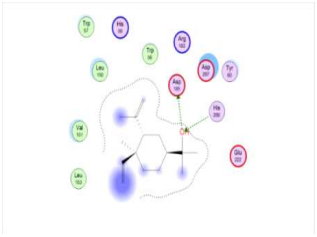


Fig. 10. 1CLV-L6 interaction

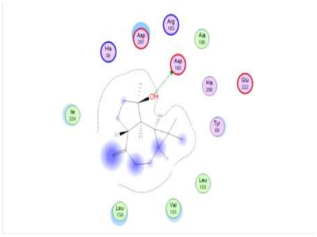


Fig. 11. 1CLV-L10 interaction

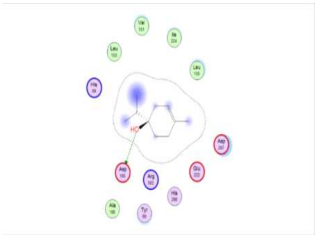


Fig. 12. 1CLV-L11 interaction

and the amino-acid ASP 185, this interaction are considered strong because it is between 2,5 Å and 3,1 Å. More than 2000 plant species with insecticidal properties have been identified (Regnault-Roger et al 2008). Therefore, the use of plant extracts as natural insecticides is of purely ecological interest and is not harmful to the environment (Hamid Oudjana 2017). Cricket damage poses a threat to the stability of agricultural areas. The damage and havoc attributed to these insects is as much a result of larval activity as that of adults (Acheuk 2012). Locust control remains one of the major concerns in the crop protection strategy of arid and semi-arid regions already subject to climatic hazards. The insecticides used are generally neurotoxic. This means that chemical control has adverse effects on human health and the environment, biological control remains the only way to eliminate them without drawbacks.

Several studies have highlighted the effectiveness of many essential oils applied as bio-insecticides. Among the works, Ould El Hadj et al (2003), observed the toxicity of the extracts of three acridifuge plants on the fifth instar larvae and adults of *Schistocerca gregaria*. Senouci (2016) confirmed through his study the power of essential oils medicinal plants of *Pistacia lentiscus* and *Marrubium vulgaris* against the bio-aggressors of the olive tree, that *Pistacia lentiscushas* an important role in biological control. According to the obtained results from molecular docking, sixteen "enzyme-ligand" complexes are formed. It has been found that there are several ligands that promote the inhibition of the enzyme 1CLV through their weakest scores. Compared to the score of the co-crystallization inhibitor (-3,5513 kcal / mol). According to the series of plants of the family Anacardiaceae, seven ligands have been determined, and those: elemol (L6), spathulenol (L10), myrcene (L8), beta-myrcene (L3), terpinen-4-ol (L11), bornyl-acetate (L4), α-terpineol (L2). According to the obtained scores, these ligands have a bio-insecticidal power towards the α-amylase enzyme of the digestive system of *D . marrocanus*. The following plants possess the best bio-insecticidal ability: L6 and L10 from *Pistacia atlanica*, L8 and L4 leaves from the fruit of *P. atlantica*, L8, L11 from leaves *P. lentiscus*, L3 from fruit of *P. lentiscus*, L11 from leaves of *P*. terebenthus, finally L4 from leaves of *P*. *vera*.

CONCLUSION

Pest control requires the use of insecticide which represents a danger to human health and the environment for this we used a biological method through the phenolic compounds of aromatics plants, these compounds have been widely studied as α-amylase inhibitors, they are extracted from essentials oil of aromatics plants of the Anacardiaceae family: Elemol, Myrcène, Spathulenol, Terpinen-4-ol, Bornyl acetate. Elemol give the best docking score, its interactions with α-amylase has the lowest energy score compared to the other complexes. Elemol forms strong one H-donnor interaction and one H-acceptor with residues of actives site of α-amylase. This study revealed that Elemol is a functional inhibitor of α-amylase activities and finally we can declare that the essential oil components of Pistacia atlantica Anacardiaceae family present a power as a bio insecticide against *Dosciostaurus marrocanus*.

REFERENCES

Acheuk Fatma 2012. *Evaluation des effets du Teflubenzuron et de l'extrait méthanolique de la plante Haplophyllum tuberculatum (Rutacée)sur le développement et la reproduction du criquet migrateur : Locusta migratoria(Linné,1758) (Orthoptera, oeudipodinae)*. Thèse doctorat en science agronomique. Ecole national supérieure agronomique El harrach Alger.

Anastasia Tsokou, Katerina Georgopoulou, Eleni Melliou, Prokopios Magiatis and Eugenia Tsitsa 2007. Composition and Enantiomeric Analysis of the Essential Oil of the Fruits and the Leaves of *Pistacia vera* from Greece. *Molecules* **12**: 1233-1239.

Bahareh Rafiei, Mohammad Ghadamyari, Sohrab Imani, Vahid Hosseininaveh and Ali Ahadiyat 2016. Purification and characterization of α-amylase in Moroccan locust, *Dociostaurus maroccanus* Thunberg (Orthoptera: Acrididae) and its inhibition by inhibitors from *Phaseolus vulgaris* L. *Toxin Reviews* **35**(3-4): 90-97

Bekkal Brikci Sohayb 2019. Contrôle biologique du nématode des Citrus *Tylenchulus semipenetrans* (Cobb 1913) (Tylenchylidae) par des substances naturelles. Mémoire master en écologie. Université de Tlemcen.

Bendjelloun M. El Ghadraoui, D. Essakhi, J. Alfiguigui and Errabhi N 2014. Contribution à l'étude de la diversité des orthoptères acridiens dans le Moyen Atlas (Maroc). Laboratoire EFE, FST, Université Sidi Mohamed Ben Abdellah, Fès-Maroc. AFPP-Dixième conférence internationale sur les ravageurs en agriculture Montpellier -22 et 23 octobre2014.

Boucherit H 2012. Etude théorique des interactions intervenant dans l'inhibition de la méthionine aminopeptidase de mycobacterium tuberculosis par diverse molecules. Thèse de magister en biochimie. Constantine : Université Mentouri Constantine. Algérie 71 p

Hamdan Imad and Afifi Fatma Ulku Ulku 2004. Studies on the in vitro and in vivo hypoglycemic activities of somemedicinal plantsused in treatment of diabetes in Jordanian traditional medicine. *Journal of Ethnopharmacology* **93**: 23-28.

Hamid Oudjana Aicha 2017. *Cholinestérases et toxicité d'extraits de quelques plantes acridicides ou acridifuges chez Schistocerca gregaria (Forskål, 1775*).Thèse doctorat science en biologie. Université Kasdi Merbah Ourgla.

Hassan Amhamdi, Fatima Aouinti1, Jean Paul Wathelet and Ali Elbachiri 2009. Chemical Composition of the Essential Oil of *Pistacia lentiscus* L. from Eastern Morocco. *Rec. Nat. Production* **3**(2): 90-95.

Lahsen El ghadraoui, Daniel Petit and Jamal El yamani 2018. Le site Al-Azaghar (Moyen-Atlas, Maroc): un foyer grégarigène du criquet marocain *Dociostaurus maroccanus* (Thunb., 1815). Université Sidi Mohammed Ben Abdellah, Faculté des Sciences et Techniques, Département de Biologie, *Bulletin de l'Institut Scientifique,* Rabat, section Sciences de la Vie, 2003, n°25, 81-86.

Louveaux Alain. et Benhalima Thami 1987- Catalogue des Orthoptères Acridiodea d'Afrique du Nord-Ouest. *Bulltein Society Entomology, France* **3**(4): 73-87.

Louveaux Alain, Mouhim Ahmed, Roux Geor Es, Gillon Yves and Barral Henri 1996. Influence du pastoralisme sur les populations acridiennes dans le massif de Siroua (Maroc). *Revue d'Ecology* **51**(2):139-151.

Mahbubeh Bozorgi, Zahra Memariani, Masumeh Mobli, Mohammad Hossein Salehi Surmaghi, Mohammad Reza Shams-Ardekani and Roja Rahimi 2013. Five *Pistacia* species (*P. vera*, *P. atlantica*, *P. terebinthus*, *P. khinjuk*, and *P. lentiscus*): A review of their traditional uses, phytochemistry, and pharmacology.Hindawi Publishing Corporation The Scientific *World Journal* 2013, Article ID 219815, 33 pages.

Marianna Usai, Giorgio Pintore, Bruno Tirillini and Mario Chessa 2006. Essential oil composition of different aerial parts of *Pistacia terebinthus* L. growing wild in Sardinia. *Journal of Essential Oil Research* **18** (July/August): 383-385.

Mehmet Emin Duru, Ahmet Cakir, Saban Kordali and Huseyin Zengin, 2003. Chemical composition and antifungal properties of essential oils of three *Pistacia* species grown in Turkey. *Fitoterapia* **74**: 170-176.

Nadhir Gourine, Isabelle Bombarda, Mohamed Yousfi and Emile M Gaydou 2010. Chemotypes of *Pistacia atlantica* leaf essential oils from Algeria. *Natural Product Communication* **5**(1): 115-120.

Ouhererre Asmaa and Abidat Rabiaa 2018. Caractérisation et l'effet de l'époque de récolte sur la composition des huiles essentielles de Schinus molle L.mémoire de master in microbiology appliqued. Université Djillali Bounnama Khmiss meliana.

Ould el hadj M, Tankari Dan-Badjo Abderahmen , Halouane F and Doumandji S 2003.- Etude comparative de la toxicité des extraits de trois plantes acridifuges sur les larves du cinquième stade et sur les adultes de *Schistocerca gregaria* Forskal, 1775 (*Orthoptera-Cyrtacanthacridinae*). *Courrier du Savoir* **3**: 81-86.

Regnault-Roger Catherine and Hamraoui Abdelaziz 1997. control of phytophagous insects by aromatic plants and their allelochemical molecules. *Ed Acta Botnay Gallica* **28**: 401-412.

Senouci Hanane 2016. Antiparasitic and antifungal activities of essential oils and hydrolates of two medicinal plants *Pistacia lentiscus* and *Marrubium vulgaris* against the pests of the olive tree, Tlemcen, Abou Bekr Belkaid University.

Received 18 July, 2020; Accepted 26 August, 2020

Indian Journal of Ecology (2020) 47(3): 808-814

Manuscript Number: 3089
NAAS Rating: 4.96

Do Exotic Trees Threaten Southern Arid Areas of Tunisia? A Case Study

Zouhaier Noumi
Department of Life Sciences, Faculty of Sciences, University of Sfax, 3000 - B.P. 1171 - Sfax, Tunisia
E-mail : zouhaiern@yahoo.fr

Abstract: This study was conducted in an afforested *Stipa tenacissima* steppe with aims to compare the effects of exotic and native planted trees (*Acacia salicina* and *Pinus halepensis*, respectively) on the understory vegetation and soil properties. For each tree species, two sub-habitats were distinguished: the canopied sub-habitat (under the tree crown) and the un-canopied sub-habitat (open grassland). Soil moisture was measured in both sub-habitats at 10 cm depth. In parallel to soil moisture, investigated the effect of tree species on soil fertility. Soil samples were collected from the upper 10 cm soil, excluding litter and stones. The nutrient status of soil (organic matter, total N, extractable P) was significantly higher under *A. salicina* compared to *P. halepensis* and open areas. This tendency remained constant with the soil water content which was significantly higher under trees compared to open sub-habitats. For water content, there were no significant differences between studied trees. Total plant cover, species richness and the density of perennial species were significantly higher under the exotic species compared to other sub-habitats. Among the two tree species, *Acacia salicina* had the strongest positive effect on the understory vegetation. It seems to be more useful as a restoration tool in arid areas and more suitable to create islands of resources and foster succession than the other investigated tree species.

Keywords: Arid ecosystems, Dry lands, Exotic tree, Native tree, Restoration, Soil characteristics, Vegetation structure

Savanna ecosystems (and arid shrub lands) are patchy ecosystems mainly structured by complex interactions between the dominant woody vegetation and their herbaceous understorey species (Barbier et al 2008, Chavan et al 2015). Most plant-plant interaction studies conducted in dry lands have stressed the importance of differences in soils between open and woody vegetated patches for explaining patterns in species biomass, richness and composition among patches (Michalet et al 2015). The overall effect of woody species on herbaceous understorey vegetation depends on the balance between their positive (facilitation) and negative (competition) effects (Noumi et al 2016). The net balance depends on numerous factors including tree or shrub species identity (i.e. suite of traits), density, nature of the understorey associated species, climate, management and herbivory among others (Abdallah et al 2012, Gea-Izquierdo et al 2010). However, it has also been shown that woody-herbaceous competition may be more intense in water-stressed environments (Maestre and Cortina 2004, Saccone et al 2009) and there is still a continuous debate on how facilitation and competition vary along water stress gradients (Maestre et al 2009, Michalet 2007, Noumi et al 2015). Gómez-Aparicio et al (2004) and Michalet (2007) stressed the importance of species traits of both the nurse and the target species (Gomez-Aparicio 2009, Maestre et al 2009). Because of their high allocation to roots, grasses are more likely to compete for water with target species than shrubs (Gómez-Aparicio 2009). Gross et al (2008) also showed that plants with shorter roots and taller shoots improve water availability, whereas small plants with longer roots such as grasses have strong negative effects on soil moisture. Legumes usually are excellent nurses because of their additional input of nitrogen to soil (Gomez-Aparicio et al 2004, Pugnaire et al 2004).

The introduction of woody plants for the restoration of degraded arid and semiarid ecosystems has become increasingly more important worldwide as a measure to protect soils, combat desertification, supply natural resources and to increase plant cover and species diversity (Cortina and Maestre 2005). However, in Mediterranean arid and semiarid areas, very few studies have performed manipulative field experiments to dissect the net effects of woody species on soil properties and understorey vegetation dynamics (Noumi et al 2012). This knowledge is necessary to understand community dynamics and to develop sound management programs. Woody species could be used in restoration actions in degraded arid areas, provided that they have a positive effect on ecosystem composition and function. In this paper, we focus on the effect of two tree species, exotic and native (*Acacia salicina* Lindl. and *Pinus halepensis* Mill., respectively) on vegetation structure and soil properties in a Tunisian dry lands. These ecosystems are characterized by relatively low biodiversity in terms of both species and interactions (Jeddi 2009). The exotic tree *A.*

salicina, an Australian leguminous plant, was introduced in many regions as a multipurpose species and successfully establishes on degraded areas by substantially increasing the surface area covered (Jeddi 2009). It has been also reported as an invasive (spontaneously spreading) tree in some countries where it was introduced (Rejmánek and Richardson 2013). However, it is possible that *A. salicina* is somewhat less invasive than some other *Acacia* species (*A. cyclops, dealbata, longifolia, mearnsii, melanoxylon, saligna*, etc.). In the studied area, *A. salicina* share habitat with *P. halepensis,* a native conifer tree widely distributed throughout the Mediterranean basin where it is one of the few native tree species that can thrive under dry conditions (Maestre and Cortina 2004). Morover, it has been extensively planted in arid and semiarid areas throughout the Mediterranean Basin, especially in its western part. Also, the objectives of this study were to compare the effects of exotic and native planted trees (*Acacia salicina* and *Pinus halepensis*, respectively) on the understory vegetation and soil properties.

MATERIAL AND METHODS

Study site: The experiment was conducted in a fenced area El Gonna (34º 41' 66"N, 10º 30' 22"E), located 20 km west of Sfax in southern Tunisia (Fig. 1). Preceding fencing, the area has been exploited as a summer rangeland that was grazed mainly by sheep and goats in an extensive grazing system. In 1995, the area was protected from grazing by the Forest Service (Forest General Direction) and planted with 1-year-old *Acacia salicina* and *Pinus halepensis* with density of 200 individuals per hectare. According to the classification proposed by the United Nations Environmental Programme (UNEP 1992), based on the aridity index (AI, the ratio of mean annual precipitation to mean annual potential evapotranspiration), the climate of study site is arid (0.05 < AI < 0.20). Temperatures range from an annual mean minimum of 2ºC to a mean maximum of 24°C. The predominant soils are alkaline sandy loam, with friable caliches at 10-25 cm depth and gypsum outcrops. Topography is mainly hilly. The area is occupied by an overgrazed *Stipa tenacissima* L. steppe and contains species indicative of the presence of gypsum, such as *Lygeum spartum, Atractylis serratuloides, Gymnocarpos decander* and *Helianthemum lippii* subsp. *intricatum*, as well as some plants such as *Artemisia herba alba* that reflect vegetation recovery after grazing exclusion.

Vegetation sampling: The experiment was carried out during the growing season of springs 2012 and 2013. We selected five 100 × 100 m plots similar in physiographic and soil features with planted *Acacia salicina* and *Pinus halepensis*. At each of the study plots, randomly selected

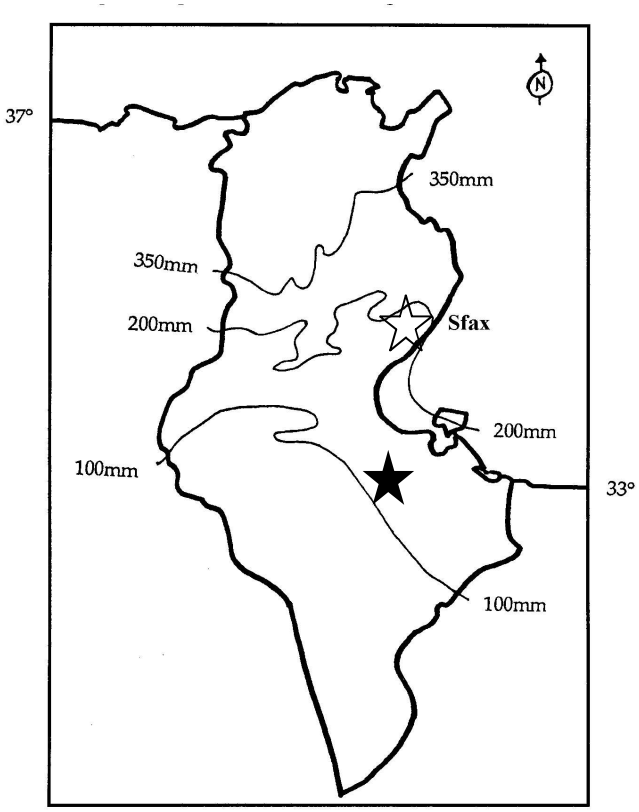


Fig. 1. Geographical localization of the study site: El Gonna (Sfax; SE Tunisia, North Africa). Black lines show isoline of annual precipitation according to Floret and Pontanier (1982)

forty individual trees (20 *A. silicina* + 20 *P. halepensis*), and measured height and canopy diameter. For *A. silicina*, average height and crown diameter were 5.3 m ± 0.41 and 4.72 m ± 0.83, respectively. These values were 6.1 m ± 0.55 and 1.9 m ± 0.69, respectively for *P. halepensis*. For each tree, located four sample quadrats of 1 × 1 m beneath the canopy at four aspects (N, S, E and W). 'Open area' refers to the quadrats located in the inter-tree areas outside the crown projection. Within each quadrat, we determined the floristic composition, species density (mean number of individuals of each species per plot), and total plant cover (%). Dry matter was estimated by the formula of Le Houérou (1987) and as used by Abdallah et al (2008):

$$DM\ (Kg\ ha^{-1}) = r \times 43.1 \pm 3.6 \qquad \text{(Eq. 1)}$$

Where r is perennial species cover.

The species diversity in the canopy and open sub-habitats was quantified using the Shannon-Weaver index (Safi and Yarranton 1973):

$$H' = -\sum Pi \log_2 Pi \qquad \text{(Eq. 2)}$$

where Pi is relative abundance of the species I calculated as ni/n where ni is mean cover of species i, and n is

total cover of all species (canopy projection to ground area). Species richness was measured as the average number of species per quadrat.

Soil sampling: Soil moisture (volumetric soil water content) was measured in different sub-habitats (under trees and open) at 10 cm depth with a TDR probe (ThetaProbe ML2x, Delta T, Cambridge, UK). Ten random points per sub-habitat type (10 under *A. salicina* + 10 under *P. halepensis* + 10 open areas) were used during the study period. The first measures were made during the dry period, whereas the rest were sampled after a 35mm rain, at the intervals of 3, 6, 9, 12 and 15 days (Noumi et al 2015). In conjunction with soil moisture, investigated the effect of trees species on soil fertility. Soil samples were collected from the upper 10 cm during the dry period. Once in the laboratory, soil samples were air-dried and sieved (2 mm) for chemical analyses. Three soil variables were analyzed: oxidizable soil organic matter, which was determined by the Walkly black procedure (Nelson and Sommers 1982), extractable phosphate and total nitrogen, which were determined by Olsen's bicarbonate extraction (Olsen and Sommers 1982) and Kjeldahl's method, respectively. Soil pH and electrical conductivity (EC) were measured by pH meter and conductivity meter, respectively (Saturated paw method, AFNOR 1987).

Statistical analysis: One-way ANOVAs were used to test the differences among sub-habitats (under *A. salicina*, under *P. halepensis* and open area) in individual species density, species richness, species diversity, total plant cover, dry matter, soil nutrients and soil water content. The program SPSS version 11.0 (SPSS, Inc., Chicago, IL, USA) was used for statistical analyses.

RESULTS AND DISCUSSION

Tree species and community structure: The 100 quadrats per sub-habitat had a total of 50 species belonging to 44 genera and 18 families (Table 1). Poaceae, Asteraceae, Brassicaceae and Fabaceae represented more than 50 % of the species pool. Species richness was higher under trees compared to open areas. Richness was three and two times higher under *A. salicina* and *P. halepensis* respectively, compared to open area. In total, 21 species were recorded under *A. salicina*, 15 under *P. halepensis* and 7 in the un-canopied sub-habitat (Table 2). The presence of trees improved all studied characteristics (floristic composition, density, total plant cover and dry matter) (Table 2). Calculated dry matter increased by 2 times under *A. Salicina* and 1.5 times under *P. halepensis* in comparison to open area. Under *A. salicina*, the total plant cover increased by 1.9 times compared to open area and by 1.6 times compared to *P. halepensis* sub-habitat. Mean values of total plant cover ranged between 41.7 % in open area to 68.4 and 82.3 % for *P. halepensis* and *A. Salicina*, respectively. Similarly, species diversity was higher under the tree canopy than in the open area: H' was 2.82 under *A. salicina*, 1.45 under *P. halepensis*, but it did not exceed 0.72 in open areas (Table 2). Overall, results showed that the presence of trees improved all the studied variables. Between tree species, the exotic *A. salicina* had higher values of vegetation characteristics compared to the native *P. halepensis*. Positive effects are often expected in arid areas, where trees improve seed trapping, nutrient, moisture, and protection from browsing or trampling (Flores and Jurado 2003). Trees are also known to have long-term effects on other species through ecosystem-engineering processes, acting on a scale of up to several hundreds of years, and including substrate trapping in mangrove and dune systems or soil weathering in all terrestrial ecosystems (He and Bertness 2014, McIntire and Fajardo 2014). Legume trees, such as *Acacia* species, are also known to improve soil nutrient availability which is firstly due to their ability to fix atmospheric nitrogen and thus improve soil fertility, and secondly to their improvement of soil water availability by reduction of actual evapotranspiration (Noumi et al 2012).

The effect of *P. halepensis* on the dynamic of spontaneous vegetation is still an open debate (Maestre and Cortina 2004). Several observational and experimental studies in semi-arid *Pinus* stands showed that this species facilitates the development of the herbaceous understory through improvement in soil conditions and microclimate (Maestre et al 2004). According to our hypothesis, the increase of the total plant cover and the DM under *Acacia* canopies is in agreement with studies showing increases of studied variables underneath tree canopies in dry lands (Abdallah et al 2008). In these environments, isolated plants act as obstacles for runoff and wind carrying organic matter, nutrients, sediments and seeds (Noumi et al 2013). These conditions create suitable microhabitats, favour plant growth and productivity and modify plant community, composition and dynamics (Cortina and Maestre 2005). Jeddi (2009), observed higher fertility of the soil below trees than outside, and this is due to the high potential of nitrogen fixation of the *Acacia* tree, to the supplied nutrients by the root system and the dead leaves of these species that create soil fertility islands (Hagos and Smit 2005). The, legume trees are also meant to improve the nutrient status of soil under their canopies (Abdallah et al 2008). In contrary, ecologists and conservation biologists often viewe exotic species as a nuisance at best to a force that can dramatically and negatively impact native ecosystems at their worst. This view is based in large part on the well documented examples in

Table 1. Species density (individuals m^{-2}) under the three types of sub habitats

Species	Family	Density		
		Acacia salicina	*Pinus halepensis*	Open
Ajuga iva	Lamiaceae	1.2[a]	0[b]	0[b]
Anacyclus clavatus	Asteraceae	0[b]	0[b]	2.1[a]
Argyrolobium uniflorum	Fabaceae	2.14[a]	1.25[b]	0[c]
Artemisia campestris	Asteraceae	1[a]	0.89[a]	0[b]
Artemisia herba alba	Asteraceae	0[b]	2.76[a]	0[b]
Asteriscus pygmeus	Asteraceae	3.7[a]	0[c]	1.31[b]
Atractylis carduus	Asteraceae	2.45[a]	1.5[b]	0[c]
Atractylis serratuloides	Asteraceae	1.2[a]	0[b]	0[b]
Bassia indica	Chenopodiaceae	0[b]	2.5[a]	0[b]
Brachypodium pinnatum	Poaceae	0[b]	1.12[a]	0.9[a]
Brassica tourneforti	Brassicaceae	3.47[a]	0[b]	0[b]
Bromus madritensis	Poaceae	5.41[a]	3.22[b]	1.11[c]
Cynodon dactylon	Poaceae	2.76[a]	0.98[b]	0[c]
Cutandia dichotoma	Poaceae	0.7[a]	0[b]	0.55[a]
Chenopodium humile	Chenopodiaceae	5.32[a]	3.2[b]	2.38[c]
Deverra tortuosa	Apiaceae	0[b]	1.45[a]	0[b]
Diplotaxis harra	Brassicaceae	4.88[a]	0[b]	0[b]
Diplotaxis simplex	Brassicaceae	5.4[a]	0[c]	1.2[b]
Echium pycnanthum	Boraginaceae	4.87[a]	2.5[b]	0.76[c]
Emex spinosus	Polygonaceae	2.51[a]	0[b]	0[b]
Erodium glaucophyllum	Geraniaceae	1.26[a]	0[b]	0.92[a]
Erodium hirtum	Geraniaceae	2.17[a]	0.8[b]	0[c]
Euricaria pinnata	Brassicaceae	3.8[a]	2.55[b]	0[c]
Fagonia cretica	Zygophyllaceae	3.12[a]	2.77[a]	1.5[b]
Gymnocarpos decander	Caryophyllaceae	0[b]	0[b]	2.3[a]
Helianthemum kahiricum	Cistaceae	2.67[a]	2.56[a]	0[b]
Helianthemum sesseliflorum	Cistaceae	1.75[a]	1.36[a]	0[b]
Hordeum murinum	Poaceae	2.95[a]	2.8[a]	1.34[b]
Hyparhenia hirta	Poaceae	1.3[a]	1.55[a]	0[b]
Kickxia aegyptiaca	Scrophulariaceae	1.2[a]	0[b]	1.5[a]
Koleria pubescens	Poaceae	1.3[a]	0[b]	0[b]
Launea angustifolia	Asteraceae	3.22[a]	2.88[a]	1.2[b]
Lygium spartum	Poaceae	0[c]	2.5[a]	1.23[b]
Malva aegyptica	Malvaceae	2.54[a]	1.21[b]	0[c]
Medicago minima	Fabaceae	6.23[a]	0[c]	2.5[b]
Paronychia arabica	Caryophyllaceae	4.13[a]	3.76[a]	2.12[b]
Plantago albicans	Plantaginaceae	1.92[a]	1.1[b]	0[c]
Polygonum equisiteforme	Polygonaceae	2.13[a]	1.5[b]	0.44[c]
Reichardia tingitana	Asteraceae	4.67[a]	0[b]	0[b]
Retama raetam	Fabaceae	1.2[a]	0[b]	0[b]
Reseda alba	Resedaceae	0[b]	0[b]	2.5[a]
Rhus tripartita	Anacardiaceae	0[b]	1.5[a]	0[b]
Rumex tingitanus	Polygonaceae	2.67[a]	1.36[b]	0[c]
Salvia aegyptiaca	Lamiaceae	0[b]	0[b]	2.23[a]
Schismus barbatus	Poaceae	8.14[a]	5.2[b]	2.33[c]
Scorzonera undulata	Asteraceae	1.44[a]	0[b]	0[b]
Senecio gallicus	Asteraceae	2.95[a]	2.66[a]	1.23[b]
Stipa capensis	Poaceae	3.35[a]	0[b]	0[b]
Stipa tenacissima	Poaceae	0[b]	2.5[a]	0[b]
Teucrium polium	Lamiaceae	1.23[a]	0[c]	0.75[b]

Mean values which are not followed by the same letter are statistically significant (Tukey's HSD-test at $P < 0.05$).

Table 2. Total plant cover (%), dry matter (kg ha^{-1}), density of species (individuals m^{-2}), diversity index, species richness, organic matter (OM), total nitrogen (N) and extractable phosphorus (P) soils occurring under *A. salicina* and *P. halepensis* canopies and in open areas

Parameters	*A. salicina*	*P. halepensis*	Open	*P*
OM (g kg^{-1})	38.6 ± 8.37^{a}	25.7 ± 4.52^{b}	10.02 ± 1.1^{c}	***
N (g kg^{-1})	1.84 ± 0.34^{a}	1.22 ± 0.21^{b}	0.72 ± 0.13^{c}	**
P (g kg^{-1})	0.06 ± 0.01^{a}	0.04 ± 0.01^{b}	0.02 ± 0.01^{c}	**
Conductivity (mS cm^{-1})	1.25 ± 0.05^{a}	1.33 ± 0.07^{a}	1.4 ± 0.09^{a}	NS
pH	7.82 ± 0.92^{a}	8.15 ± 0.06^{a}	7.35 ± 0.71^{a}	NS
Dry matter (Kg ha^{-1})	3212 ± 211^{a}	2326 ± 233.77^{b}	1559 ± 116.5^{c}	**
Species density (individuals m^{-2})	27.8 ± 2.1^{a}	25.27 ± 1.37^{b}	8.6 ± 1.15^{c}	*
Total plant cover (%)	82.3 ± 0.55^{a}	68.42 ± 0.27^{b}	41.72 ± 0.66^{c}	*
Diversity index *H'*	2.82 ± 1.61^{a}	1.45 ± 1.3^{b}	0.72 ± 0.21^{c}	**
Species richness	21 ± 3.07^{a}	15.5 ± 2.8^{b}	7 ± 0.95^{c}	***

Mean values which are not followed by the same letter are statistically significant (Tukey's HSD-test at $P < 0.05$).

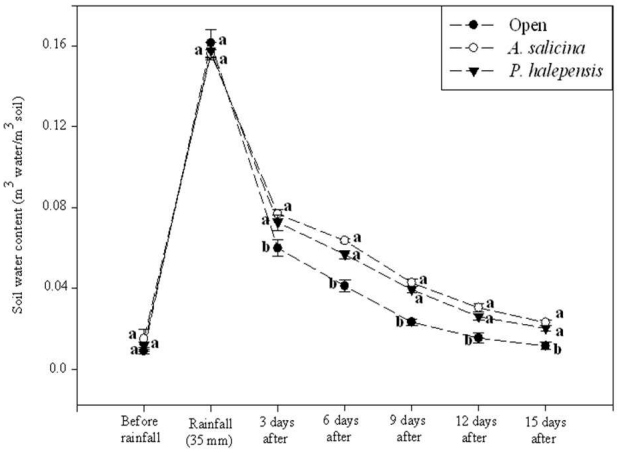


Fig. 2. Soil water content restricted to three types of subhabitats during March mean values which are not followed by the same letter are statistically significant (Tukey's HSD-test)

which the introduction of an exotic species led to widespread population reductions and even extinctions of native species.

Trees and soil properties: During the dry period, there were no significant differences in soil water content between sub-habitats (Fig. 2). Three days after a 35mm rain, there was significantly more soil water under canopied sub-habitats, and the open sub-habitats had the lowest values (Fig. 2). This trend remained constant at the intervals of 6, 9, 12 and 15 days after the rain event. Although unsignificant, our results showed that *Acacia* tree sub-habitat had the highest soil water content. Most plant-plant interaction studies conducted in dry ecosystems have stressed the importance of differences in soils between open and vegetated patches for explaining patterns in species biomass, richness and composition among patches (Weedon and Facelli 2008, Michalet et al 2015). In study, measurements concerning soil chemical properties differed for all variables, with the highest values found under tree sub-habitats (Table 2). Soil under *Acacia* had significantly higher organic matter (OM), N content and extractable P content than those under *P. halepensis*. The open sub-habitat was characterized by the lowest values for these parameters with significant differences. In contrast, there were no significant differences between canopied sub-habitats and un-canopied sub-habitats for pH and electrical conductivity. The trees are sources of soil enrichment. Specifically, our study showed that several soil fertility proxies (OM, total N and extractable P) were significantly higher in the canopy area of trees compared to open areas. The statistical analyses revealed a significant difference between the canopied effects. However, the highest means of measured soil variables were under *A. salicina* compared to *P. halepensis*. Soils under woody canopies are more fertile than soils from the surrounding grassland (Abdallah et al 2008, Noumi et al 2012, Mbah and Njoku 2020). The increase of soil organic matter and nutrient content can be a result of an increase in the amount of plant litter on the one hand, and a decrease in soil compaction on the other hand (Xie and Wittig 2004). In parallel with soil fertility, we found an improvement in water status of the understorey.

CONCLUSIONS

In accordance with our initial hypothesis that legume exotic trees had positive effects on vegetation dynamics, the results of this study showed the positive effects of the exotic legume on the understory vegetation composition in arid ecosystems. These positive effects were most evident in an increase of abundance of grass species, such as *Plantago*

albicans, Helianthemum kahiricum and *Artemisia campestris* that are known for their requirement to use the high amount of water and soil nutrients. Therefore, they showed a strong preference for the canopied sub-habitat. Thus, it seems to be more useful as a restoration tool in arid Tunisian areas and more suitable to create islands of resources and foster succession than the other investigated tree species.

ACKNOWLEDGMENTS

This research work was kindly supported by grants from D.G.F (Direction Générale des Forêts). I wish to thank Mr. Marcel Rejmanek, Professor of Plant Ecology, Department of Evolution and Ecology, University of California for review of English on previous versions of the manuscript.

REFERENCES

Abdallah F, Noumi Z, Ouled Belgacem A, Michalet R, Touzard B and Chaieb M 2012. The influence of *Acacia tortilis* (Forssk.) ssp. *raddiana* (Savi) Brenan presence, grazing, and water availability along the growing season, on understory herbaceous vegetation in southern Tunisia. *Journal of Arid Environments* **76**: 105-114.

Abdallah F, Noumi Z, Touzard B, Ouled Belgacem A, Neffati M and Chaieb M 2008. The influence of *Acacia tortilis* (Forssk.) subsp. *raddiana* (Savi) and livestock grazing on grass species composition, yield and soil nutrients in arid environments of South Tunisia. *Flora* **203**: 116-125.

AFNOR 1987. *Recueil de normes françaises, qualité des sols, méthodes d'analyses.* 1. edit. Association française de normalisation (Afnor), pp. 19-30.

Barbier N, Couteron P and Lefever R 2008. Spatial decoupling of facilitation and competition at the origin of gapped vegetation patterns. *Ecology* **89**: 1521-1531.

Chavan SB, Rao GR and Keerthika A 2015. Quantification of greenhouse gas emission from five agroforestry systems in semi-arid alfisols of India during rainy season. *Indian Journal of Ecology* **42**(1): 1-8.

Cortina J and Maestre FT 2005. Plant effects on soils in dry lands. Implications for community dynamics and dry land restoration. In. '*Tree Species Effects on Soils: Implications for Global Change*'. (Eds D Binkley, O Menyailo). Pp. 85-118. (NATO Science Series, Kluwer Academic Publishers, Dordrecht).

Flores J and Jurado E 2003. Are nurse–protégé interactions more common among plants from arid environments? *Journal of Vegetation Science* **14**: 911-916.

Gea-Izquierdo G, Allen-Díaz B and Miguel AS 2010. How do trees affect spatio-temporal heterogeneity of nutrient cycling in Mediterranean annual grasslands? *Annals of Forest Science* **67**: 112-123.

Gómez-Aparicio L, Zamora R and Gómez JM 2004. Applying plant positive interactions to reforestation of Mediterranean mountains: a meta-analysis of the use of shrubs as nurse plants. *Ecological Applications* **14**: 1128-1138.

Gómez-Aparicio L 2009. The role of plant interactions in the restoration of degraded ecosystems: A meta-analysis across life-forms and ecosystems. *Journal of Ecology* **97**: 1202-1214.

Gross N, Robson TM and Lavorel S 2008. Plant response traits mediate the effects of subalpine grasslands on soil moisture. *New Phytologist* **180**: 652-662.

Hagos MG and Smit GN 2005. Soil enrichment by *Acacia mellifera* subsp. *detinens* on nutrient poor soil in a semi-arid Southern Africa savanna. *Journal of Arid Environments* **61**: 47-59.

He Q and Bertness MD 2014. Extreme stresses, niches, and positive species interactions along stress gradients. *Ecology* **95**:1437-1443.

Jeddi K 2009. *La restauration écologique en milieu aride de Tunisie: Cas de la protection et du reboisement du site d'El Gonna*. Sfax, p 142.

Maestre FT, Callaway RM, Valladares F and Lortie CJ 2009. Refining the stress-gradient hypothesis for competition and facilitation in plant communities. *Journal of Ecology* **97**: 199-205.

Maestre FT, Cortina J, Bautista S, Susana B and Juan B 2004. Does *Pinus halepensis* facilitate the establishment of shrubs in Mediterranean semi-arid afforestation? *Forest Ecology and Management* **176**: 147-160.

Maestre FT and Cortina J 2004. Are *Pinus halepensis* plantations useful as a restoration tool in degraded semi- arid Mediterranean area? *Forest Ecology and Management* **198**: 303-317.

Maestre FT and Cortina J 2004. Insights into ecosystem composition and function in a sequence of degraded semiarid steppes. *Restoration Ecology* **12**: 494-502.

Maestre FT, Valladares F and Reynolds JF 2005. Is the change of plant-plant interactions with abiotic stress predictable? A meta-analysis of field results in arid environments. *Journal of Ecology* **93**: 748-757.

Mwah CN, Joke C 2020. Response of soil properties to different tillage methods and wood-ash application on productivity of castor (*Ricinus cumunis* L.). *Indian Journal of Ecology* **46**(3): 541-546.

McIntire EJB and Fajardo A 2014. Facilitation as a ubiquitous driver of biodiversity. *New Phytologist* **201**: 403-416.

Michalet R, Brooker RW, Lortie CJ, Maalouf JP and Pugnaire FI 2015. Disentangling the direct and indirect effects of a legume shrub on its understorey community. *Oikos* **124**: 1251-1262.

Michalet R 2007. Highlighting the multiple drivers of change in interactions along stress gradients? *New Phytologist* **173**: 3-6.

Nelson DW and Sommers LE 1982. Total carbon, organic carbon, and organic matter. In 'Methods of Soil Analysis.' (Eds AL Page.) (American Society of Agronomy, Soil Science Society of America, Madison, Wis).

Noumi Z, Abdallah L, Touzard B and Chaieb M 2012. *Acacia tortilis* (Forssk.) subsp. *raddiana* (Savi) Brenan as a foundation species: a test from the arid zone of Tunisia. *The Rangeland Journal* **34**: 17-25.

Noumi Z, Chaieb M, Michalet R and Touzard B 2015. Limitations to the use of facilitation as a restoration tool in arid grazed savanna: A case study. *Applied Vegetation Science* **18**: 391-401.

Noumi Z, Chaieb M, Le Bagousse−Pinguet Y and Richard M 2016. The relative contribution of short−term versus long−term effects in shrub−understory species interactions under arid conditions. *Oecologia* **180**: 529-542.

Olsen SR and Sommers LE 1982. Phosphorus. In 'Methods of Soil Analysis.' (Eds AL Page) pp. 403-430. (American Society of Agronomy, Soil Science Society of America, Madison, Wis).

Pugnaire FI, Armas C and Valladares F 2004. Soil as a mediator in plant-plant interactions in a semi-arid community. *Journal of Vegetation Science* **15**: 85-92.

Rejmánek M and Richardson DM 2013. Trees and shrubs as invasive alien species-2013 update of the global database. *Diversity and Distributions* **19**: 1093-1094.

Saccone P, Pagès JP, Delzon S, Brun JJ and Richard M 2009. The role of biotic interactions in altering tree seedling responses to an extreme climatic event. *Journal of Vegetation Science* **20**: 403-414.

Safi A and Yarranton GA 1973. Diversity, floristic richness and species evenness during a secondary (post-fire) succession. *Ecology* **54:** 897-902.

United Nations Environment Programme 1992. World atlas of desertification. London, UK: Edward Arnold.

Weedon JT and Facelli JM 2008. Desert shrubs have negative or neutral effects on annuals at two levels of water availability in arid lands of South Australia. *Journal of Ecology* **96**: 1230-1237.

Xie Y and Wittig R 2004. The impact of grazing intensity on soil characteristics of *Stipa grandis* and *Stipa bungeana* steppe in North China (autonomous region of Ningxia). *Acta Oecologica* **25**: 197-204.

Received 21 July, 2020; Accepted 26 August, 2020

Indian Journal of Ecology (2020) 47(3): 815-820

Manuscript Number: 3090
NAAS Rating: 4.96

Assessment of Tree Species Diversity and Their Carbon Sequestration Potential in Tumkur University Campus, Tumkur

H.B. Lakshmi and Vinod Kumar

Department of Studies and Research in Botany, Tumkur University, Tumakuru-572 101, India
E-mail: lacchhuracchhu@gmail.com

Abstract: Now a day's Urban ecology is playing a very important role in increasing the amount of carbon uptake in the cities by planting trees in garden, campuses and houses to mitigate climate change and greenhouse gases. The present study is on the tree diversity of the Tumkur University campus by estimating the tree biomass and carbon sequestration. There are 67 species recorded including 1248 individuals. Among 67 plant species, the maximum carbon sequestration is by *Albizia lebbeck* (1.63 t tree^{-1}), followed by *Samanea saman* (1.44 t tree^{-1}) and *Bombax malabaricum* (1.43 t tree^{-1}). High carbon sequestration show strong positive correlation with few variables like number of individuals, density and abundance. Results indicate the potentials of urban ecology and carbon mitigation.

***Keywords*:** Carbon sequestration, Biodiversity, Greenhouse gases, Tree diversity

Urbanisation is a global phenomenon. It would result in rapid changes in population densities and land usage for industry and residential purposes. There will be large scale migration of rural population in search of job and this plays an important role in maintaining sustainable ecosystem in the rural area. The urban planning should focus on plantation of suitable trees, check the emission of pollutants to maintain the air quality index, water, soil sustaining biodiversity etc. In the process of greening the city and introduction of new species, erosion of native species replaced by exotic and alien species recorded (Chauhan et al 2008). New York lost 578 native species and gaining 411 exotics and Adelaide lost 89 and gained 611 new species. Industrialization and indiscriminate use of chemical fertilizers has polluted soil and water. These changes have an adverse effect on human population, community characteristics and ecosystem structure. Urbanization and deforestation is unbalancing the natural carbon cycle and consequently global warming and climate change occurs. Consequent increase in global temperature due to Greenhouse gases especially CO_2.The earth's mean atmospheric CO_2 in 2018 was recorded as 410ppm which is the highest ever recorded . In this regard enhancing sink this ever increasing CO_2 through plantation of trees is a much appreciated scientific endeavour (Chauhan et al 2016). Further, identifying potential plant species with high CO_2 sinking efficiency in an urban ecosystem will advance our understanding in better management of urban ecosystem. Tumkuru being a cosmopolitan town with a population of 3.06 lakh is located about 70 km from Bangalore. It has an increased CO2 concentration and temperature due to heavy traffic. Which can be mitigated by increasing the carbon sink and by growing tree species with ability to assimilate more of carbon Survey was conducted at the campus of Tumkur University, Tumkuru to know the diversity of plants and the CO_2 sink efficiency.

MATERIAL AND METHODS

Study area: The campus has 100 acres of geographical area and divided into 6 sectors. Each sector is about 100ft X 100 ft. The campus lies between latitudes 13° 20′ 16″ North and Longitude 77° 7′ 13″ east and an average altitude of 753.07 feet above mean sea level. Temperature is fluctuates around 28° /13° C. Total of 60,000 sqft. Area was covered in the survey including all the vegetated area of the campus to understand the total diversity of plants and their richness and frequency.

Sampling technique: Out of 100 acres of university campus six quadrants of 100 X 100 ft. were selected to check the plant diversity, richness, frequency, abundance and biomass to calculate the standing tree carbon sequestration potential. Plant species having the minimum girth of 10cm at breast height was selected. Tree parameters were measured to estimate the standing biomass through non-destructive method. Individuals of each species were counted.

Tree Height and diameter at breast height (DBH): Biomass of tree species was determined by non-destructive method by measuring the DBH (Diameter at Breast Height) and tree height. The height of the trees was measured by using Easy Measure an android application version 1.4 an approximate height was obtained. Diameter was measured with the help of tree caliper.

Above and below the ground biomass of the tree (AGB & BGB): Dry biomass above the soil is dependent on the density of wood. The wood density of each species was

obtained from the world Agro-forestry Database. Wherever the wood density of tree species was not available, the standard average value of 0.6gm cm^{-3} was used. The bio-volume was calculated by multiplying height and diameter and AGB by multiplying bio-volume and wood density.

AGB (g) = volume of biomass (cm3) x wood density (g cm^{-3})

Below ground biomass was measured by multiplying AGB by 0.26 factor and carbon factor of 0.5 was used to calculate the carbon sequestration.

BGB (g) = 0.26 x above ground biomass (ton)

Relative frequency (F), density (D) and abundance (A) were calculated to analyse the vegetation data. By adding the relative values of frequency, density and dominance of the plant species Important Value Index (IVI) was calculated to record the dominance of species and their association.

Leaf area: Smallest to largest leaves of plant species were used to be calculate the leaf area. The leaves measured against1cm grid on the graph sheet and their outlines were traced. Number of squares of centimetre square in the leaf area traced was counted and the area of the partial squares was also counted to calculate the total leaf area.

RESULTS AND DISCUSSION

There are 1248 individuals belonging to 67 species and 55 genera in the campus. The average carbon assimilation of the study area was around 0.4017 t of carbon per tree with a total carbon assimilation of 26.917 t (Table 1). *A. lebbeck* has the highest amount of carbon assimilation (1.63 t $tree^{-1}$) and *M. koenigii* accumulated the lowest carbon of 0.002 ton $tree^{-1}$.



Fig. 1. Insat image showing the study areas

The total aerial biomass was 43.066 tons with an average aerial biomass of 0.64 t $tree^{-1}$. Among the 67 species studied *A. lebbeck* with 2.59 t $tree^{-1}$ has the highest aerial biomass as compared to other species. Minimum above ground bio-mass was in *M. koenigii* 0.004 t $plant^{-1}$. Total underground biomass was 10.75 tons with an average 0.15 tonne/tree. Among the 67 plant species *A. lebbeck* has the maximum below ground biomass and *M. koenigii* lowest. The total biomass of the area was 54.14tons with average biomass of 0.808 t $tree^{-1}$.

Carbon sequestration on acreage basis depends on various other factors like frequency, density, abundance and biomass and biovolume (Table 2).

Table 1. Total biomass, carbon sequestration by the tree of Tumkurcampus, Tumakuru (t $tree^{-1}$)

Botanical name	Number of Individual	Mean AGB	Mean BGB	Mean biomass	Mean carbon sequestration.
Acacia auriculiformis	1	1.5	0.39	1.89	0.94
A. melanoxylon	5	0.36	0.09	0.45	0.22
Albizia amara	1	1.58	0.41	1.99	0.99
A. lebbeck	6	2.59	0.67	3.26	1.63
Araucaria cocci	44	0.12	0.03	0.15	0.07
Areca catechu	1	0.13	0.03	0.17	0.08
Artocarpus heterophyllus	27	0.05	0.032	0.08	0.04
Azadirachta indica	75	0.24	0.06	0.31	0.15
Bauhinia variegate	49	0.25	0.06	0.31	0.15
Bombax malabaricum	2	2.28	0.59	2.87	1.43
Callistemon lanceolatus	16	0.02	0.007	0.03	0.01
Cassia fistula	1	0.04	0.01	0.05	0.02
C. renigera	1	1.55	0.404	1.96	0.98
C. siamia	11	0.48	0.12	0.6	0.3
C. spectabilis	2	0.41	0.107	0.52	0.26
Cocos nucifera	10	1.27	0.33	1.6	0.8
Cordia oblique	4	0.21	0.05	0.26	0.13

Cont...

Table 1. Cont...

Botanical name	Number of Individual	Mean AGB	Mean BGB	Mean biomass	Mean carbon sequestration.
Mussaenda sp.	5	0.14	0.02	0.17	0.08
Nyctanthes arbortristis	4	0.038	0.01	0.04	0.02
Parkia biglandulosa	3	0.89	0.23	1.12	0.56
Peltophorum pterocarpum	109	1.1	0.28	1.38	0.69
Phylanthus emblica	1	0.097	0.02	0.11	0.05
Plumaria alba	1	0.027	0.0007	0.028	0.01
Polyalthia longifolia	75	0.6	0.15	0.76	0.38
Pongamia pinnata	52	0.08	0.021	0.101	0.05
Psidium guajava	2	0.06	0.01	0.08	0.04
Pterocarpus marsupium	3	0.08	0.02	0.103	0.051
Samanea saman	68	2.29	0.59	2.89	1.44
Santalum album	5	0.05	0.013	0.06	0.033
Sapindus trifoliatus	59	0.08	0.02	0.102	0.051
Spathodea companulata	9	0.64	0.16	0.806	0.4
Sterospermum suaveolens	3	0.05	0.014	0.06	0.03
Swietenia mahagoni	5	0.06	0.017	0.08	0.04
Syzygium cumini	36	0.24	0.06	0.302	0.15
Tabebui argentia	4	0.18	0.04	0.23	0.11
Tamarindus indica	9	0.13	0.03	0.34	0.17
Tectona grandis	8	0.23	0.06	0.29	0.14
Terminalia arjuna	8	2.11	0.26	2.37	1.18
T.catappa	5	0.06	0.016	0.079	0.03
T. tomentosa	2	0.02	0.01	0.034	0.01
Thespesia populnea	52	0.16	0.04	0.204	0.102
Tuja occidentalis	1	1.24	0.32	1.56	0.78
Cycas circinalis	5	0.04	0.01	0.05	0.02
Dalbergia sissoo	27	0.208	0.05	0.26	0.13
Delonix regia	39	1.46	0.38	1.84	0.92
Enterolobium contortisiliquum	1	1.48	0.38	1.86	0.93
Eucalyptus cypellocarpa	3	1.34	0.34	1.69	0.84
E. obliqua	2	0.04	0.02	0.06	0.03
Feronia elephantum	3	1.09	0.28	1.38	0.69
Ficus benghalensis	10	1.71	0.44	2.16	1.08
F. glomerate	4	0.809	0.21	1.01	0.509
F. mysorensis	1	1.68	0.43	2.11	1.05
F. racemose	10	1.29	0.33	1.63	0.81
F.religiosa	15	1.39	0.36	1.75	0.87
Grevillea robusta	222	0.25	0.06	0.31	0.15
Holoptelea integrifolia	2	1.16	0.3	1.46	0.73
Jacaranda mimosifolia	2	0.61	0.16	0.77	0.38
Lagerstroemia parviflora	2	0.016	0.002	0.01	0.009
Leucaena leucocephala	13	0.53	0.13	0.66	0.33
Madhuca longifolia	13	0.35	0.09	0.45	0.22
Mangifera indica	5	0.72	0.18	0.91	0.45
Melia azedarach	4	1.71	0.44	2.16	1.08
Michelia champaka	3	0.82	0.21	1.03	0.51
Millingtonia hortensis	9	0.29	0.07	0.36	0.18
Morinda tinctorial	8	0.03	0.007	0.038	0.01
Muntingia calabura	48	0.307	0.07	0.38	0.19
Murraya koenigii	1	0.004	0.001	0.005	0.002

Table 2. Relative density, frequency, dominance, abundance, important value index of plant species of Tumkur campus

Botanical name	Realative density (%)	Relative frequency (%)	Relative dominance (%)	Relative abundance	Mean IVI
Acacia auriculiformis	0.08	14.28	0.19	9	14.56
A. melanoxylon	0.401	28.57	0.606	1	29.57
Albizia amara	0.8	14.28	0.17	1	14.53
A. lebbeck	0.48	14.28	2.09	6	16.85
Araucaria cocci	3.53	57.14	1.25	6.75	60.56
Arecanut catechu	0.08	14.28	0.017	10	14.38
Artocarpus heterophyllus	2.16	57.14	0.3	1.5	60.56
Azadirachta indica	6.01	57.14	2.05	2	64.14
Bauhinia variegate	3.93	57.14	1.2	12.25	62.22
Bombax malabaricum	0.16	14.28	0.58	2	15.02
Callistemon lanceolatus	1.28	42.85	0.07	1.25	44.17
C. fistula	0.8	14.28	0.004	10.4	45.44
C. renigera	0.08	14.28	0.19	4	14.56
C. siamia	0.88	28.57	0.68	5.5	30.13
C. spectabilis	0.16	14.28	0.13	13	14.58
Cocos nucifera	0.8	14.28	2.02	9	17.1
Cordia obliqua	0.32	14.28	0.12	1	14.79
Cycas circinalis	0.401	14.28	0.02	2.5	14.71
Dalbergia sissoo	2.16	57.14	0.83	4.5	59.39
Delonix regia	3.13	71.42	9.09	9.75	83.65
Enterolobium contortisiliquum	0.802	14.28	0.33	4	15.12
Eucalyptus cypellocarpa	0.24	28.57	0.09	1	28.9
E. obliqua	0.16	14.28	0.09	1	14.46
Feronia elephantum	0.24	14.28	0.42	3	14.94
Ficus benghalensis	0.802	14.28	2.19	4	17.28
F. glomerate	0.32	28.57	0.13	2	29.02
F. mysorensis	0.08	14.28	0.21	8	14.79
F. racemose	0.8	42.85	1.65	1	45.31
F. religiosa	1.203	71.42	4.12	3	76.74
Grevillea robusta	17.81	57.14	7.47	55.5	82.57
Holoptelea integrifolia	0.16	14.28	0.024	2	14.46
Jacaranda mimosifolia	0.16	14.28	0.15	11	16.49
Lagerstroemia parviflora	0.16	28.57	0.23	19.666	28.96
Leucaena leucocephala	1.04	42.85	0.8	4.33	44.69
Madhuca longifolia	1.04	14.28	0.42	48	15.37
Mangifera indica	0.401	14.28	0.48	1.5	15.17
Melia azedarach	0.32	14.28	0.87	2	15.44
Michelia champaka	0.24	28.57	3.15	5	29.13
Millingtonia hortensis	0.72	28.57	0.64	1.5	29.93
Morinda tinctorial	0.64	14.28	0.38	1	15.3
Muntingia calabura	3.85	14.28	4.05	10	22.29
Murraya koenigii	0.802	14.28	0.005	4	15.09

Cont...

Table 2. Cont...

Botanical name	Realative density (%)	Relative frequency (%)	Relative dominance (%)	Relative abundance	Mean IVI
Musanda sp.	0.401	14.28	0.01	17.33	14.7
Nyctanthes arbortristis	0.32	28.57	0.06	1	28.95
Parkia biglandulosa	0.24	28.57	0.62	2.5	29.43
Peltophorum pterocarpum	8.79	57.14	15.81	27.25	81.74
Phylanthus emblica	0.08	14.28	0.07	1	14.43
Plumaria sp.	0.08	14.28	0.003	1	14.36
Polyalthia longifolia	6.01	57.14	4.18	18.75	67.34
Pongamia pinnata	4.17	71.42	0.54	5.333	76.14
Psidium guajava	0.16	28.57	0.044	2	28.77
Pterocarpus marsupium	0.24	14.28	0.02	1	14.56
Samanea saman	5.54	71.42	25.71	11.33	102.67
Santalum album	0.401	57.14	0.03	1	57.57
Sapindu strifoliatus	4.17	42.85	0.66	5	48.25
Spathodea companulata	0.72	42.85	1.87	1	44.87
Sterospermum suaveolens	0.24	28.57	0.01	5	28.81
Swietenia mahagoni	0.401	14.28	0.16	1	14.85
Syzygium cumini	2.88	57.14	0.98	18.75	58.12
Tabebuia argentia	0.32	14.28	0.17	5	16.39
Tamarindus indica	0.72	28.57	0.12	4.5	29.41
Tectona grandis	0.64	14.28	0.24	1.5	15.17
Terminalia arjuna	0.64	28.57	0.24	2.66	29.45
T. catappa	0.4	14.28	0.07	5	14.58
T. tomentosa	0.16	14.28	0.02	1	14.48
Thespesia populnea	4.17	42.85	1.06	2	48.09
Tuja occidentalis	0.08	14.28	0.01	1.5	14.38

Jithila and Prasadan (2018) estimated total carbon sequestration of 610 selected plants 138.367 t year^{-1}. Highest carbon sequestration was in *Artocarpus heterophyllus* (33709 kg year^{-1}) lowest in *Spondiasn pinnata* (52.69 kg year^{-1}). Similar results have been recorded by Jaiswal et al (2014) and Mouna et al (2019). Chauhan et al (2019) got more proportion of biomass in stem (53.67%) and in root (25.61%) rather than in branch (12.56%) and in leaf (8.16%). Mahajan et al (2018) have estimated highest above and below ground bio mass in *Mangifera indica* (46.19 Mg ha^{-1}) and recorded more carbon stock in *Mangifera indica* (21.28 Mg ha^{-1}). Rai and Gupta (2018) concluded that degradation and loss of forest coupled with reduction in Biomass and Carbon sink. Gavali and Shaikh (2013) and concluded that the well managed vegetation in a campus will have great impact on the ecology of the campus. In Tumkur university campus consisting of 1248 individual among that about 13 tree species showed high carbon sequestration, the top three trees such as *A. lebbeck, Samanea saman, Bombax malabaricum,* and number of individuals, relative density, relative dominance, relative abundance, ivi, height, girth and biovolume was high in selected species, *S. saman* even though it is high in dendrometric variables but *Albizia lebbeck* shows high carbon sequestration in the campus. Thus observation results high wood density is also related to carbon sequestration not only the volume.

This potential strategy may help in carbon capture and sequestration and to meet the committed reduction in the emission intensity (INDC) by the year 2030. The importance of this method may lead to mitigate global warming, pollution and climate variation, especially in urban area.

CONCLUSION

Tumkur university campus consisting of 1248 individual among that about thirteen tree species showed high carbon sequestration, the top three trees such as *Albizia lebbeck, Samanea saman, Bombax malabaricum. Samanea saman* even though it is high in dendrometric variables but *Albizia*

lebbeck shows high carbon sequestration in the campus. Thus *Albizia lebbeck* will have great impact on reduction of Carbon capture. The importance of this method may lead to mitigate global warming, pollution and climate variation, especially in urban area.

REFERENCES

Chauhan SK, Gumber KK, Sharma R and Saralach HS 2019. Dynamics in biomass expansion factor, root to shoot ratio and wood quality parameters in different girth class of *Gmelina arborea* Roxb. *Indian Journal of Ecology* **46**(1): 111-115.

Chauhan SK, Chauan R and Saralach HS 2008. Exotics in Indian Forestry. *Exotics in Indian Forestry* (Eds. Chauhan SK, Gill SS, Sharma SC and Chauhan R). Agrotech Publishing Academy, Udaipur, pp.24-56.

Chauhan SK, Sharma R, Panwar P and Chander J 2016. Short rotation forestry: A path for economic and environmental prosperity. In: Forestry Technologies-A complete value chain Approach – Vol.1 (Eds Prathiban KT and Seenivasan R), Scientific Publishers, Jodhpur, pp. 260-288.

Chavan BL and Rasal GB 2012. Carbon sequestration potential of young *Annona reticulata* and *Annona squamosa* from university campus of Auranbad. *International journal of Physical and Social Sciences* **2**(3): 193-198.

Chourasia S 2012. Carbon sequestration study on *Dalbergiasisso* planted in different geometry (Doctoral dissertation, JNKVV, Jabalpur).

Dhanwantri K, Sharma P, Mehta S and Prakash P 2014. Carbon sequestration, Its methods and Significance. *Environmental sustainability: Concepts, Principles, Evidences and Innovations* **151***(*2): 17-25.

Dhyani SK, Handa AK, Newaj R, Chavan SB, Alam B, Prasad R and Shakhela RR 2017. Estimating carbon sequestration potential of existing agroforestry systems in India. *Agroforestry Systems* **91**(6): 1101-1118.

Gavali RS and Shaikh HMY 2016.Estimation of carbon storage in the Tree Growth of Solapur University campus, Maharashtra, India. *International Journal of Science and Research* **5**(4): 2364-2367.

Jithila PJ and Prasadan PK 2018. Carbon sequestration by trees-a study in the Western Ghats, Wayanad Region. *Indian Journal of Ecology* **45**(4): 234-239..

Kallur M 2003. Carbon stock dynamics in the tropical rain forests of the Uttarakannada district, Western Ghats, India. *International Journal of Environment and Pollution* **19**(2): 139.

Mahajan V 2018. *Carbon Sequestration Potential of Land –use Systems in Sub Tropics of Jammu & Kashmir* (Doctoral dissertation ,Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu, Jammu).

Mihriemate RL 2019. *Carbon sequestration potential of Different land use System Under East Siang District, Arunachal Pradesh* (Doctoral dissertation, College of Horticulture and Forestry, Central Agricultural University, Pasighat).

Mouna S, Jabeen FTZ, Dakshayini J, Haleshi C and Seetharam YN 2019. Carbon sequestration and tree diversity of Timmalapura Reserve Forest, Tumakuru, Karnataka. *Indian Journal of Ecology* **46**(1)*:* 116-125.

Prasad PRC and Lakshmi PM 2015. Estimation of biomass density and carbon storage in the forests of Andra Pradesh, India with emphasis on their deforestation and degradation conditions. *European Journal of Ecology* **1**(1): 52-63.

Rai P and Gupta B 2018. Estimation of biomass and carbon stock variations in vegetation of differently managed *Quercus leucotrichophora* forests along an elevation gradient in Western Himalaya, India. *Indian Journal of Ecology* **45**(1):100-106.

Rao VS and Rao BRP 2015. Carbon sequestration potential of tropical deciduous forests of Nallamalais, India. *Asian Journal of Plant Science and Research* **5**(3):24-33.

Reddy MC, Priya RM and Madiwalar SL 2014. Carbon sequestration potential of teak plantations of different agro-climatic zones and age-gradations of Southern India. *Current World Environment* **9**(3): 785-789.

Rupa P and Venkatachalam T 2018. Studies on air pollution tolerance index of native plant species to enhance greenery in industrial area. *Indian Journal Ecology* **45**(1): 1-5.

Shivanna H 2015.*Carbon Sequestration of Ten year Old Different Tree Species Planted In Shelter Belt of Northern Transitional Zone of Karnataka* (Doctoral dissertation, University of Agricultural Sciences Dharward).

Swamy KR, Shivaprasad D, Bammanahalli S, Lamani N and Shivanna H 2017. Carbon storage potential of shelter belt agroforestry system in northern transitional zone of Karnataka, India. *Journal of Applied and Natural Science* **9**(3): 1390-1396.

Mahajan V, Raina NS and Gupta LM 2018. Biomass and carbon stocks in agroforestry land use system in sub- tropics of J&K. *Indian Journal of Ecology* **45**(2): 276-280.

Yashmitha U and Avudainayagam S 2014. Carbon storage potential of *Eucalyptus tereticornis* plantations. *Indian Forester* **140**(1): 53-58.

~~*Received 29 July, 2019; Accepted 15 March, 2020*~~

Indian Journal of Ecology (2020) 47(3): 821-830

Manuscript Number: 3091
NAAS Rating: 4.96

Floristic Diversity Assessment of Dhauligiri Hill and its Adjoining Areas of Bhubaneswar City, Odisha, India

Sanjeeb Kumar Das, Padmini Bisoyi[1], Ashutosh Subudhi[2], Samarendranath Naik[3] and Sourav Ranjan Pradhan[4]

Department of Botany, Regional Institute of Education (NCERT), Bhubanewar-751 022, India
[1]Department of Life Science, JawaharlalNehru University, New Delhi-110 067, India
[2,4]Departmentof Botany, Utkal University, Vanivihar, Bhubaneswar- 751 004, India
[3]Departments of Botany, Odisha University of Agriculture and Technology, Bhubaneswar-751 022, India
E-mail: sanjeebdas75@yahoo.com

Abstract: The present paper aimed to study the floristic diversity of Dhauligiri hill and its adjoining areas of Bhubaneswar city. A total of 254 plant species, which are distributed in 174 genera and 73 families. Different life forms diversity in decreasing orders were herbs (82), shrubs (40), trees (43), grasses (45) and climbers (18). Euphorbiaceae is the dominant family among dicots and Poaceae in monocots. Ten plant species were found to be vulnerable, endangered while 40 plant species were Invasive Alien Plant species (IAPs). The 16 poisonous/toxic plant species were recorded. This is preliminary observation, however, it is recommended to initiate the activities such as inventory of useful species, habitat, characteristics, identification of species for various economic uses and formulation and implementation of plan of action taking consideration of the needs of people and sustainable management.

Keywords: Floristic diversity, Life form diversity, IAPs, Poisonous plant, Medicinal value

Floral diversity does influence the rates or nature of ecosystem processes, and a majority of studies concluded that a reduction in biodiversity does have a negative effect on ecosystem function. Floral diversity provides a useful measure of the quality of the environment and of the probability of sustainability. There are other several plants which have a strong association with another and if one species is destroyed, then it may cause a threat to another species. There are associations like parasitism, symbiosis, saprophytism and epiphytism which are completely dependent on others. Floral diversity is the natural resources and wealth of a country and acquiring knowledge of it is of immense scientific and commercial importance. Plant community plays a vital role in the sustainable management by maintaining biodiversity and conserving the environment. Floristic studies are taxonomical studies of a flora of a given area. It helps us to assess the plant wealth and its potentiality of any given area (Vediya and Kharadi 2011). The present study was the first attempt to make an inventory and analysis of entire flora of Dhauligiri hill and its adjoining.

MATERIAL AND METHODS

Bhubaneswar is located in the Khorda district of Odisha, India between 20°12'N to 20°25'N latitude and 85°44'E to 85°55”E longitude on the western fringe of the coastal plain across the main axis of the Eastern Ghats.The city stands at the Western side of the “Mahanadi Delta” on the bank of river Kuakhai, a distributary of Mahanadi river 30 km south-west of the city of Cuttack.

The present study has been carried out based on primary data collected through survey method and floristic study was based on holistic and eco-systematic perceptiveness. The floristic survey was undertaken in the Dhauligiri and its adjoining region (Fig. 1) to document floral diversity of the region. Voucher specimens were collected along with live photographs were taken with the help of camera. Details procedure of the collected plants in the field such as their preservation, collection of data, identification was carried out following methods described in the books such as vascular plant systematics (Radford et al 1974) and a 'Handbook of Field and Herbarium Method' (Jain and Rao 1977). The plants were identified in the Botany Section of Regional Institute of Education, Bhubaneswar and documented following the book “Flora of Orissa” by Saxena and Brahmam (1994). The names of the plant dealt herewith have been updated in pursuance with ICBN (Tokyo Code, Grenter et al 1974).

RESULTS AND DISCUSSION

254 species are recorded, out of which 82 herbs, 40 shrubs, 45 grasses, 43 trees, 18 climbers, 3 parasites, 13 hydrophytes, 1 gymnosperm, 5 pteridophytes, 2 bryophytes and 2 lichens were found and their percent wise distribution has been depicted in (Table 1). The details of plants recorded

with their scientific names, common names (English) and family has been listed in Table 2 to Table 9.

The herbs are the most predominant plant found in the area of Dhauligiri and its adjoining areas. Among herbaceous families, Asteraceae is the most dominant followed by Acanthaceae, Amaranthaceae, Fabaceae and Scrophulariaceae. In grass species, Poaceae family is dominant followed by Cyperaceae. Among climbers Asclepiadaceae, Cucurbitaceae, Fbaceae and Vitaceae are plentily found and in parasitic climbers, Cuscutaceae is the dominant family. Among hydrophytes, Pontederiaceae is the most dominant. In Pteridophytes, Bryophytes, lichens, all families occupies same position (Fig. 2).

Among families Euphorbiaceae, Caesalpiniaceae, Acanthaceae and Asteraceae were the dominant families in dicotyledons where as in monocotyledons, Poaceaea and Cyperaceae were the dominant families. Out of 73 families, the 10 most dominant families having plants in decreasing order were Poaceae, Cyperaceae, Euphorbiaceae, Caesalpiniaceae, Acanthaceae, Asteraceae, Moraceae, Laminaceae, Fabaceae and Mimosaceae (Table 10).

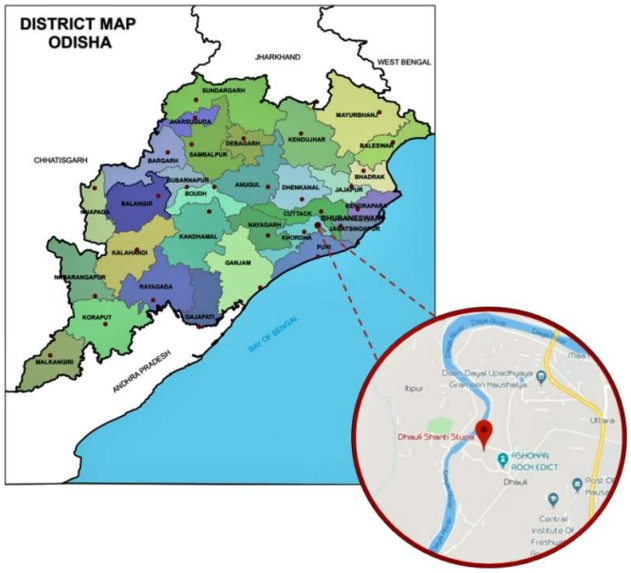


Fig. 1. The study area

Table 1. Diversity of species in and around of Dhauligiri hill

Category	Number of species	Percentage of species
Trees	43	16.92
Shrubs	40	15.74
Herbs	82	32.28
Grasses	45	17.71
Climber	18	7.08
Parasites	03	1.18
Hydrophytes	13	5.11
Gymnosperm	01	0.39
Bryophyte	02	0.78
Pterdophytes	05	1.96
Lichen	02	0.78
Total	254	100

The, 10 plant species were vulnerable, endangered and threatened. Forty plant species were identified Invasive Alien Plant species (IAPs) with *Sida acuta* L., *Alternanthera paranychioides* St., *Cleome viscosa* L., *Parthenium hysterophorus* L., *Tridax procumbens* L., *Mimosa pudica* L. being abundant in the study area (Das et al 2019).

Out of 254 plant species recorded, 90 were medicinally important. Euphorbiaceae followed by Lamiaceae was the most dominant families among economically important plant species recorded. This confirmed the observation made by Kumar and Satapathy (2011). Genera wise *Cyperus* followed by *Phyllanthus, Ficus* and *Panicum* were the dominant genera in the present study. A total of 16 poisonous /toxic plant species were identified such as *Aregemone Mexicana* L., *Cascabela thervetia* L., *Calotropis gigantean* R.Br., *Colocasia esculenta* L., *Datura stramonium* L., *Jatropha gossypifolia* L., *Lantana camara* L., *Parthenium hysterophorus* L. and *Ricinus communis* L. Besides toxicity as certain poisonous plants have medicinal importance and other economic values, those need to be conserved and used sustainably. The small pond present in the feet of Dhaulagiri Hill, Daya river, Kousalyaganga canal are ideal habitat for large number of aquatic, semi-aquatic and marsh land plants. The common plants are *Pistia stratiotes, Azolla pinata, Eichhornia crassipes, Hydrilla verticillata, Blyxa, echinosperma, Nymphae pubescens*. Besides the native flora, several other useful species, exotic ornamentals and forestry species have been introduced in this region. The common avenue plants are *Delonixregia, Acacia auriculiformis, Drypetes ruxburghii, Caesalpinia pulcherrima, Callistemon citrinus, Soraca asoca* and *Polyalthia longifolia.* Present study reports 254 plant species which are distributed in 73 families 174 genera (Table 12). Dicotyledons consist of 169 species with 142 genera and Monocot belongs to 85 species and 32 genera. The study area reports 174 genera and 254 species which appear to be a good representation of the flora for a small region.

Out of 73 families, monocotyledons share 19.17% (14 families) and Dicotyledons share 80.82% (59 families). Monocotyledons represent 18.39% (32 genera) and Dicotyledons 81.60% (142 genera) of total genera. Dicotyledons share 66.53% and Monocotyledons share 33.46% of total no. of species found in the study area (Table 12).

Table 2. Diversity of herbs in and around Dhauligiri hill

Scientific name	Common name	Family
Alternanthera sessilis (L) R.Br. ex. DC.	Sessile Joy weed	Amaranthaceae
A.paronychioides var. *pitosa* (Moq.)Suess.	Smooth chaff flower	Amaranthaceae
A. philoxeroides (Mart.) Grisb.	Aligator weed	Amaranthaceae
Aerva lanata (L.) Juss.	Mountain knotgrass	Amaranthaceae
Achyranthes aspera L.	Devil's horsewhip	Amaranthaceae
Gomphrena celosioides Mart.	Cockscomb gomphrena	Amaranthaceae
Tridax procumbens L.	Tridax daisy	Asteraceae
Parthenium hysterophorus L.	Santa maria feverfew	Asteraceae
Xanthium indicum DC.	Rough cocklebur	Asteraceae
Vernonia cinerea (L.) Less.	Little ironweed	Asteraceae
Emilia sonchifolia (L.) DC ex Dc.	Lilac tassel flower	Asteraceae
Synedrella nodiflora (L.) Gaert.	Cindrella weed	Caricaceae
Carica papaya L.	Papaya	Caricaceae
Commelina benghalensis L.	Benghal day flower	Commdinaceae
C. erecta L.	White mouth day flower	Commdinaceae
Euphorbia hirta L.	Asthma plant	Euphorbiaceae
E. heterophylla L.	Wild poinsettia	Euphorbiaceae
E. thymifolia L.	Asthma plant	Euphorbiaceae
Phyllanthus fraternus G.L. Webster	Gulf leaf flower	Euphorbiaceae
P. virgatus G. Forst	Virgate leaf flower	Euphorbiaceae
P. urinaria L.	Gripe weed, Stone breaker	Euphorbiaceae
Croton bonplandianus Bailla	Bonplands croton	Euphorbiaceae
Andrographis paniculata (Burm.)	Green chiretta	Acanthaceae
Lindernia crustacean (L.) F. mud	Malaysian false pimpernel	Acanthaceae
L. ciliata (Colsm) Pennet.	Fringed lindernia	Acanthaceae
Blepharis maderaspatensis (L.) B. Heyne ex. Roth	Madras blepharis	Acanthaceae
Justicia betonica L.	Shrimp plant	Acanthaceae
J. quinqueangularis K.D. Koenig Roxb.	Five angled justice	Acanthaceae
Eranthemum capense L.	Konkan eranthemum	Acanthaceae
Cleome viscosa L.	Asian spider flower	Capparaceae
C. rutidosperma DC.	Fringed spider flower	Capparaceae
Desmodium triflorum (L.) DC.	Creeping tick frefoil	Fabaceae
D. gangeticum (L.) DC.	Sal leaved desmodium	Fabaceae
Alysicarpus vaginalis (L.) DC.	Alyce clover	Fabaceae
Indigofera linnaei Ali.	Birdsville indigo	Fabaceae
I. tinctoria L.	True indigo	Fabaceae
I. nummulariifolia (L.) Alston	Coinwort indigo	Fabaceae
Crotalaria pallida Klotzsch	Chiquechique	Fabaceae
C.prostrata Willd.	Prostate rattlepod	Fabaceae
C. verrucosa L.	Blue rattlepod	Fabaceae
C. albida Roth.		Fabaceae
Ocimum canum Sims	American basil	Lamiaceae
Anisochilus carnosus (L.f.) Wall.	Thick leaf lavender	Lamiaceae

Cont...

Table 2. Cont...

Scientific name	Common name	Family
Sida acuta Burm.f.	Wire weed	Malvaceae
S. cordifolia L.	Country mallow	Malvaceae
S. cordata (Burn.f.)	Country mallow	Malvaceae
S. rhombifolia L.	Jelly leaf	Malvaceae
Urena lobata L.	Caesarweed, congo jute	Malvaceae
Abelmoschus moschatus Medik.	Musk mallow	Malvaceae
Hedyotis corymbosa (L.) Lam.	Diamond flower	Rubiaceae
Glinus oppositifolius (L.) Aug. DC.	Jima	Moilluginaceae
Dracaena spicata Roxb.		Agavaceae
Trianthema portulacastrum L.	Desert horse purslane	Aizoaceae
Amaranthus spinosus L.	Spiny pigweed	Amaranthaceae
A.viridis L.	Pigweed	Amaranthaceae
Evolvulus alsinoides (L.) L.	Slender dwarf morning-glory	Convolvulaceae
E. nummularius (L.) L.	Roundleaf bindweed	Convolvulaceae
Breynia retusa (Dennst.) Alston	Cup and saucer plant	Phyllanthaceae
Phyllanthus tenellus Roxb.	Mascarene island leaf flower	Phyllanthaceae
Mimosa pudica L.	Touch me not plant	Mimosaceae
Mollugo nudicaulis Lam.	Naked stem carpetweed	Mimosaceae
Boerhavia diffusa L.	Red Spiderling	Nyctaginaceae
Argemone mexicana L.	Mexican prickly poppy	Papaveraceae
Portulaca oleracea L.	Purslane	Portulacaceae
P. quadrifida L.	Chickenweed	Portulacaceae
Mitracarpus villosus (Sw.) DC.		Rubiaceae
Scoparia dulcis L.	Sweet broom weed	Scrophulariaceae
Adenosma indianum (Lour.) Merr.		Scrophulariaceae
Mecardonia procumbens (Mill.) Small	Baby jump-up	Scrophulariaceae
Tricohdesma zeylanicum (Burn.f.) R.Br.	Camel bush, Cattle bush	Solanaceae
Solanum virginianum L.	Yellow-fruit nightshade	Solanaceae
Riumfetta pentandra A. Rich.	Fivestamenburrback	Sterculiaceae
Melochia corchorifolia L.	Chocolateweed	Tiliaceae
Corchorus aestuans L.	East Indian Mallow	Tiliaceae
Pilea microphylla (L.) Liebm.	Gunpowder plant	Urticaceae
P. cadierei Gagnep. Ex Guillaumin	Aluminium plant	Uricaceae
Hybanthus enneaspermus (L.) F.Muell	Spade flower	Violaceae
Colocasia eculenta (L.) Schott.	Taro	Araceae
Spilanthus paniculata f. bicolor J. Kost.	Panicled Spot Flower	Asteraceae
Cassia tora L.	Stinking cassia	Caeselpiniaceae
Micrococca mercurialis (L.) Benth.	Mercury Doughwood	Euphorbiaceae
Musa paradisiaca L.	Banana (Plantain)	Musaceae

Table 3. Diversity of grasses in and around Dhauligiri hill

Scientific name	Common name	Family
Eleusine indica (L.) Gaertn.	Indian Goosegrass	Poaceae
Eragrostis cilliaris (L.) R.Br.	GophertailLovegrass	Poaceae
E. ciliata (Roxb.) Nees.	Lovegrass	Poaceae
E. unioloides (Petz.) Nees ex. Steud.	Chinese Lovegrass	Poaceae
Panicum brevifolium L.		Poaceae
P. psilopodium Trin.		Poaceae
P. notatum Retz.	Bahia grass	Poaceae
P. paludosum Roxb.	Chesapeake panicgrass	Poaceae
Paspalum scrobiculatum L.	Kodomillet	Poaceae
P. flavidum (Retz.) A. Camus	Yellow watercrown grass	Poaceae
P. geminatum L.	Egyptian panicgrass	Poaceae
Echinochloa colona (L.) Link	Deccan grass	Poaceae
Brachiaria ramosa (L.) Stapf.	Browntop millet	Poaceae
B. distachya (L.) Stapf.	Armgrass millet	Poaceae
B. mutica (Forssk.) Stapf.	Scotch grass	Poaceae
Bothriochloa pertusa (L.) A. camus	Silver grass	Poaceae
Aristida setacea Retz.		Poaceae
Saccharum spontaneum L.	Wild sugarcane	Poaceae
Heteropogon contortus (L.) P. Beauv. Ex. Roem & Schulf	Tanglehead	Poaceae
Oplismenus compositus	Running mountain grass	Poaceae
Cyperus rotundus L.	Common Nut Sedge	Cyperaceae
*C. distans*f.		Cyperaceae
C. kyllingia Endl.	Nut grass	Cyperaceae
C. triceps Endl.		Cyperaceae
C. dubbing Rottb.		Cyperaceae
C. articulatus L.	Jointed flatsedge	Cyperaceae
C.iria L.	Ricefieldflatsedge	Cyperaceae
C. paniceus Boeck.		Cyperaceae
C. compressus	Annual sedge	Cyperaceae
C. platystylis R.Bc.		Cyperaceae
C. polystachyos Rottb.	Bunchy sedge	Cyperaceae
C. haspan L.	Haspanflatsedge	Cyperaceae
C. pygmeaus Rottb.		Cyperaceae
Bulbostylis barbata (Rottb.) C.B. Clarke	Water grass	Cyperaceae
B. stenophylla (Elliott) C.B. Clarke	Sandy field hairsedge	Cyperaceae
Fimbristylis miliacea (L.) Vahl.	Hoorah grass	Cyperaceae
F. aestivalis Vahl.	Summer fimbry	Cyperaceae
Lipocarpha sphacelata (Vahl.) Kunth		Cyperaceae
Digitaria cilliaris (Retz.) Koeler	Southern crabgrass	Poaceae
D. abludens (Roem.&Schutt) Veldkamp		Poaceae
D. longiflora (Retz.) Pers.	Indian crabgrass	Poaceae
Dactyloctenium aegyptium Willd.	Crowfoot grass	Poaceae
Chloris barbata S.W.	Swollen finger grass	Poaceae
Vetiveria zizanioides (L.) Nash	Cuscus grass	Poaceae
Cynodon dactylon (L.) Pers.	Bermuda grass	Poaceae

Table 4. Diversity of shrubs in and around Dhauligiri hill

Scientific name	Common name	Family
Agave Americana L.	Century plant	Agaraceae
Sansevieria roxburghiana Schult. & F.	Indian bowstring hemp	Agaraceae
Cascabela thevetia L.	Yellow oleander	Apocynaceae
Ervatamia divaricate (L.) Burkill.	Crape jasmine	Apocynaceae
Holarrhena pubescens Wall. ex.G. Don	Bitter oleander	Apocynaceae
Calamus guruba Buch. Ham. Ex. Mart		Areceae
Chromolaena odorata (L.) King. & Rob.	Siam weed	Asteraceae
Cassia occidentalis L.	Coffee senna	Caesalpiniaceae
Caesalpinia pulcherrima (L.) SW.	Peacock flower	Caesalpiniaceae
Bauhinia acuminate L.	White orchid	Caesalpiniaceae
Crataeva magna (Lour.) DC.	Garlic pear tree	Capparaceae
Jatropha gossypifolia L. Poit.	Cottonleaf physic nut	Euphorbiaceae
Pedilanthus tithymaloides (L.) Poit.	Devil's backbone	Euphorbiaceae
Phyllanthus reticulates Poir.	Black-honey shrub	Euphorbiaceae
Ocimum sanctum L.	Holy basil	Lamiaceae
Hyptis sauaveolens (L.) Poit.	Pignut	Lamiaceae
Hibiscus rosa-sinensis L.	China rose	Malvaceae
Abelmoschusmanihot (L.) Medik.	Sweet hibiscus	Malvaceae
Bougainvillea spectabilis Willd.	Great bougainvillea	Nyctaginaceae
Nyctanthes arbor-tristis L.	Coral jasmine	Oleaceae
Jasminum sambac (L.) Aiton	Arabian jasmine	Oleaceae
Bambusa arundinacea (Retz.) Willd.	Bamboo	Poaceae
Punica granatum L.	Pomegranate	Puniacaceae
Morinda pubescens Sm.	Indian mulberry	Rubiaceae
M. citrifolia L.	Indian mulberry	Rubiaceae
Ixora coccinea L.	Jungle geranium	Rubiaceae
Parvetta crassicaulis Bremek.	Indianpavetta	Rubiaceae
Carissa spinarum L.	Conkerberry	Rutaceae
C. carandas L.	Christ's thorn	Rutaceae
Glycosmis pentandra (Rati) Correa		Rutaceae
Mimusops elengi L.	Spanish cherry	Sapotaceae
Duranta repens L.	Skyflower	Verbenaceae
Lippia javanica (Burm.f.) Spreng.	Lemon bush	Verbenaceae
Lantana camara L.	Tick berry	Verbenaceae
Calotropis procera (Aiton) N.T. Aiton	Crown flower	Asclepidaceae
C. gigantean (L.) Dryand	Crown flower	Asclepidaceae
Bauhinia variegate L.	Mountain ebony	Caesalpiniaceae
Pandanus fascicularis Lam.	Screw-pine	Pandanaceae
Adenosma indianum (Lour.) Merr.		Scrophulariaceae
Solanum torvum SW.	Turkey berry	Solanaceae

Table 5. Diversity of trees species in and around Dhauligiri hill

Scientific name	Common name	Family
Cassia siamea Lam.	Siamese Sena	Caesalpiniaceae
C. fistula L.	Golden Shower	Caesalpiniaceae
Peltophorum pterocarpum (DC.) K. Heyne	Copperpod	Caesalpiniaceae
Delonix regia (Hook.) Raf.	Gulmohar	Caesalpiniaceae
Drypetes roxburghii (Wall.) Harus	Lucky bean tree	Euphorbiaceae
Lannea coromandelica (Houdt.) Merr.	Indian ash tree	Euphorbiaceae
Lagerstroemia reginae Roxb.	Queen crape	Lythraceae
Azadirachta indica A. Juss.	Neem	Meliaceae
Samanea saman (Jacq.) Merr.	Monkey pod tree	Mimosaceae
Leucaena leucocephala (Lam.) de wit.	River tamarind	Mimosaceae
Albizia lebbeck (L.) Benth.	Siris tree	Mimosaceae
Acacia auriculiformis Benth.	Earleaf acacia	Mimosaceae
A. nilotica sp. indica (Benth.) Brenan	Gum Arabic	Mimosaceae
Ficus benghalensis var. benghalensis L.	Banyan	Moraceae
F. benghalensis var. *Krishnae* (C.D.C.) Corner	Banyan	Moraceae
F. microcarpa L.f.	Chinese banyan	Moraceae
F. racemosa L.	Cluster fig tree	Moraceae
F. tinctoria G. Forst.	Dye fig	Moraceae
F. religiosa L.	Sacred fig	Moraceae
Streblus asper Lour.	Sand paper tree	Moraceae
Artocarpus heterophyllus Lam.	Jackfruit	Moraceae
Mangifera indica L.	Mango	Anacardiaceae
Anacardium occidentale L.	Cashew	Anarcardiaceae
Polyalthia longifolia (Sonn.) Thwaites	Mast tree	Annonaceae
Plumeria rubra L.	Red frangipani	Apocynaceae
Phoenix sylvestris (L.) Roxb.	Silver date palm	Areacaceae
Areca catechu L.	Areca palm	Areacaceae
Cocos nucifera L.	Coconut	Areacaceae
Kigelia Africana (Lam.) Benth.	Sausage tree	Bignoniaceae
Cieba pentandra (L.) Gaertn.	Kapok tree	Bombacaceae
Saraca asoca (Roxb.) Nilld.	Ashok	Caesalpiniaceae
Terminalia cattapa L.	Indian almond	Combretaceae
Pongamia pinnata (L.) Pierre	Pongameoiltree	Fabaceae
Gliricidia sepium (Jacq.) Walp	Mexican lilac	Fabaceae
Callistemon citrinus (Curtis) Skeels	Crimson bottlebrush	Hythraceae
Syzygium cumini (L.) Skeels	Black plum	Myrtaceae
Ziziphus mauritiana Lam.	Indian jujube	Rhamnaceae
Cleistanthus collinus (Roxb.) Benth ex Hook.f.	Garari	Rutaceae
Aegle marmelos (L.) Correa	Stone apple	Rutaceae
Ailanthus excels Roxb.	Tree of heaven	Simaroubaceae
Sterculia foetida L.	Java olive	Steruliaceae
Bridelia retusa (L.) A. Juss.	Spinous kino tree	Tiliaceae
Gmelina arborea (Roxb.)	Gamhar	Verbenaceae

Table 6. Diversity of climber species in and around Dhauligiri Hill

Scientific name	Common name	Family
Aristolochia indica L.	Indian birthwort	Aristolochiaceae
Gymnema sylvestre (Retz.) R.Br. ex.SW	Australian cowplant	Asclepiadaceae
Pergularia daemia (Forssk.) Chiov	Pergularia	Asclepiadaceae
Mikania micrantha (L.) Willd.	Bitter vine	Asteraceae
Combretum indicum (L.) DeFilipps	Rangoon creeper	Combretaceae
Solena amplexicaulis (Lam.) Gandhi	Creeping cucumber	Cucurbitaceae
Dioscorea wallichi Hook. f.		Dioscoreaceae
D. oppositifolia L.	Chinese yam	Dioscoreaceae
Coccinia grandis (R.) Voigt	Ivy gourd	Cucurbitaceae
Atylosia scarabaeoides (L.) Benth.	Showy pigeonpea	Fabaceae
Abrus precatorius L.	Jequirity bean	Fabaceae
Tinospora cordifolia (Willd.) Miers	Heart-leaved moonseed	Menispermaceae
Jasminum multiflorum (Burm.f.) Andrews	Star jasmine	Oleaceae
Passiflora foetida L.	Wild water lemon	Passifloraceae
Cardiospermum halicacabum L.	Balloon vine	Sapindaceae
Cayratia trifolia (L.) Domin	Bush grape	Vitaceae
C. pedata (Lam.) Gagnep	Birdfoot grape vine	Vitaceae
Ampelocissus latifolia (Roxb.) Planch.	Wild grape	Vitaceae

Table 7. Diversity of parasitic species in and around Dhauligiri hill

Scientific name	Common name	Family
Cuscuta reflexa Roxb.	The giant dodder	Cuscutaceae
C. chinensis Lam.	Chinese dodder	Cuscutaceae
Cassytha filiformis L.	Love-vine	Lauraceae

Table 8. Diversity of hydrophytes species in and around Dhauligiri hill

Scientific name	Common name	Family
Aponogeton natans (L.)Engl. & K. Krause	Floating lace plant	Aponogetonaceae
Pistia stratiotes L.	Water lettuce	Araceae
Hydrocera triflora (L.) Wiglt&Arn.	Marsh henna	Balsminaceae
Hydrilla verticillata (L.f.) Royle	Water thyme	Hydrocharitaceae
Spirodella polyrhiza (L.) Schleit	Common duckweed	Lemnaceae
Nymphoides hydrophylla (Lour.) Kuntze	Crested floating heart	Menyanthaceae
Nymphaea pubescens Willd.	Hairy water lily	Nymphaceae
Monochoria hastata (L.) Solm	Arrow leaf pondweed	Pontederiaceae
M. vaginalis (Burn. f.) Prest	Oval leaf pondweed	Pontederiaceae
Eichhornia crassipes (Mart.) Salms.	Water hyacinth	Pontederiaceae
Lindernea rotundifolia (L.) A Iston	Round leaf lindernia	Acanthaceae
Dentella repens (L.)	Creeping lickstoop	Rubiaceae
Sagittaria guyanensis Kunth.	Guanese arrowhead	Alismataceae

Table 9. Diversity of gymnosperms, pteridophytes, bryophytes and lichen in and around Dhauligiri hill

Scientific name	Common name	Family
Gymnosperm		
Cycas circinalis L.	Queen sago	Cycadaceae
Pteridophytes		
	Maiden hair fern	Pteridaceae
Azolla pinnata R.Br.	Mosquito fern	Salviniaceae
Dryopteris cochleata (D.Don) C.Chr.	Wood fern	Dryopteridaceae
Marsilea quadrifolia L.	Water clover	Marsileaceae
Pteris vittata L.	Ladder brake	Pteridaceae
Bryophytes		
Tortula ruralis Hedw.	Common wall moss	Pottiaceae
Riccia huebeneriana L.	Floating crystalwort	Ricciaceae
Lichens		
Flavoparmelia caperata (L.) Hale	Greenshield lichen	Parmeliaceae
Rhizocarpon geographicum (L.) DC.	Map lichen	Rhizocarpaceae

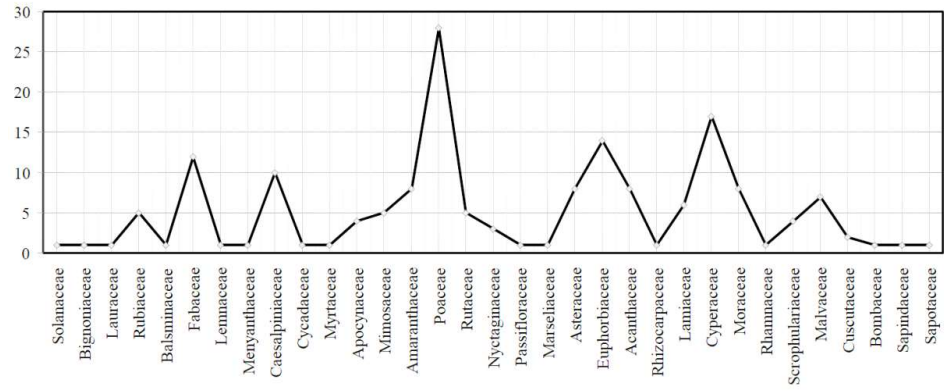


Fig. 2. Families recorded in study area

Table 10. Family wise distribution of plant species recorded in the study area

Family	Number
Poaceae	25
Cyperaceae	17
Euphorbiaceae	14
Fabaceae	12
Caesalpiniaceae	10
Amaranthaceae	08
Asteraceae	08
Acanthaceae	08
Moraceae	08
Malvaceae	07
Lamiaceae	06
Rubiaceae	05
Rutaceae	05
Mimosaceae	05
Apocynaceae	04
Arecaceae	04
Scrophalariaceae	04
Asdepediaceae	04
Verbenaceae	04
Nyctaginaceae	03

Table 11. Genus wise distribution of plant species recorded in the study area

Genus	Number
Cyperus	13
Phyllanthus	06
Ficus	06
Sida	04
Crotolaria	04
Panicum	04
Euphorbia	03
Paspalum	03
Digitaria	03
Cassia	03

Table 12. Diversity of family, genera and species

	Dicot		Monocot		
Category	No.	Percentage	No.	Percentage	Total
Family	59	80.82	14	19.17	73
Genera	142	81.60	32	18.39	174
Species	169	66.53	85	33.46	254

CONCLUSION

The herbs were predominant with more numbers than other flowering and non flowering plants. Asteraceae among dicots and Poaceae among monocots are dominant families. Some plants were recorded as Invasive Alien Plant species (IAPs), poisonous/toxic plants, and vulnerable, endangered as well as threatened species. In addition more plants were recorded as medicinally important. Anthropogenic activities and unrestricted moments of pilgrims around its adjoining areas are the root cause of loss of plant species. It is necessary to minimize and restrict these activities in order to save rare endangered plant species as well as natural resources around this sacred hill.

ACKNOWLEDGEMENT

We are very much thankful to Principal, Regional Institute of Education (NCERT), Bhubaneswar for providing necessary laboratory facilities for storage of Herbarium during plant identification. The help and co-operation during plant survey rendered by informants, guide and local people are highly acknowledged.

REFERENCES

Das SK, Satapathy MK and Bisoi SS 2017. Floristic diversity of an Urban Environment: Poisonous plants of Bhubaneswar Smart City, India, *International Research Journal of Environment Sciences* **6**(1): 41-52.

Das SK, Subudhi A, Naik S, Pradhan RS and Bisoi SS 2019. Origin, diversity and uses of Invasive Alien plant species in

Utkal University Campus, Bhubaneswar, Odisha, *International Journal of Life Science* **7**(3): 509-517.

Farooquee NA and Saxena KG 1996. Conservation and utilization of medicinal plants in high hills of the Central Himalayas, *Environmental Conservation* **23**(1): 75-80.

Grenter W 1994. *International Code for Botanical Nomenclature* (Tokyo code), Koningsteen, Koeltz Science Book, 400p.

Jain, SK and Rao RR 1977. *A handbook of field and herbarium methods* Today and Tomorrow's Printers and Publishers.

Kumar S and Satapathy MK 2011. Medicinal plants in an urban environment: Herbaceous Medicinal flora from the campus of Regional Institute of Education, Bhubaneswar, Odisha, *International Journal of Pharmacy and Life Science* **2**(10): 1206-1210.

Philips EA 1959. *Methods of vegetation study* Henry Holt and Co. Inc. New York. 318p.

Radford AE, Dickison WC, Massey JR and Bell CR 1974. *Vascular Plant Systematics.* 891p.

Saxena HO and Brahmam M 1994-96. *Flora of Orissa*. Vol.1-4. Orissa Forest Development Corporation, Bhubaneswar.

Vediya SD and Kharadi HS 2011. Floristic diversity of Isari zone, Megharaj range forest district Sabarkantta, Gujarat, India, *International Journal of Pharmacy and Life Science* **2**(9): 1033-1034.

Received 25 May, 2020; Accepted 12 August, 2020

Indian Journal of Ecology (2020) 47(3): 831-841

Manuscript Number: 3092
NAAS Rating: 4.96

Vegetation Analysis in Chora and Joyalbhanga Forest Area of Raniganj Coal Field, West Bengal, India

M. Saikat, P. Debnath[1] and C. Pinaki[2]

Department of Zoology, Raghunathpur College, Purulia-723 133, India
[1]Department of Botany, Durgapur Government College, Durgapur-713 214, India
[2]Department of Botany, West Bengal State University, West Bengal-700 126, India
E-mail: sairaniganj@gmail.com

Abstract: The Chora and Joyalbhanga area is famous for coal mining under Raniganj Coal Field (RCF), West Bengal. These two sites have also known for dense forest. Mining operation has seriously harmed the vegetation and the overall ecosystem of these areas. During the current investigation, 22 species from 15 families were reported at the two sampling locations. Highest and lowest total density values were recorded for *Pongamia pinnata* and *Streblus asper* in Chora whereas, *Azadirachta indica* and *Aegle marmelos* in Joyalbhanga. *Streblus asper* and *Aegle marmelos* were the two dominant tree species in Chora and Joyalbhanga respectively in terms of IVI (34.39 and 38.13 respectively) though in both the wasteland herb and shrub species were more dominant tree species. Agglomerative hierarchical clustering (AHC) analysis indicates the relationship among all species in the study area. It was apparent from the study that clumped type of distribution in both the study sites were prevalent. The phytosociological lists additionally showed the impact of mining activity on the vegetation structure of the mining areas. The study suggested that *Streblus asper* and *Aegle marmelos*, *Croton bonplandianus*, *Setaria glauca*, *Clerodendrum infortunatum* and *Tephrosia purpuria* could be utilized in reclamation process due to their high frequency and higher regeneration capability. The study highlighted the fact that the resulting vegetation assessment might be used as a relevant means of predicting the appropriateness of specific species to revegetate the mined locations.

Keywords: Coal field, Vegetation, Reclamation, Density, Evenness

Mining in any form puts tremendous effects on ecosystem and overall environment. The main consequences of excess mining are deforestation, pollution and instabilities in social ecology (Rai et al 2010, Singh et al 2011). Excavation starts in this area after the nationalization of coal mines under Bankola coal area of RCF (1973 onwards). The Pandabeswar block of Paschim Barddhaman district, West Bengal is conferring on opulent natural vegetation and large reserve of mineral resources specially coal. Excavation starts in this area after the nationalization of coal mines and is one of most coal producing zone of India under Raniganj Coal fields (1973 onwards). During the previous decades, a sensational increment in mining, which lead to huge scale annihilation and crumbling of environment. The extraction of minerals from nature frequently makes awkward nature, which antagonistically influence the biological system and condition. The informal and unscientific mining represents a genuine danger, bringing about the decrease of forest cover, soil loss and decrease of overall biodiversity (Kumar et al 2015). These changes cause alternation in nutrient, depletion of resources and trophic interactions (Almas et al 2004, Ghose 2004, Pawar et al 2014). Hence the knowledge of the restoration of degraded environment is very much needed to make a blueprint of reclamation process (Carpanezzi 2005). The accomplishment of recovery of natural ecosystems depends on the reclamation and restoration of environmental procedures in charge of the reproduction and support of a utilitarian network or community (Gandolfi et al 2007). The rate of success and community creation is administered by nearby site factors. The species which are most compatible with site conditions can persist grow and ultimately become a vital part of the community. Moreover, continuous monitoring and review of vegetation is an essential factor to maintain species diversity (Attua and Pabi 2013, Evariste et al 2010). Inventory and analysis of vegetation dynamics can provide an important tool for biodiversity assessment and conservation, particularly in the deforested and degraded areas due to excess coal mining (Baraloto et al 2013). The effect of mining on vegetation composition were widely studied in West Bengal (Kar et al 2016, Biswas et al 2014, Mondal et al 2019), in India (Kumar et al 2017, Jhariya et al 2016, Guha 2014, Singh et al 2014) and in the other countries also (Donggan et al 2011, Tom-Dery et al 2012). These sorts of data is imperative to recognize key tolerant species which are crucial for the recovery process just as to distinguish best preservation endeavors in a supportable manner in the mine influenced territories. The study could provide baseline data for better reclamation and management strategies. The information and data from this study can be applied to assess forest, identify ecologically important vegetation species in the

coal mine areas. The goal of this paper is to think about the local vegetation structure and species, assorted variety in two forest region under a Pandabeswar block of RCF, West Bengal, India.

MATERIAL AND METHODS

Study area: The research sites are situated in the Paschim Barddhaman district of West Bengal, India, which are part of the RCF under Pandabeswar block. The data were collected from two sites, namely Chora and Joyalbhanga, in the years 2017 to 2019. Chora is located 23°40´21.4´´N and 87°12´21.9´´E at 74.8m elevation and Joyalbhanga is located in between 23°41´40.2´´N and 87°17´20.3´´E at 84m elevation in Pandabeswar block under Durgapur subdivision.

Sampling: Random quadrats of 10 × 10 m size were laid for quantification of trees and saplings. In each of this quadrat, a sub-quadrat of 5 × 5 m size was randomly laid for measuring seedling and shrubs. Similarly another quadrat of 50 × 50 cm size within 1 × 1 m quadrat was laid for measuring herbs.

Vegetation analysis: Different layer of vegetation were quantitatively analyzed through frequency, density, abundance values (Curtis and McIntosh 1950), and A/F ratio (Whiteford 1949). Basal area and importance value index (IVI) using standard methods (Cintron and Novelli 1984, Chauhan et al 2009). In this classification, the percentage frequency of the species was classified as A, B, C, D, and E, where A speaks to rare or uncommon (0–20%), B speaks to low frequency (20–40%), C speaks to intermediate frequency (40–60%), D speaks to moderately high frequency (60–80%), and E speaks to high frequency or common (80–100%). Whitford's index was used to establish the pattern of distribution. Whitford's index = if A/F ratio: < 0.025: Regular distribution, 0.025-0.05: Random distribution, >0.05: Contagious or clumped distribution (Saxena and Singh 1984, Tripathi et al 1991, Jhariya et al 2012).

Diversity indices: Diversity indices were calculated following the Shannon-Weaver diversity index (Shannon and Weaver 1963). Concentration of dominance was determined following Simpson's index method (Simpson 1949). Vegetations were also measured for species richness (Marglef 1958), equitability (Pielou 1966), Berger-Parker Dominance Index (Berger and Parker 1970), Similarity index between vegetation composition of two study sites was determined by using Jaccard's and Sorenson's index of similarity (Sorenason 1948, Krebs 1999). We also used co-efficient of similarity, followed by Ochiai (1957).

Statistical analysis: To examine and explain the degree of resemblance among various plant organisms, AHC was done based on the phyto-sociological attributes by using SPSS statistical software.

RESULTS AND DISCUSSION

Vegetation structure of tree layer: In the two study sites, twenty 22 species representing 15 families were recorded during the present investigation (Table 1 and 2). The total density of trees ranged between 0.04 to 1.56/quadrat in Chora and 0.1 to 1.44/ quadrat in Joyalbhanga. Highest and lowest total density values were recorded for *Pongamia pinnata and Streblus asper* in Chora whereas, *Azadirachta indica* and *Aegle marmelos* in Joyalbhanga. The dominant representatives were *S. asper and A. marmelos* in Chora and Joyalbhanga respectively, contributing the higher IVI in the respective directions. The higher importance value of *S. asper and A marmelos* indicated its ability to grow in the degraded environment. The A/F ratio of individual species ranged between 0.014 and 1 in Chora, whereas, 0.031 and 0.875 in Joyalbhanga. It was apparent from the study that most of the species showed clumped type of distribution in both the study sites. Basal area ranged from 0.104 to 3.974 $m^2 ha^{-1}$ and the highest for *Pongamia pinnata* and lowest for *Ficus racemosa* in Chora (Table 1). In the Joyalbhanga basal area ranged from 0.028 to 1.734 $m^2 ha^{-1}$ and the highest for *Caesalpinia pulcherrima* and lowest for *Vitex negundo* (Table 2). Throughout our study, we find that *S. asper* and *A. marmelos* can be used successfully for eco-restoration the corresponding study areas. Lower density of tree species in deteriorated habitat could be attributed to extensive deforestation for mining purposes and also inadequate seed propagation from neighboring woodlands in deteriorated landscape (Robinson and Handel 2000).

Phytosociology is a strong predictor of ecological health. Alterations in the abiotic variables will contribute in a relatively short period of time to modifications in the population framework (Hassan et al 2007). Current analysis represented tree density for all of the test sites was very small. The bulk of organisms displayed both random and contagious distribution behavior in the study areas. Due to multiple mining operations, the tree species was lower at all the mining sites (Sarma et al 2010). In comparison, Rahman et al (2010) and Kumar et al (2014) observed somewhat the same findings in the mined regions. In the mined regions higher basal area was reported owing to the existing of the wide girth class trees because they were not affected by the miners during the mining (Sarma et al 2010).

A rank-abundance curve is formed for the analysis of biodiversity pattern of tree species in the two study areas. A more extensive curve demonstrates the higher species richness and the evenness were determined by the shape of the curve. A completely horizontal curve indicates completely evenly distributed system, but the steeper curve indicates less evenly distributed system. The proportion is plotted on

Table 1. Phyosociological attributes of tree layer of Chora

Species	Family	Life- form	D/quadrat	A	F	FC	A/F	IVI	BA m^2/ha
Acacia auriculiformis	Mimosaceae	PH	0.06	1.50	4	A	0.375	5.94	0.252
A. nilotica	Mimosaceae	PH	0.10	1.67	6	A	0.278	7.20	0.363
Ailanthus excelsa	Simaroubaceae	PH	0.92	1.15	80	D	0.014	25.74	0.126
Albizia lebbeck	Mimosaceae	PH	0.42	1.11	38	B	0.029	13.79	1.266
Alstonia scholaris	Apocynaceae	PH	0.40	1.11	36	B	0.031	13.28	1.093
Azadirachta indica	Meliaceae	PH	0.24	1.20	20	A	0.060	9.39	0.126
Borassus flabellifer	Arecaceae	PH	0.04	2.00	2	A	1.000	6.98	0.521
Dalbergia sissoo	Papilionaceae	PH	0.28	1.08	26	B	0.041	10.35	0.588
Eucalyptus globulus	Myrtaceae	PH	0.36	1.20	30	B	0.040	12.21	1.168
Ficus benghalensis	Moraceae	PH	0.24	1.00	24	B	0.042	9.37	2.399
F. racemosa	Moraceae	PH	0.26	1.44	18	A	0.080	10.07	0.104
F. religiosa	Moraceae	PH	0.34	1.00	34	B	0.029	11.98	1.467
Gmelina arborea	Lamiaceae	PH	0.74	1.19	62	D	0.019	21.19	1.910
Leucaena leucocephala	Fabaceae	PH	0.74	1.23	60	C	0.021	21.01	0.181
Lagerstroemia speciosa	Lythraceae	PH	0.24	1.71	14	A	0.122	10.08	1.227
Phoenix dactylifera	Arecaceae	PH	0.18	1.80	10	A	0.180	9.09	0.700
Pongamia pinnata	Papilionaceae	PH	0.04	1.00	4	A	0.250	4.16	3.974
Senna siamea	Caesalpiniaceae	PH	1.10	1.34	82	E	0.016	28.60	1.019
Streblus asper	Moraceae	PH	1.56	3.25	48	C	0.068	34.39	0.119
Terminalia arjuna	Combretaceae	PH	0.26	1.18	22	B	0.054	9.85	0.505
Trema orientalis	Cannabaceae	PH	0.32	1.33	24	B	0.056	11.28	0.159
Ziziphus jujuba	Rhamnaceae	PH	0.36	2.57	14	A	0.184	14.06	0.211

*Cry: Cryptophytes, Hc: Haemicryptophytes, Th: Helophytes, Ph: Phenerophytes, Che: Chamaephyte, D=Density, A=Abundance, F=Frequency, FC=Frequency Class, IVI=Important Value Index, BA: Basal area

Table 2. Phyosociological attributes of tree species of Joyalbhanga

Species	Family	Life- form	D/quadrat	A	F	FC	A/F	IVI	BA m^2/ha
Acacia auriculiformis	Mimosaceae	PH	0.26	0.357	20	A	0.065	11.07	0.357
Aegle marmelos	Rutaceae	PH	1.44	0.168	68	D	0.031	38.13	0.168
Ailanthus excelsa	Simaroubaceae	PH	0.30	0.469	24	B	0.052	12.38	0.469
Alangium salvifolium	Cornaceae	PH	0.58	0.120	36	B	0.045	19.36	0.120
Albizia lebbeck	Mimosaceae	PH	0.16	1.239	10	A	0.160	8.26	1.239
Alstonia scholaris	Apocynaceae	PH	0.14	1.059	4	A	0.875	11.35	1.059
Azadirachta indica	*Meliaceae*	PH	0.10	0.107	4	A	0.625	8.39	0.107
Butea monosperma	Fabaceae	PH	0.96	0.348	26	B	0.142	26.44	0.348
Caesalpinia pulcherrima	Fabaceae	PH	0.26	1.734	20	A	0.065	11.07	1.734
Dalbergia sissoo	Papilionaceae	PH	0.72	0.162	24	B	0.125	21.51	0.162
Phoenix dactylifera	Arecaceae	PH	0.26	0.327	16	A	0.102	10.92	0.327
Shorea robusta	Dipterocarpaceae	PH	0.30	0.549	20	A	0.075	12.03	0.549
Spondias mombin	Malvaceae	PH	0.24	0.399	16	A	0.094	10.38	0.399
Streblus asper	Moraceae	PH	1.38	0.118	36	B	0.106	33.96	0.118
Terminalia arjuna	Combretaceae	PH	0.26	0.421	22	B	0.054	11.27	0.421
T. catappa	Combretaceae	PH	0.24	0.545	18	A	0.074	10.45	0.545
Vitex negundo	Lamiaceae	PH	0.92	0.028	38	B	0.064	25.72	0.028
Ziziphus jujuba	*Rhamnaceae*	PH	0.36	0.127	8	A	0.563	17.32	0.127

See Table 1 for details

the vertical pivot (Fig. 1). It is very clear from the figure that one site has species richness of 22 and another site has species richness of 18. The two sites were with a declining profile, indicating some species have a higher abundance than others that is species are not evenly distributed. From this information it can clearly state that Chora is more diverse than Joyalbhanga due to the large width of the curve. The trees of medium girth class (70-90cm) dominated in Chora. In Joyalbhanga the trees with relatively low girth class (30-50cm) had the maximum individuals (Fig. 2).

Vegetation structure of herb layer: An aggregate of 82 herb species belongs to 41 families were recorded in two investigation sites. Chora comprises 43 species representing 21 families and Joyalbhanga comprises 39 species representing 20 families (Table 3 and 4). The total density of herb species in chora was 42.22 and 32.44 in Joyalbhanga. The maximum density was recorded by *Oplismenus compositus* (2.92) *and Dactyloctenium aegyptium* (2.60) in Chora and Joyalbhanga respectively. The IVI of individual herb ranged between 1.96 and 14.83 in Chora and in Joyalbhanga it was between 1.62 and 16.98, the highest value was recorded by *Croton bonplandianus* and lowest by *Senna obtusifolia* in Chora and in Joyalbhanga, the highest value was recorded by *Dactyloctenium aegyptium* and lowest by *Solanum virginianum*. The A/F ratio of individual species were ranged between 0.007 and 1 in Chora, whereas, 0.022 and 4.75 in Joyalbhanga. It appears that most of the species were contagiously distributed. From the result, it appears that successful establishment and propagation of herb layer is more prominent due to lower density of tree species providing more light as available resources for the ground vegetation. The higher number of herbaceous species in the mined areas could be due to colonizing ability of herbs in the degraded area (Sarma et al 2010).

Vegetation structure of shrub layer: An aggregate of 21 shrub species belongs to 17 families were found in the two investigation sites. Chora represents 13 species and Joyalbhanga comprises 8 species (Table 5). Total density of shrub species was 7.6 in and 3.74 in Joyalbhanga. The maximum was recorded by *Clerodendrum infortunatum* in Chora and *Tephrosia purpuria* in Joyalbhanga. The IVI of individual Shrub ranged between 8.65 and 48.85 in Chora and in Joyalbhanga it was between 18.27 and 68.82. The A/F ratio of individual species were ranged between 0.014 and 0.278 in chora, whereas, 0.059 and 0.389 in Joyalbhanga. It appears that most of the species were contagiously distributed. Lack of tree species can contribute to greater solar insolation available to the newly born plant species. There is a deficit in information about the abundance and

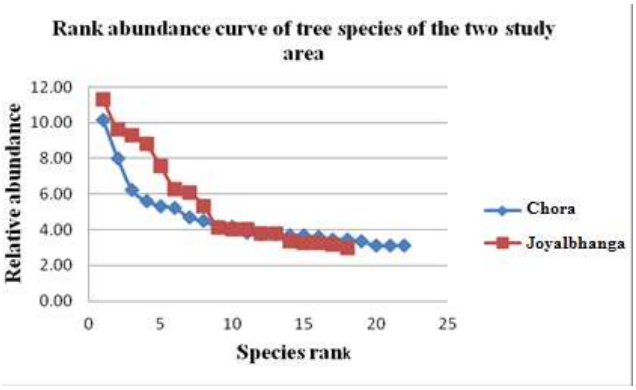


Fig. 1. Rank-abundance curve of tree species

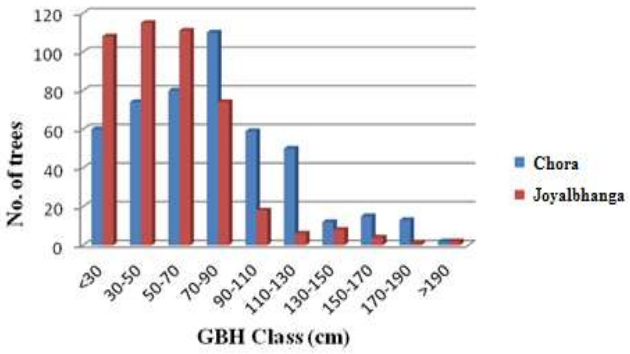


Fig. 2. Distribution of trees in different girth classes in the study area

distribution of plants, shrubs and herbs in both local and national mining sites. The densities recorded in this investigation are well correlated with some of the other research (Mishra et al 2008, Jhariya et al 2012, 2014).

Species' mode of distribution is also linked to their competitive biology. The contagious pattern of species distribution shows the mosaicness of the forest area. The contagious aspect of the species indicates that the natural landscape is rapidly degraded and patchy owing to mining. Sarma (2002, 2005) found a specific trend of distribution of plants in the coal mining regions of the Meghalaya Nokrek biosphere reserve. The densities recorded in this present work are well comparative with certain other research (Mishra et al 2008, Jhariya et al 2012, 2014). The distribution of species of tree into the frequency classes of Raunkiaer reflected that most of the species were of rare class and low frequency class whereas the high frequency class or common frequency class was completely absent in the study region. IVI represents the supremacy of organisms and their ecological succession. High IVI values of a species indicate its high regeneration capacity and greater ecological amplitude. In our study, *S. asper* and *A. marmelos* reflected the highest IVI value. Therefore, these species can be

Table 3. Phyosociological attributes of herb species in Chora

Species	Family	Life- form	D/quadrat	A	F	FC	A/F	IVI
Acalypha indica	Euphorbiaceae	TH	0.38	2.38	16	A	0.148	3.60
Achyranthus aspera	Amaranthaceae	TH	0.40	2.86	14	A	0.204	3.86
Ageratum conyzoides	Asteraceae	TH	0.16	2.00	8	A	0.250	2.31
Alternanthera sessilis	Amaranthaceae	HC	2.64	3.00	88	E	0.034	13.92
Amaranthus spinosus	Amaranthaceae	TH	0.30	3.75	8	A	0.469	3.88
Boerhaavia repens	Nyctaginaceae	CH	0.58	5.80	10	A	0.580	6.13
Cleome viscosa	Cleomaceae	TH	0.60	3.33	18	A	0.185	4.92
Coldenia procumbens	Boraginaceae	HC	1.12	1.65	68	D	0.024	8.10
Crotalaria juncea	Papilionaceae	TH	0.90	1.67	54	C	0.031	6.71
Croton bonplandianus	Euphorbiaceae	TH	1.78	1.14	156	E	0.007	14.83
Cyperus rotundus	Cyperaceae	CRY	0.76	1.41	54	C	0.026	6.19
Dactyloctenium aegyptium	Poaceae	TH	2.58	2.58	100	E	0.026	14.23
Desmodium gangeticum	Papilionaceae	HC	1.20	7.50	16	B	0.469	9.19
D. triflorum	Papilionaceae	HC	2.30	2.95	78	D	0.038	12.45
Eclipta alba	Asteraceae	TH	1.80	3.10	58	C	0.054	10.12
Eragrostis cilianensis	Poaceae	HC	0.76	7.60	10	A	0.760	7.84
Eupatorium odoratum	Asteraceae	CH	0.64	1.07	60	C	0.018	6.04
Euphorbia hirta	Euphorbiaceae	TH	0.16	2.67	6	A	0.444	2.65
Evolvulus nummularis	Convolvulaceae	HC	0.54	3.38	16	A	0.211	4.69
Gamochaeta coarctata	Asteraceae	TH	0.44	2.44	18	A	0.136	3.91
Gomphrena serrata	Amaranthaceae	TH	0.60	3.33	18	A	0.185	4.92
Heliotropium indicum	Boraginaceae	TH	1.18	2.68	44	C	0.061	7.47
Hyptis suaveolens	Lamiaceae	TH	0.64	1.28	50	C	0.026	5.57
Melochia corchorifolia	Malvaceae	HC	0.18	1.13	16	A	0.070	2.23
Merremia tridentata	Convolvulaceae	HC	0.36	6.00	6	A	1.000	5.50
Mimosa pudica	Mimosaceae	HC	0.10	2.50	4	A	0.625	2.27
Oplismenus compositus	Poaceae	TH	2.92	4.56	64	D	0.071	14.18
Oxalis corniculata	Oxalidaceae	HC	0.70	5.83	12	A	0.486	6.56
Panicum repens	Poaceae	TH	0.78	4.88	16	A	0.305	6.32
Parthenium hysterophorus	Asteraceae	TH	2.46	3.24	76	D	0.043	12.90
Pennisetum setaceum	Poaceae	TH	1.38	1.97	70	D	0.028	9.07
Phyllanthus annus	Phyllanthaceae	TH	1.12	1.75	64	D	0.027	7.92
Polygonum hydropiper	Polygonaceae	HC	1.14	5.70	20	A	0.285	8.01
Ruellia tuberosa	Acanthaceae	TH	0.64	1.45	44	C	0.033	5.32
Rungia pectinata	Acanthaceae	TH	2.18	6.41	34	B	0.189	11.86
Scoparia dulcis	Plantaginaceae	TH	0.76	2.92	26	B	0.112	5.51
Senna obtusifolia	Caesalpiniaceae	TH	0.14	1.40	10	A	0.140	1.96
Sida acuta	Malvaceae	TH	0.90	3.75	24	B	0.156	6.31
S. cordata	Malvaceae	TH	0.92	4.18	22	B	0.190	6.54
Solanum sisymbriifolium	Solanaceae	TH	0.42	3.50	12	A	0.292	4.24
S. virginianum	Solanaceae	TH	0.14	2.33	6	A	0.389	2.37
Spermacoce ocymoides	Rubiaceae	TH	0.30	5.00	6	A	0.833	4.65
Tridax procumbens	Asteraceae	TH	2.22	2.41	92	E	0.026	12.75

See Table 1 for details

Table 4. Phyosociological attributes of herb species of Joyalbhanga

Species	Family	Life-form	D/quadrat	A	F	FC	A/F	IVI
Achyranthus aspera	Amaranthaceae	TH	0.80	1.38	58	C	0.024	8.17
Aerva lanata	Amaranthaceae	TH	0.44	2.20	20	A	0.110	4.60
Alternanthera sessilis	Amaranthaceae	HC	2.24	2.29	98	E	0.023	16.51
Anisomeles indica	Lamiaceae	TH	0.16	4.00	4	A	1.000	3.77
Blumea lacera	Asteraceae	TH	0.06	1.50	4	A	0.375	1.62
Boerhaavia repens	Nyctaginaceae	CH	1.60	2.42	66	D	0.037	12.06
Centella asiatica	Apiaceae	HC	0.08	2.00	4	A	0.500	2.05
Cleome viscosa	Cleomaceae	TH	1.18	2.11	56	C	0.038	9.72
Crotalaria juncea	Papilionaceae	TH	0.78	2.05	38	B	0.054	6.99
Croton bonplandianus	Euphorbiaceae	TH	1.58	2.93	54	C	0.054	11.40
Dactyloctenium aegyptium	Poaceae	TH	2.60	3.17	82	E	0.039	16.98
Desmodium gangeticum	Papilionaceae	HC	0.08	2.00	4	A	0.500	2.05
D. triflorum	Papilionaceae	HC	1.20	2.14	56	C	0.038	9.81
Digitaria ciliaris	Poaceae	TH	0.46	11.50	4	A	2.875	10.24
Eclipta alba	Asteraceae	TH	0.58	3.63	16	A	0.227	5.76
Eragrostis tenella	Poaceae	HC	1.06	2.12	50	C	0.042	8.87
Eupatorium odoratum	Asteraceae	CH	1.36	2.34	58	C	0.040	10.61
Euphorbia hirta	Euphorbiaceae	TH	0.76	1.41	54	C	0.026	7.74
Evolvulus nummularis	Convolvulaceae	HC	1.18	1.74	68	D	0.026	10.41
Gnaphalium coarctatum	Asteraceae	TH	1.30	2.32	56	C	0.041	10.25
Gomphrena serrata	Amaranthaceae	TH	0.92	1.92	48	C	0.040	8.13
Heliotropium indicum	Boraginaceae	TH	0.44	1.69	26	B	0.065	4.71
Leucas aspera	Lamiaceae	TH	0.20	3.33	6	A	0.556	3.57
Lindenbergia indica	Orobanchaceae	TH	0.34	5.67	6	A	0.944	5.72
Mimosa pudica	Mimosaceae	HC	0.90	2.65	34	B	0.078	7.48
Ocimum basilicum	Lamiaceae	TH	0.14	2.33	6	A	0.389	2.64
Oldenlandia corymbosa	Rubiaceae	HC	0.56	2.33	24	B	0.097	5.39
Oplismenus compositus	Poaceae	TH	1.96	4.26	46	C	0.093	12.91
Oxalis corniculata	Oxaliadaceae	HC	0.72	2.00	36	B	0.056	6.61
Parthenium hysterophorus	Asteraceae	TH	2.50	7.81	32	B	0.244	16.07
Phyllanthus annus	Phyllanthaceae	TH	0.10	2.50	4	A	0.625	2.48
Rungia pectinata	Acanthaceae	TH	0.98	7.00	14	A	0.500	9.33
Sesamum indicum	Pedaliaceae	TH	0.96	4.36	22	B	0.198	7.96
Setaria glauca	Poaceae	TH	0.76	19.00	4	A	4.750	16.71
Sida acuta	Malvaceae	TH	0.18	4.50	4	A	1.125	4.20
S. cordata	Malvaceae	TH	0.44	3.67	12	A	0.306	5.04
Solanum sisymbriifolium	Solanaceae	TH	0.64	1.19	54	C	0.022	7.21
Solanum virginianum	Solanaceae	TH	0.06	1.50	4	A	0.375	1.62
Tridax procumbens	Asteraceae	TH	0.14	2.33	6	A	0.389	2.64

considered as capable of higher regeneration potential in the concerned study sites. The low IVI may be attributed towards rarest occurrence of species (Pascal and Pellissier 1996, Oyun et al 2009), as confirmed by Raunkiaer's frequency distribution of the tree species. Species rarity can be due to the presence in the stands of plentiful scattered organisms with lower frequency (Oyun et al 2009). The high proportion of uncommon species contained in the collieries in various layers of vegetation suggests that most organisms in an ecological environment are rare, instead of typical (Magurran and Henderson 2003).

Diversity indices: Species richness of 78 species in Chora and 65 species in Joyalbhanga was recorded indicates that the forest is rich in plant diversity. The two study areas also have higher evenness values. Concentration of dominance mirrors the quantity of chance a species are experienced during sampling. Lower value indicates higher chances of encountering a species in the study areas, Shannon-Wiener diversity index was high. It was likewise contrarily corresponding to concentration of dominance (Galav et al 2005, Dash et al 2009). This index is additionally a declaration of community structure and unpredictability of an environment. A high index value demonstrates that these study sites have high plant diversity and stable communities.

The diversity indices (Table 6) of plant species reflected a significant level of variation between two sites and also among the different layers of vegetation. In Chora, species richness was 1.93, 0.94 and 0.67 for tree, herbs and shrub layers, respectively. Shannon-Wiener index for tree, herbs and shrubs were 2.760, 3.473 and 2.334, respectively in Chora. Simpson concentration of dominance was estimated for Chora were 0.052, 0.030 and 0.087, respectively. Berger-Parker Dominance Index estimated was 0.170, 0.018 and 0.071, respectively, for the different layer of vegetation in Chora. In Joyalbhanga, the Evenness values for tree, herbs and shrubs layer were 2.06, 2.13 and 2.10, respectively.

In Joyalbhanga, species richness was more in herbs followed by tree, and shrub. Shannon-Wiener index also indicated the same trend. Simpson concentration of dominance was estimated for Joyalbhanga were 0.068, 0.048 and 0.129, respectively. Berger-Parker Dominance Index estimated was 0.041, 0.023 and 0.267, respectively,

Table 5. Phyosociological attributes of shrub species

Species	Family	Life- form	D/quadrat	A	F	FC	A/F	IVI
Chora								
Calotropis gigantea	Asclepiadaceae	CH	0.18	1.29	14	A	0.092	10.64
C. procera	Asclepiadaceae	CH	0.10	1.67	6	A	0.278	8.65
Clerodendrum infortunatum	Lamiaceae	CH	1.32	1.38	96	E	0.014	48.85
Jatropha gossipyfolia	Euphorbiaceae	CH	0.50	3.57	14	A	0.255	22.61
Ricinus communis	Euphorbiaceae	CH	1.08	2.08	52	C	0.040	35.79
Tephrosia purpuria	Papilionaceae	CH	0.54	3.86	14	A	0.276	24.11
Triumfetta rhomboidea	Tiliaceae	TH	0.96	2.29	42	C	0.054	32.12
Urena lobata	Malvaceae	CH	1.04	3.06	34	B	0.090	33.56
Ziziphus oenoplia	Rhamnaceae	CH	0.60	2.31	26	B	0.089	22.99
Olax scandens	Olacaceae	CH	0.24	1.50	16	A	0.094	12.72
Lippia alba	Verbenaceae	CH	0.64	2.91	22	B	0.132	24.44
Woodfordia fruticosa	Lythraceae	CH	0.14	1.40	10	A	0.140	9.39
Flacourtia indica	Salicaceae	PH	0.26	2.17	12	A	0.181	14.13
Joyalbhanga								
Abutilon indicum	Malvaceae	CH	0.14	1.75	8	A	0.219	18.27
Calotropis gigantea	Asclepiadaceae	CH	0.18	2.25	8	A	0.281	21.97
C. procera	Asclepiadaceae	CH	0.14	2.33	6	A	0.389	20.00
Clerodendrum infortunatum	Lamiaceae	CH	1.00	3.13	32	B	0.098	64.49
Mallotus repandus	Euphorbiaceae	CH	0.14	2.33	6	A	0.389	20.00
Ricinus communis	Euphorbiaceae	CH	0.58	2.90	20	A	0.145	44.08
Senna alata	Fabaceae	PH	0.52	1.86	28	B	0.066	42.33
Tephrosia purpuria	Papilionaceae	CH	1.04	2.48	42	C	0.059	68.82

See Table 1 for details

for the different layer of vegetation in Joyalbhanga (Table 6). In Joyalbhanga, the Evenness values for tree, herbs and shrubs layer were 2.07, 2.10 and 1.98. Jacard similarity index and Soresen Similarity between the two study areas was 0.444 and 0.615, respectively. Similarity Co-efficient Ochiai, 1957 for the two study areas was 0.618 (Table 6). The Shannon index was observed to be smaller at each location in contrast to the herb population throughout the current examination. This might be attributed to a slower tempo of population development and diversification (Simpson 1964) and environmental degradation (Connel and Oris 1964). Kumar et al (2017) have recorded very close findings in northern Chhattisgarh's Bishrampur collieries. The diversity index for herbaceous species increased with mining proximities suggesting that mining operation favored colonization of certain species in the newly created habitats. Comparable perception was made by Lyngdoh 1995, Das Gupta 1999 and Sarma 2002). Sarma et al (2010) stated that the tree and shrub species Shannon diversity index was poor

Table 6. Overall community structure of Chora and Joyalbhanga

Parameters	Habitat	Chora	Joyalbhanga
No. of species	Tree	22	18
	Herbs	43	39
	Shrubs	13	8
	Total	78	65
No. of genera	Tree	19	17
	Herbs	40	36
	Shrubs	12	7
	Total	71	60
No. of families	Tree	15	15
	Herbs	21	20
	Shrubs	11	6
	Total	47	41
Species richness (D)	Tree	1.03	0.85
	Herbs	0.94	0.97
	Shrubs	0.67	0.59
Evenness	Tree	2.06	2.07
	Herbs	2.13	2.10
	Shrubs	2.10	1.98
Shannon	Tree	2.760	2.598
	Herbs	3.473	3.345
	Shrubs	2.334	1.787
Simpson co-dominance	Tree	0.052	0.068
	Herbs	0.030	0.048
	Shrubs	0.087	0.129
Berger-Parker Dominance Index	Tree	0.170	0.041
	Herbs	0.018	0.023
	Shrubs	0.071	0.267

Jacard similarity index - 0.444 , Soresen Similarity -0.615, Similarity Co-efficient Ochiai, (1957)-0618

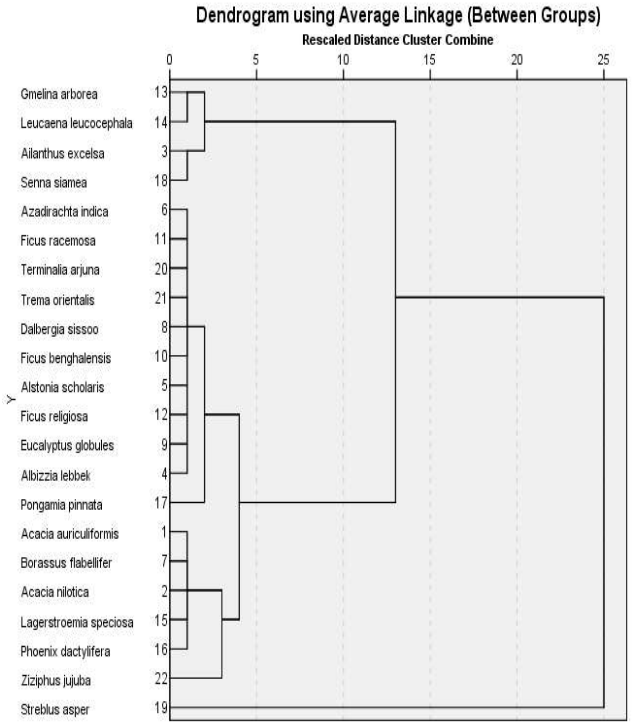


Fig. 3. Dendrogram showing the relationship among tree species of Chora

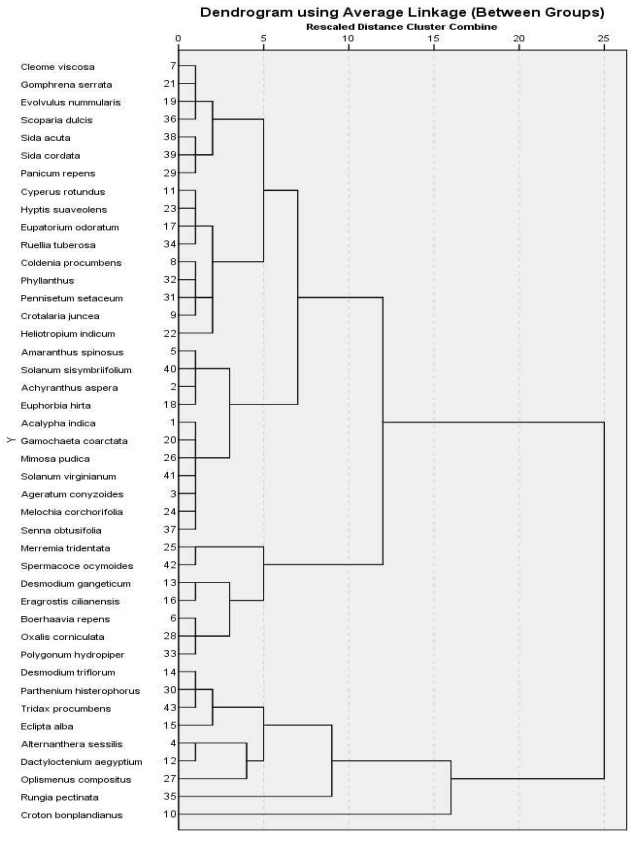


Fig. 4. Dendrogram showing the relationship among herb species of Chora

in mined regions as opposed to unmined regions. Nevertheless, the surface habitat diversity index did not distinguish between the mined and unmined zones. The superiority index of Simpson demonstrates an opposite pattern to that of the diversity index.

Statistical analysis: In Chora, 4 primary clusters and in Joyalbhanga 6 clusters are formed for the tree species (Fig. 3 and 6). The more the distance scale of the clusters the more the plant species are remotely related to each other. In Chora, the 1st cluster shows close similarity between the *Gmelina arborea and Leucaena leucocephala.* Cluster 2 comprises of *Ailanthus excelsa* and *Senna siamea.* Cluster 3

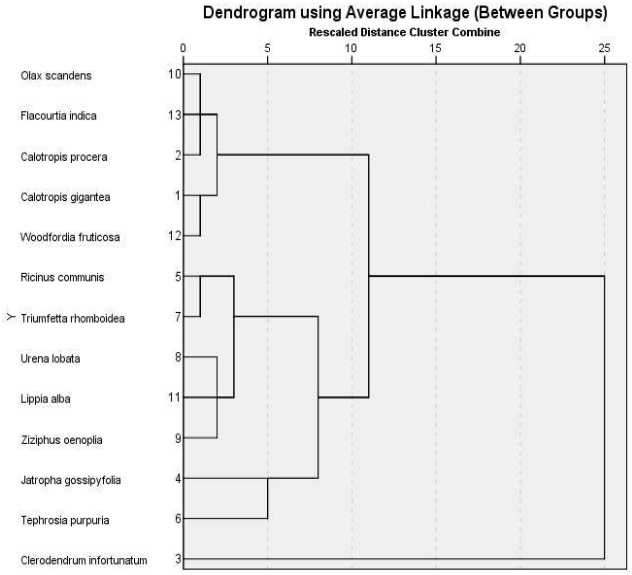


Fig. 5. Dendrogram showing the relationship among shrub species of Chora

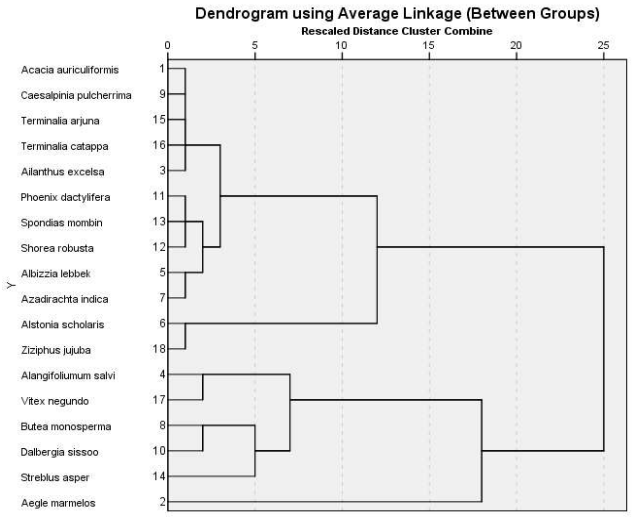


Fig. 6. Dendrogram showing the relationship among tree species of Joyalbhanga

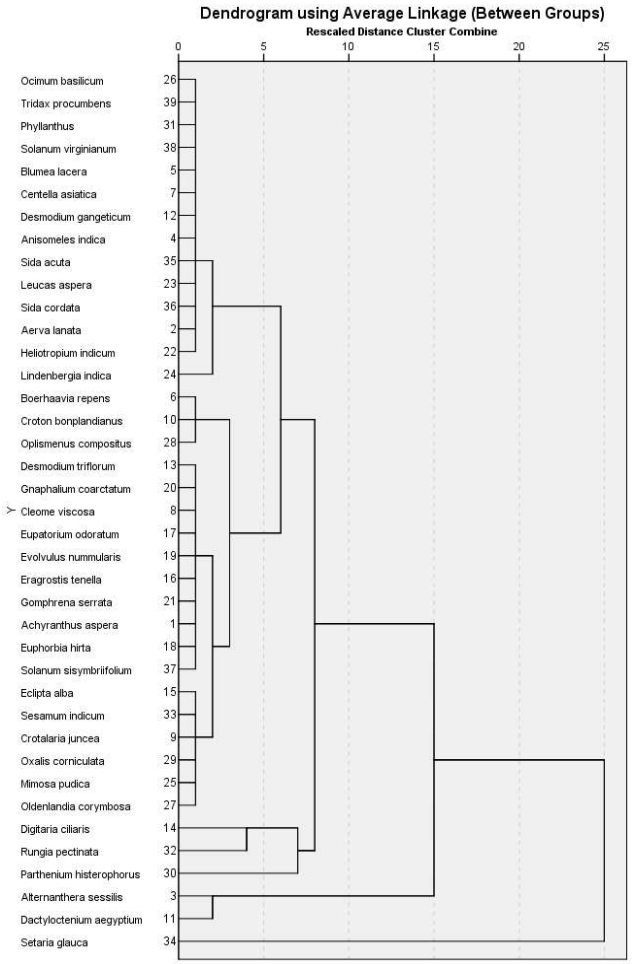


Fig. 7. Dendrogram showing the relationship among herb species of Joyalbhanga

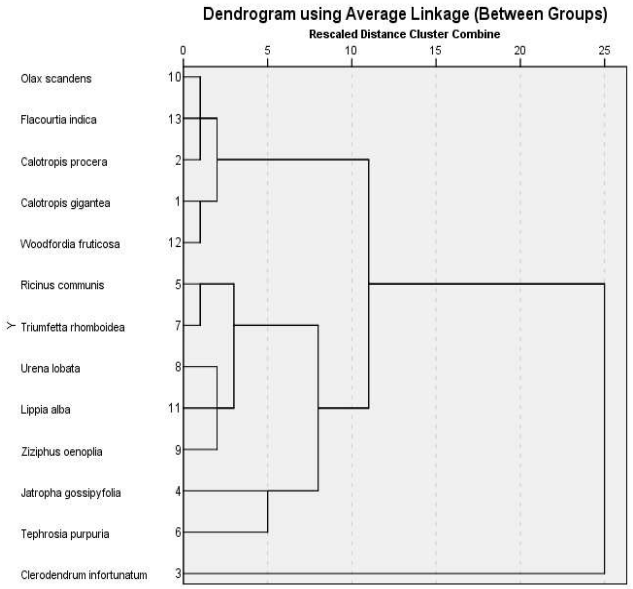


Fig. 8. Dendrogram showing the relationship among shrub species of Joyalbhanga

contains most of the tree species such as, *Azadirachta indica, Ficus racemosa, Terminalia arjuna, Trema orientalis, Dalbergia sissoo, Ficus benghalensis, Alstonia scholaris, Ficus religiosa, Eucalyptus globulus and Albizia lebbeck.* Cluster 4 contains 5 tree species*: Acacia auriculiformis, Borassus flabellifer, Acacia nilotica, Lagerstroemia speciosa* and *Phoenix dactylifera.* In Joyalbhanga, 1st cluster comprises 5 tree species: *Acacia auriculiformis, Caesalpinia pulcherrima, Terminalia arjuna, Terminalia catappa and Ailanthus excelsa.* Cluster 2 contains *Phoenix dactylifera, Spondias mombin and Shorea robusta.* Cluster 3 comprises of *Albizia lebbeck and Azadirachta indica.* Cluster 4 comprises of *Alstonia scholaris* and *Ziziphus jujuba.* Cluster 5 contains *Alangium salvifolium* and *Vitex negundo.* Cluster 6 comprises of *Butea monosperma* and *Dalbergia sissoo* (Fig. 6). For the herb species there are 11 clusters formed in Chora and 6 in case of Joyalbhanga (Fig. 4 and 7). In Chora, cluster 1,3,4,5 contains 5 herb species each and cluster 6 comprises a large number of herb species. In Joyalbhanga, cluster 1and 3 comprises the largest number of herb species. For the shrub species, 5 clusters are formed in Chora and in Joyalbhanga only 3 are formed (Fig. 5 and 8). Quite similar trend was also reported by Kumar et al (2017).

CONCLUSION

Coal surface mining has contributed to major shifts in land-use practices in these mining regions. It also facilitated the modification of soil quality by higher mine spoil deposition. Diversity of herbaceous plants was prevalent compared with other vegetative strata, indicating that mining activities contribute to settlement of different organisms in freshly transformed environment. Still, the study indicates adverse impacts of mining operations on an area's vegetation. These actions also ought to be carefully supervised. Enhancement of site efficiency is a crucial requirement from the viewpoint of the management of mined wasteland. The key conclusions of this investigation include the screening of *Streblus asper* and *Aegle marmelos* species to be utilized in the potential reclamation strategy as these species possess higher regeneration potentiality and cosmopolitan distribution. Phytosociological studies might be useful to the conservation strategist and forest developers for effective and sustainable management of forest in the mining areas.

REFERENCES

Almas AR, Bakken LR and Mulder J 2004. Changes in tolerance of soil microbial communities in Zn and Cd contaminated soils. *Soil Biology and Biochemistry* **36**: 805-813.

Ashton PS 1972. The Quaternary geomorphological history of western Malesia and lowland forest phytogeography, pp.35–62. In PS Singh and M. Ashton (eds.), *The Quaternary era in Malesia*, Transactions of the Second Aberdeen-Hull Symposium on Malesian Ecology,1971. Hull (UK). University of Hull Department of Geography Miscellaneous Series 13.

Attua EM and Pabi O 2013. Tree species composition, richness and diversity in the northern forest-sananna ecotone of Ghana. *Journal of Applied Biosciences* **69**: 5437-5448.

Austin MP, Ashton PS and Smith PG 1972. The application quantitative methods to vegetation survey III. A re-examination of rain forest data from Brunei. *Journal of Ecology* **60**: 305-324.

Baraloto C, Molto Q, Rabaud S, Hérault B, Valencia R, Blanc L and Fine PVA, Thompson J 2013. Rapidsimultaneous estimation of above ground biomass and tree diversity across Neotropical forests: A comparison of field inventory methods. *Bitropica* **45**: 288-298

Berger WH and Parker FL 1970. Diversity of planktonic Foraminifera in deep sea sediments. *Science* **168**: 1345-1347

Carpanezzi AA 2005. Fundamentos para a reabilitação de ecossistemas florestais. Restauração florestal: Fundamentos e estudos de caso. Colombo: *Embrapa Florestas* **18**: 27-45.

Biswas CK, Mishra SP and Mukherjee A 2014. Diversity and composition of vegetation on aged coalmine overburden dumps in Sonepur Bazari area, Raniganj, West Bengal. *Journal of Environmental Biology* **35**(1): 173-177.

Chauhan SK, Gupta N, Yadav S and Chauhan R 2009. Biomass and carbon allocation in different parts of agroforestry tree species. *Indian Forester* **135**: 981-993.

Cintron G, Novelli YS 1984. *Methods for studying mangrove structure*, p. 251. In: Snedaker C and Snedaker G (eds.) the Mangrove Ecosystem Research Methods, UNICSO.

Connel JH and Oris E 1964. The ecological regulation of species diversity. *The American Naturalist* **48**: 399-414.

Curtis JT and McIntosh RP 1950. The interrelations of certain analytic and synthetic phytosociological characters. *Ecology* **31**: 434-455.

Das Gupta S 1999. *Studies on vegetal and microbiological processes in coal mining affected areas.* Ph.D. Thesis. North Eastern Hill University, Shillong. India.

Dash PK, Mohapatra PP and Rao YG 2009. Diversity and distribution pattern of tree species in Niyamgiri hill ranges, Orissa, India. *Indian Forester* **135**: 927-942

Donggan, G. Zhongke B, Tieliang S, Hongbo S and Wen Q 2011. Impacts of coal mining on the above ground vegetation and soil quality: A case study of Qinxin coal mine in Shanxi province, China. *Clean-Soil Air Water* **39**(3): 219-225.

Evariste FF, Bernard-Aloys N and Nole T 2010. The important of habit characteristics for tree diversity in the Mengame Gorilla Reserve (South Cameroun). *International Journal of Biodiversity and Conservation* **2**: 155-165.

Galav PK, Katewa SS, Chaudhary BL and Jain A 2005. Phytosociological studies on the grassland community of southern Aravalli hills of Rajasthan. *Indian Forester* **131**: 493-952.

Gandolfi S, Rodrigues RR and Martins SV 2007. Theoretical bases of the forest ecological restoration, pp 280. **In**: Rodrigues R R and Martins S V (eds.) *High Diversity Forest Restoration in Degraded Areas.* New York: Nova Science Publishers.

Ghose MK 2004. Effect of opencast mining on soil fertility. *Journal of Scientific and Industrial Research* **63**: 1006-1009.

Guha D 2014. A case study on the effects of coal mining in the environment particularly in relation to soil, water and air causing a socio-economic hazard in Asansol-Raniganj area, India. *International Research Journal Social Science* **3**(8): 39-42.

Hassan A, Wahab R, Alias MA, and Salim RM 2007. Growth performance of 9-year-old selected 5 indigenous wood species planted on degraded forest land. *International Journal of Agricultural Research* **2**: 302-306.

Hewit N and Kellman M 2002. True seed dispersal among forest fragments: Dispersal ability and biogeographical controls. *Journal of Biogeography* **29**(3): 351-363.

Jhariya MK, Bargali SS, Swamy SL and Kittur B 2012. Vegetational structure, diversity and fuel loads in fire affected areas of tropical dry deciduous forests in Chhattisgarh. *Vegetos* **25**(1): 210-224.

Jhariya MK, Kittur BH and Bargali SS 2016. Assessment of herbaceous biomass: A study in Rowghat mining areas (Chhattisgarh), India. *Journal of Applied and Natural Science* **8**(2): 645-651.

Kar D and Palit D 2016. Assessment of plant species assemblages with their distribution in an open cast mining area of Raniganj coalfield, West Bengal, India. *International Journal of Scientific & Engineering Research* **7**(7): 443-452

Krebs CJ 1999. *Ecological methodology*. 2nd. ed. Menlo Park, CA: Addison Wesley Longman.

Kumar N, Kumar A and Singh M. 2014. Floristic diversity assessment in ecologically restored limestone (building stone) mine near Chechat village, Kota district, Rajasthan. *Ecología* **4**(1): 16–25.

Kumar A, Jhariya MK, Yadav DK and Banerjee A 2017. Vegetation dynamics in Bishrampur collieries of northern Chhattisgarh, India: Eco-restoration and management perspectives. *Environmental Monitoring and Assessment* **189** (371): 1-29.

Kumar A, Jhariya MK and Yadav DK 2015. Community characters of herbaceous species in plantation sites of coal mine. *Journal of Plant Development Science* **7**(11): 809-814.

Kumar A, Marcot BG and Saxena A 2006. Tree species diversity and distribution patterns in tropical forests of Garo hills. *Current Science* **91**: 1370-1381.

Lyngdoh T 1995. *Community dynamics and edaphic changes in relation to coal mining in Meghalaya*. Ph.D. Thesis. North-Eastern Hill University, Shillong. India.

Magurran AE and Henderson PA 2003. Explaining the excess of rare species in natural species abundance distributions. *Nature* **422**: 714-716.

Marglef DR 1958. Information theory in ecology. *General Systems Yearbook* **3**: 36-71.

Mishra RK, Upadhyay VP and Mohanty RC 2008. Vegetation ecology of the Similipal Biosphere reserve, Orissa, India. *Journal of Applied Ecology and Environmental Research* **6**(2): 89-99.

Mondal S, Palit D and Chattopadhyay P (2019a). Species diversity and vegetation structure of coal mine generated wasteland of Raniganj Coal Field, West Bengal, India. *International Journal of Current Research and Review* **11**(13): 13-25.

Ochiai A 1957. Zoogeographical studies on the soleoid fishes found in Japan and its neighbouring regions-II. *Bulletin of the Japanese society of scientific fisheries* **22**(9): 526-530.

Odum EP 1971. *Fundamentals of Ecology* (3rd edn.). Philadelphia: WB Saunders Co., p.574.

Oyun MB, Bada SO and Anjah GM 2009. Comparative analysis of the floral composition at the edge and interior of Agulii Forest reserve, Cameroon. *Journal of Biological Sciences* **9**(5): 431-437.

Pascal LP and Pellissier R 1996. Structure and floristic composition of a tropical Evergreen Forest in south-West India. *Journal of Tropical Ecology* **12**: 191-210.

Pawar GV, Singh L, Jhariya MK and Sahu KP 2014a. Effect of anthropogenic disturbances on biomass and carbon storage potential of a dry tropical forest in India. *Journal of Applied and Natural Science* **6**(2): 383-392.

Pawar GV, Singh L, Jhariya MK and Sahu KP 2014b. Assessment of diversity along the disturbance gradient in dry tropics of Chhattisgarh, India. *The Ecoscan* **8**(3&4): 225-233.

Pielou EC 1966. Species diversity and pattern diversity in the study of ecological succession. *Journal of Theoretical Biology* **10**: 370-383.

Received 04 June, 2020; Accepted 19 August, 2020

Rahman H, Khan MASA, Fardusi MJ and Roy B 2010. Status, distribution and diversity of invasive forest undergrowth species in the tropics: a study from northeastern Bangladesh. *Journal of Forest Science* **26**(3): 149-159.

Rai AK, Paul B and Singh G 2010. A study on the bulk density and its effect on the growth of selected grasses in coal mine overburden dumps, Jharkhand, India. *International Journal of Environmental Sciences* **1**(4): 677-684.

Raunkiaer C 1934. *The Life Form of Plants and Statistical Plant Geography*. Claredon Press, Oxford.

Robinson GR and Handel SN 2000. Directing spatial patterns of recruitment during an experimental urban woodland reclamation. *Ecological Applications* **10**: 174-188.

Sarma K, Kushwaha SPS and Singh KJ 2010. Impact of coal mining on plant diversity and tree population structure in Jaintia Hills district of Meghalaya, north East India. *New York Science Journal* **3**(9): 79-85.

Sarma K 2002. *Coal mining and its impact on environment of Nokrek Biosphere Reserve, Meghalaya.* Ph.D. Thesis. North-Eastern Hill University, Shillong. India.

Sarma K 2005. *Impact of coal mining on vegetation: A case study in Jaintia Hills District of Meghalaya, India*. Dissertation, International Institute for Geo-Information Science and Earth Observation Enschede, The Netherlands.

Saxena AK and Singh JS 1984. Tree population structure of central Himalayan forest associations and implications concerning their future composition. *Vegetos* **54**: 61-69.

Shannon CE and Weaver W 1963. *The mathematical theory of communication* (323). Urbana: University of Illinois Press.

Silver WL, Kueppers LM, Lugo AE, Ostertag R and Matzek V 2004. Carbon sequestration and plant community dynamics following reforestation of tropical pasture. *Ecological Applications* **14**: 1115-1127.

Simpson EH 1949. Measurement of diversity. *Nature* **163**: 688.

Singh RBP, Singh A and Choudhary SK 2014. Impact of opencast coal mining on the quality of surfacewater, groundwater and vegetation: A case study in Simlong coalfield, Sahibganj, Jharkhand. *International Journal on Emerging Technologies* **5**(2): 95-105.

Singh AK, Mahato MK, Neogi B, Mondal GC and Singh TB 2011. Hydrogeochemistry, elemental flux and quality assessment of mine water in the Pootkee-Balihari mining area, Jharia coalfield, India. *Mine Water and the Environment* **30**(3): 197-207.

Sorenson T 1948. A method of establishing groups of equal amplitude in a plant society based on similarity of species content. *K then Scientific Company* **5**: 1-34.

Tom-Dery D, Dagben ZJ and Cobbina SJ 2012. Effect of illegal small-scale mining operations on vegetation cover of arid northern Ghana. *Research Journal of Environmental and Earth Sciences* **4**(6): 674-679.

Tripathi BC, Rikhari HC, Bargali SS and Rawat YS 1991. Species composition and regeneration in disturbed forest sites in the oak zone in and around Nainital. *Proceedings of Indian National Science Academy B* **57**: 381-390.

Turner MG 1987. *Landscape heterogeneity and disturbance*. New York: Springer- Verlag.

Wang J, Borsboom AC and Smith GC 2004. Flora diversity of farm forestry plantations in Southeast Queensland. *Ecological Management & Restoration* **5**: 43-51.

Webb CJ, Tracey JG, Williums WT and Lance GN 1967. Studies in the numerical analysis of complex rain forest communities 1. A comparison of methods, applicable to site species data. *Journal of Ecology* **55**: 171-191.

Whiteford PB 1949. Distribution of woodland plants in relation to succession and colonial growth. *Ecology* **30**: 199-200.

Indian Journal of Ecology (2020) 47(3): 842-848

Manuscript Number: 3093
NAAS Rating: 4.96

Heterogeneous Landscape Assessment using Multi-Temporal LISS4 and Hybrid Approach: A Case Study in Barak Valley, India

Demsai Reang, Aparajita De* and Ashesh Kumar Das

Department of Ecology and Environmental Science, Assam University, Silchar-788011, India
**E-mail: aparajitade.ecology@gmail.com*

Abstract: Remotely sensed data of landscapes characterized by diverse interacting patches or ecosystems displays greater degree of mixed pixels making it strenuous to accurately delineate the different land components. The present study aims to analyse the spatial characteristics of such a landscape (Barak valley) using multi-temporal IRS-R2 LISS4 mosaic data and a hybrid classification approach. Agriculture was the predominant land use type with an aerial extent of 2457.3 km^2 (35.5%). Riverbank farming land is a significant land use type in the region that is spatially assessed and mapped for the first time in the study. This land use type covered a total area of 16.27 km^2. An overall map classification accuracy of 91.1% is achieved. The study approach adopted may be applied for mapping of similar landscapes consisting of small land use land cover components. The final map would serve as vital baseline data for management, conservation, research activities and monitoring of different land resources of Barak valley.

Keywords: GIS, Land use land cover, IRS-R2 LISS4, Remote Sensing, Riverbank farming land

The land use land cover (LULC) pattern of a region is an outcome of natural and socio-economic factors and their utilization by humans. A rural landscape in developing countries like India is generally characterised by small LULC features. This is a result of unplanned development and misdirected management policies in the past (Gupta 2009). Such heterogeneity in a landscape makes it challenging to accurately map and study using low and moderate resolution satellite data as it is not always feasible to acquire very high-resolution data for the purpose due to their high cost. One of the core purposes of satellite remote sensing is to interpret observed data and classify different land features. As such, conventional classification techniques like the isodata or maximum likelihood algorithm are often incapable of performing satisfactorily in the presence of mixed pixels. Hence, in recent times, many new classification techniques are being adopted, such as the 'hybrid' technique that incorporate more than just a single classification scheme. A hybrid classification is a supervised/unsupervised approach coupled with geographical information systems (Kamusoko and Aniya 2009) and takes the advantage of both classification schemes (Pradhan et al 2010). Hybrid classification techniques has been promoted by several workers (Reddy 2009, Alimjan et al 2017), who are of the opinion that the technique reduces classification effort on one hand and results in maps with higher accuracy on the other. Vatsavai and Bhadhuri (2011) have noted that hybrid classification technique resulted in maps with over 15% accuracy over conventional classifier.

The study region i.e. Barak valley, being within the Indo-Burma biodiversity hotspot region of India is very rich in natural resources. Despite the abundant resources, the region still remains economically under-developed (Sarkar et al 2019). This may attribute to the lack of proper planning and management. This region has been subjected to a lot of degradation in the past. The forests are currently confined to the peripheral parts of the region, while the tea plantations have been established by clearing large tracts of foothill forests. The forests are highly fragmented and degraded due to constant anthropogenic interference, establishment of shifting cultivation areas and plantation systems (Nandy and Das 2013, Borah et al 2016). Another characteristic of this region is the privately owned homegardens that are small sized. The average size of the homegardens as reported by Das and Das (2005) is 0.26 ha. There are a large number of water bodies in the central region. However, these are also relatively small sized, ranging between 1-50 ha (Reang et al 2018a). The landscape is comprised of numerous north and south flowing rivers that drains into the river Barak. The topography is highly undulating with the central plains being broken up by isolated hillocks and small hill ranges. It is therefore evident that this region has very small landholdings, making the landscape very heterogeneous. Our main objective was to spatially assess this heterogeneous landscape using satellite data of 5.8 m resolution through a combination of different classification techniques, as there is no comprehensive LULC map for the entire of Barak valley. Past studies for the region were either

done by use of low resolution data and single classification technique, or carried out for a single district (Das 2012, Devi et al 2012, Das and Das 2014). Herein, the present study adopted a hybrid classification approach through use of LISS4 data to spatially assess the entire Barak valley region. The final map provides comprehensive information of the land patterns of the region which may greatly benefit the management and planning activities in the area.

MATERIAL AND METHODS

Study area: The study was carried out in Barak valley i.e. the southernmost part of Assam, Northeast India. This region comprises of three districts; Cachar, Hailakandi, and Karimganj (Fig. 1), situated between 24°8'-25°8' north latitude and 92°15'-93°15' east longitude with a total geographical area of 6922 km^2. The Barak is the principal river of the valley with its numerous tributaries including Dhaleswari, Longai, Jiri, Chiri, Sonai, Rukni, etc. (Reang et al 2018a). Besides the rivers, the region has numerous wetlands, oxbow lakes, floodplain lakes, and other temporary reservoirs. The region has undulating topography characterised by hills, hillocks, wide plains, and low-lying waterlogged areas. The valley has very gentle slopes of average height 22m asl towards the east to 1657m asl in the north (Gupta 2000). The vegetation of the region is dominated by Cachar tropical evergreen forest (1B/C3) and Cachar semi-evergreen forest (2B/C2) (Champion and Seth 1968). The region experiences a warm humid climate with mean annual rainfall of 2440-4100 mm, mostly received during the southwest monsoon season (May to September) and mean monthly maximum and minimum temperatures of 33.9°C and 9.2°C. The soil of the region is a mixture of alluvial soil, sandy loam, muddy loam superimposed upon stones, gravels, and conglomerates.

Data and software: Satellite data with medium spatial resolution is frequently used for regional level study (Lu and Weng 2007). As the study region is comprised of small sized land components that have a great degree of intermixing, use of relatively high spatial resolution data was considered. IRS-R2 LISS4 data with a spatial resolution of 5.8 m was used. Five scenes extended over the entire study area (Table 1).

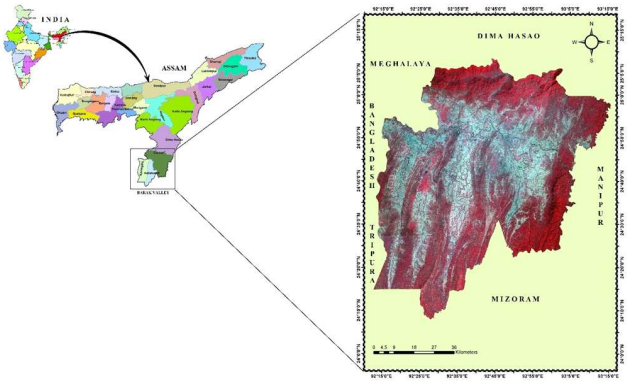


Fig. 1. Location of the study area (IRS-R2 LISS4 mosaic)

Data were procured from the National Remote Sensing Centre (NRSC), Hyderabad, India. In Northeast India, the period May-November is generally characterized by high cloud cover, and only a period of 4 to 6 months window is relatively cloud-free (Kurien et al 2019). For this reason, all data procured were from relatively cloud free period for better interpretation and classification results. Earth Resources Data Analysis System (ERDAS Imagine) 2013 and ArcGIS 10.4 software were used for image interpretation, classification, analyses and map composition. To discriminate between the different LULC categories, additional information (ancillary data) was important (Thakkar et al 2017). The Survey of India (SOI) topographic sheets, Global Positioning System (GPS) ground coordinates and Google Earth Pro map service system were incorporated as ancillary data in the present study. Prior knowledge of land classes' occurrence was also used to increase the classification efficacy and accuracy significantly.

Data processing: The data were pre-processed for geometric correction followed by contrast enhancement, stacking, mosaicking and extraction of area of interest. No radiometric enhancement was done in order to not interfere with the actual spectral information. The digitally scanned Survey of India (SOI) topographic sheets (1:50,000 scale) was used for rectification of the satellite imageries using first-

Table 1. Details of the satellite data used

Sat ID	Sensor	Path	Row	Wavelength width in μm/band	Swath size	Scene date	Spatial resolution
IRS-R2	LISS4	112	55	0.52-0.59(Green) 0.62-0.68 (Red) 0.77-0.86(NIR)	70 km	25/Feb/2011	5.8 m
IRS-R2	LISS4	112	54			25/Feb/2015	5.8 m
IRS-R2	LISS4	111	54			10/Mar/2011	5.8 m
IRS-R2	LISS4	111	55			10/Mar/2013	5.8 m
IRS-R2	LISS4	111	54			10/Mar/2015	5.8 m

order polynomial ensuring RMS error of less than a pixel. Imageries were registered to the Universal Transverse Mercator (UTM) map projection (zone 46N) and World Geodetic System (WGS) 84, respectively.

Classification: Classification of the final pre-processed data was done using a hybrid classification approach following Kamusoko and Aniya (2009), where GIS analyses such as neighbourhood, recode and overlay were adopted. The classification techniques used in the present study involved four different steps: i. unsupervised classification; ii. supervised classification and iii. visual interpretation technique and iv. overlay technique.

The LISS4 mosaicked data was initially classified through unsupervised classification technique using the isodata algorithm. From the resultant output clusters, only the truly large homogeneous classes were identified and classified. This output was designated as LULC I. Clusters that were heterogeneous in nature were processed next. Ancillary data was then integrated to validate the clusters showing spectral mixing and their spectral signatures were generated. Supervised maximum likelihood classification (MLC) technique was then run through signature input. A minimum of 30 training signatures were considered for all the classes in the process (Kurien et al 2019). This was followed by a recode function, where all different clusters were finally assigned and classified, and the resultant output was designated as LULC II. The above technique co-mingles the unsupervised and supervised approaches and is known as 'hybrid' technique. To further assess comprehensively, visual interpretation technique was applied. In the process, the spectrally confusing pixels of some small or spectrally similar classes such as tea-garden and the associated forest land; small sized water bodies; streams; urban built-up; important landmarks, etc. were delineated and classified. Also, the reserve forest boundary polygons was integrated to stratify the total area of vegetation designated for protection against the privately owned forested area (Reang et al 2018b). This was followed by conversion of digitized layers and removal of pixels with no values. The resultant layer and the classified LULC II were then overlaid to prepare the final map of Barak valley. The LULC scheme was composed following the Anderson scheme levels I and II (Anderson et al 1976) as a guideline. The scheme was modified accordingly based on locale specific requirements for the study area. The summary of the process/technique applied is represented (Fig. 2), and accuracy estimation of the classified map was evaluated. Accuracy assessment increases the authenticity and usefulness of a classified map in the decision-making process (Thakkar et al 2017). Random number generator was used to generate x, y coordinates within the entire study

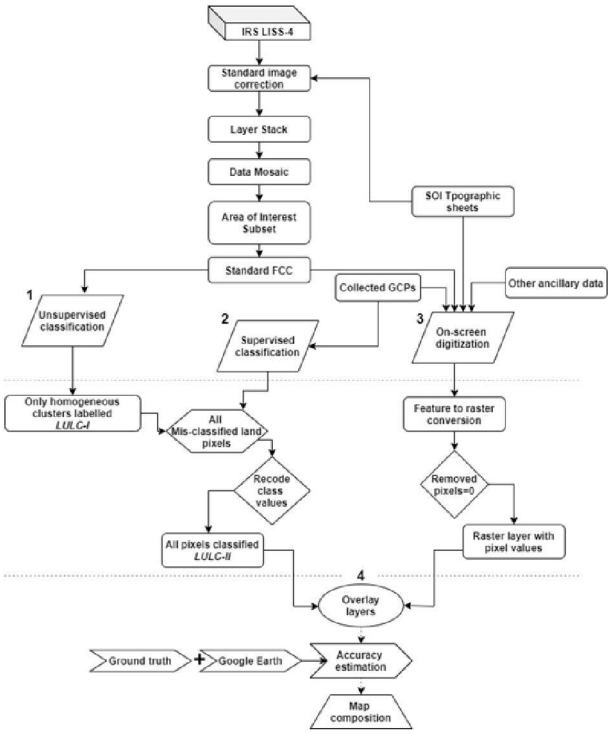


Fig. 2. Paradigm for the preparation of LULC map

area. All these locations were then ground validated in the field or evaluated using Google Earth Pro map service system for inaccessible locations. Error matrices were analysed using the accuracy parameters; Overall accuracy, Producer's accuracy, and User's accuracy. Classification accuracy was calculated using the formula (Rashid et al 2013).

$$\rho = (n / N) \times 100$$

Where 'ρ' is the classification accuracy, 'n' is the number of correctly classified points and 'N' is the number of points checked in the actual ground.

RESULTS AND DISCUSSION

The final LULC map of Barak valley comprised of eight major classes i.e. agriculture, riverbank farming land, reserve forest (RF), tress outside forests (TOF), scrubland, tea plantation, urban built-up and waterbodies (Fig. 3). In addition, other important landmarks and features were also incorporated to make the final map more useful for regional researchers and managers. These include; Silchar Medical College (SMC), Silchar Airport (SA), National Institute of Technology (NIT), Assam University Silchar (AUS), Railway network, National highway and, major rivers along with their tributaries. The total aerial statistics and percent cover extent of the different LULC is presented in Table 2. The composed final map achieved an overall classification accuracy of 91.1%.

Agriculture: This land use class mainly include areas currently under wet-rice, irrigation, cultivated land or land being prepared for raising crops. Physical boundaries are broadly defined to encompass the main areas of agricultural activity in the area. Agriculture in this region is predominated by relatively small sized farms growing mainly rice. From the final map statistics it was observed that area under agriculture was the dominant land class (2457.3 km^2) occupying 35% of the total study area. Paddy and vegetables are the principal crops grown in the region. The agricultural land is mostly concentrated in the central region of the study area surrounding the river Barak, which is the primary river. The agricultural fields extend towards the peripheral forested regions wherever the land is more or less flat and hence suitable for cultivation of paddy. This finding corroborates the fact that, agriculture/cultivation practices is the mainstay of the local economy and that the area is mostly rural.

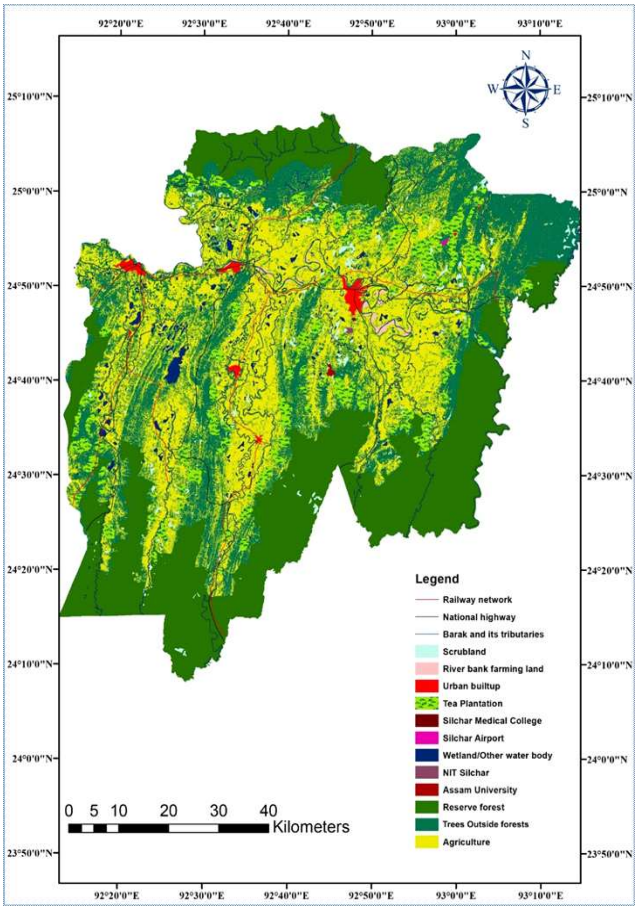


Fig. 3. Land use land cover map of Barak valley

Table 2. Area statistics of the different LULC components

LULC classes	Area (km^2)	Area (%)
Agriculture	2457.3	35.5
Assam University	2.33	0.03
NIT Silchar	1.6	0.02
Reserve forest and protected area	1897.08	27.41
River bank farming land	16.27	0.24
Scrubland	83.35	1.20
Silcharairport	1.55	0.02
Silcharmedical college	1.1	0.02
Tea plantations	484.51	7.00
Trees outside forests	1717.69	24.81
Urban built-up	47.32	0.68
Wetland/other water body	211.86	3.06
Total	6922	100

Riverbank farming: This land use class primarily indicates that piece of land along the river bank that is engaged for farming during dry period. It is a significant occupation observed in this region that involves cultivation of vegetables and spices along the banks of river Barak and its numerous tributaries during the period October - April. The present study also identified and mapped this very important land use type. A total area of 16.27 km^2 was recorded under this land use type. This land use practice is of utmost economic importance for the people of the region as most of the available vegetables in the local markets were grown here. This farming practice is done solely for the purpose of boosting the individual household economy. Cultivation is carried out strictly on a temporary basis during the dry months when the depths of rivers were minimal and river banks were exposed and/or dry. Since the satellite data procured was of the dry period, it was possible to map this important land use category. This category has not been mapped so far for Barak valley by previous workers.

RF and TOF: These land cover classes include areas mainly composed of trees. Majority of the land in Barak valley was vegetated. Total vegetation cover area was observed more than half i.e. 52.2% of the total geographical area. Devi et al (2012) similarly reported 52% of the total area to be under vegetation. Vegetation in this region comprised of homegardens, plantation systems, privately owned forests and reserved forest. Therefore, in the present study, the area under forest vegetation was further stratified into two classes, *viz*. i. Reserve Forest (RF) and ii. privately owned forests, plantations, homegardens, etc. The latter is termed as trees outside forest (TOF).

The total area designated under RF was reported to be slightly higher (1897.08 km^2) than the TOF (1717.69 km^2) in Barak valley. The RFs of the region include; Upper Jiri, Lower Jiri, Barak, Innerline, Sonai, Katakhal, Patheria Hills, Duhalia, Singla, Badshahi tilla, Tilbhum, and Longai. The region also has a protected wildlife sanctuary (Borail wildlife

sanctuary) that is divided into east and west blocks. For the present study, the entire protected forest network is classed together as RF. The RF of this region is undergoing severe degradation due to anthropogenic disturbances as reported by the present author in a related work (Reang et al 2018b). During ground validation, some of the common tree species encountered in this region were *Artocarpus chama* Buch.-Ham, *Cynometra polyandra* Roxb., *Ficus benghalensis* L., *Gmelina arborea* Roxb., *Mesua ferrea* L., *Pterygota alata* (Roxb.) R.Br., *Tetrameles nudiflora* R.Br., and *Toona ciliata* M. Roem.

Scrubland: The scrubland class included the non-vegetated areas, bare or exposed land, small shrubs and bushes, grasslands, and shifting cultivation fallows. It accounted for ca 83.35 km^2 of the total area. Delineation of this land category was challenging due to their small size and interspersed nature intermixing with the other land cover categories. A total area of 55.3 km^2 was estimated for this land cover class by Das and Das (2014) which is lesser in area than the present study and is likely due to difference in the classification technique approach.

Tea plantation: Tea plantation is one of the dominant plantation systems in the valley since the British period and plays a key role in providing employment opportunities and economy of the local people living in the region. Total area under this land cover class was 484.51 km^2. This was slightly more than the area calculated by Das and Das (2014) i.e. 396.41 km^2 as different techniques were employed to calculate the area in the two studies. In the present study, a hybrid technique was employed while Das and Das (2014) used visual interpretation technique only. The increased value may also be attributed to the increase in the size of the various existing tea plantations over time. Apart from the tea plantations, other common plantation systems in the region include teak, rubber, banana, pineapple, agar, and betel nut. However, it was not feasible to delineate these land cover categories as their spectral reflectance matched with that of homegardens or privately owned forest lands. Also due to their very small size and scattered distribution, it is difficult to segregate them from the forest lands. Kurien et al (2019) also observed that the horticultural plantations were integrated with forests in the maps prepared by Forest Survey of India. This was because of similar canopy cover.

Urban built-up: This land use class include areas where there are high concentration of people in permanent, along with man-made structures and developmental activities. The urban built-up class occupied an area of 47.32 km^2 (0.68%). Since most part of the region is rural, relatively less area was reported under the urban built-up category. The three districts; Cachar, Hailakandi, and Karimganj in general have only its main district town under the urban built-up class that are relatively large in area. Silchar of Cachar district is the main commercial town of the region.

Water body: This land cover class include all the areas that exhibits surface water body. The total area under perennial waterbodies was estimated to be 211.86 km^2 (3.06%). An increase of about 65.81 km^2 in the total water body area cover was recorded as compared to an earlier study conducted for this region (Devi et al 2012). This may be due to the difference in the data used, time period of data and the classification techniques. However, the Wetland Atlas Report (2011) estimated a total area of 194.69 km^2 under wetlands in Barak valley which corresponds to the findings of the present study. Due to the absence of appropriate legal provisions for protection and conservation, the wetlands/waterbodies of Barak valley have undergone severe degradation and shrinkage (Gupta 2012, Reang et al 2018a).

Others: This LULC category includes other important land features in the study region. These include; Assam University, National Institute of Technology, Airport and Medical College. The corresponding total area of these landmarks are 2.33 km^2, 1.6 km^2, 1.55 km^2 and 1.1 km^2 respectively, and the linear distance under national highway and railway lines within Barak valley was 354.96 km and 294.4 km respectively.

Classification accuracy: The final map prepared achieved an overall classification accuracy of 91.1% (Table 3). The present study estimate was comparable to other works that applied the hybrid classification techniques (Kamusoko and Aniya 2009, Tang and Pannell 2009). The highest producer's accuracy of 100% was recorded for the important landmarks. This was due to the sufficient ancillary information and prior knowledge of the studied land features. The class Agriculture had the least producer's accuracy of 82%. The agricultural land occupying the central region was relatively homogeneous and was classified accurately. However, there were numerous small agricultural fields scattered amongst other LULC categories. This finding was also reported by other workers in this region (Gupta 2009). The smaller agricultural fields showed a great deal of intermixing with the adjacent LULC types. Producer's accuracy was also recorded as low as 83% for the class TOF. This land cover class showed maximum spectral mixing with tea plantation class. Tea plantation is constituted by a large number of shade trees that resulted in similar reflectance to the TOF class.

CONCLUSION

The following are the key findings of the present study. The map prepared is first of its kind for the region. The

Table 3. Accuracy evaluation of the LULC map

Mapped class	LULC classes	Sl	Rl	Ub	Tp	Sc	Sa	Wo	Ns	Au	Rf	Tf	Ag	Total	UA (%)
	Sl	44	0	0	2	0	0	1	0	0	0	1	2	50	88
	Rl	0	43	3	0	0	0	4	0	0	0	0	0	50	86
	Ub	0	0	55	0	0	0	2	0	0	0	0	3	60	92
	Tp	0	0	0	51	0	0	0	0	0	0	4	5	60	85
	Sc	0	0	0	0	20	0	0	0	0	0	0	0	20	100
	Sa	0	0	0	0	0	10	0	0	0	0	0	0	10	100
	Wo	0	0	0	1	0	0	43	0	0	0	3	3	50	86
	Ns	0	0	0	0	0	0	0	20	0	0	0	0	20	100
	Au	0	0	0	0	0	0	0	0	20	0	0	0	20	100
	Rf	0	0	0	0	0	0	0	0	0	66	1	3	70	94
	Tf	0	0	0	2	0	0	0	0	0	3	55	0	60	92
	Ag	1	0	0	1	0	0	1	0	0	1	2	74	80	93
Total		45	43	58	57	20	10	51	20	20	70	66	90	550	
PA (%)		98	100	95	89	100	100	84	100	100	94	83	82		
OA %								91.1							

UA=User's accuracy, PA =Producer's accuracy, OA =Overall accuracy, Sl =Scrubland, Rl =River bank farming land, Ub =Urban built-up, Tp =Tea plantation, Sc =Silchar medical college, Sa =Silchar airport, Wo =Wetland/Other waterbody, Ns =NIT Silchar, Au =Assam university, Rf =Reserve forest, Tf =Trees Outside forests, Ag =Agriculture.

detailed LULC map has been prepared using relatively high resolution LISS4 data and a hybrid approach. A very important LULC category has been delineated and mapped for the first time *viz*., the riverbank farming. This is of great economic significance to the local populace of this region. Another important contribution of the paper is the delineation and mapping of the RF and TOF boundaries. This map thus presents a synoptic view of the land resources of Barak Valley. The map will help conservationists, policy makers and other researchers for planning and implementing various research activities. The prepared map can be used as baseline data for carrying out different conservation-related programmes such as ecological niche modelling, assessment of ecosystem services etc. Since the RF and TOF boundaries are delineated, it will help monitor forest encroachment which is a serious and recurring problem in this region. This study therefore demonstrated the great potential of LISS4 imagery for mapping of heterogeneous landscape such as Barak valley and may be applied in other areas of comparable size and heterogeneity. However, the study also indicated that several small sized plantations were not distinguishable on the map. The overall accuracy of the final map could be further improved by the use of higher-resolution imagery and advanced object-based image analysis techniques instead of conventional pixel-based techniques.

ACKNOWLEDGMENT

The authors acknowledge the Department of Science and Technology and its FASTTRACK programme for funding the project (SERB/F/2489/12). The authors also acknowledge the Department of Forest, South Assam Circle for providing vital information on the major land use land cover of Barak valley.

REFERENCES

Alimjan G, Sun T, Jumahun H, Guan Y, Zhou W and Sun H 2017. A hybrid classification approach based on support vector machine and k-nearest neighbor for remote sensing data. *International Journal of Pattern Recognition and Artificial Intelligence* **31**(10): 1750034.

Anderson JR, Hardy EE, Roach JT and Witmer RE 1976. *A land use and land cover classification system for use with remote sensor data*, Washington: United States Government Printing Office.

Borah N, Rabha D and Athokpam FD 2016. Tree species diversity in tropical forests of Barak valley in Assam, India. *Tropical Plant Research* **3**(1): 1-9.

Champion HG and Seth SK 1968. *A revised survey of the forest types of India*. Manager of Publications, Government of India press, Nasik.

Das P 2012. Study of Barak river meander and associated hazard around Silchar town, Assam, using remote sensing and GIS. *Earth Science India* **5**(2): 51-59.

Das T and Das AK 2005. Inventorying plant biodiversity in homegardens: A case study in Barak Valley, Assam, North East India. *Current science* **89**(1): 55-163.

Das T and Das A K 2014. Mapping and identification of homegardens as a component of the trees outside forests using remote sensing and geographic information system. *Journal of Indian Society of Remote Sensing* **42**(1): 233-242.

Devi NP, Reddy CS, De A and Dutta BK 2012. Spatial assessment of land use in Barak valley, Assam using satellite remote sensing data. *National Academy Science Letters* **35**(5): 493-495.

Gupta A 2000. Forests of Barak Valley, Assam: History, management and status of wildlife habitats. In: Arunachalam A and Khan ML (eds). *Sustainable Management of Forests-India*. International

Book Distributors, Dehradun.

Gupta A 2009. Development of Barak valley: the Question of Sustainability. In: Bhattacharjee JB (eds). *Development strategies of Barak valley (Assam)*. Akansha Publishing House, New Delhi.

Gupta A 2012. Water resource management in Barak valley, Assam, North East India: Status, needs and Priorities. *Bionano Frontier* **5**: 1-5.

Kamusoko C and Aniya M 2009. Hybrid classification of Landsat data and GIS for land use/cover change analysis of the Bindura district, Zimbabwe. *International Journal of Remote Sensing* **30**(1): 97-115.

Kurien AJ, Lele S and Nagendra H 2019. Farms or forests? Understanding and mapping shifting cultivation using the case study of West Garo Hills, India. *Land* **8**(9): 133.

Lu D and Weng Q 2007. A survey of image classification methods and techniques for improving classification performance. *International Journal of Remote Sensing* **28**(5): 823-870.

Nandy S and Das AK 2013. Comparing tree diversity and population structure between a traditional agroforestry system and natural forests of Barak valley, Northeast India. *International Journal of Biodiversity Science, Ecosystem Services and Management* **9**(2): 104-113.

Pradhan R, Ghose MK and Jeyaram A 2010. Land cover classification of remotely sensed satellite data using bayesian and hybrid classifier. *International Journal of Computer Applications* **7**(11): 1-4.

Rashid I, Romshoo SA and Vijayalakshmi T 2013. Geospatial modelling approach for identifying disturbance regimes and biodiversity rich areas in North Western Himalayas, India. *Biodiversity and Conservation* **22**(11): 2537-2566.

Reang D, De A and Das AK 2018a. Water Resources of Barak valley, India: spatial assessment of lentic and lotic system using remote sensing and GIS at 5.8 m resolution. *International Journal of Advanced Remote Sensing and GIS* **7**(1): 2633-2642.

Reang D, De A, Das AK and Dhanda P 2018b. Forest health degradation in Barak valley: A NDVI-based study. *Indian Journal of Forestry* **41**(4): 319-328.

Reddy MB 2009. Land cover classification using IRS LISS III satellite image and Digital Elevation Model in hilly environment: A case study in Nongkhyllem Wildlife Sanctuary, Meghalaya. *Indian Forester* **135**(4): 487-499.

Sarkar P, Das T and Mandal R 2019. Assessing human dependency on the provisioning ecosystem services of Chatla floodplain wetland of Barak valley, Assam, Northeast India. *Indian Journal of Ecology* **46**(3): 516-520.

Tang Y and Pannell C W 2009. A hybrid approach for land use/land cover classification. *GIScience & Remote Sensing* **46**(4): 365-387.

Thakkar AK, Desai VR, Patel A and Potdar MB 2017. Impact assessment of watershed management programmes on land use/land cover dynamics using remote sensing and GIS. *Remote Sensing Applications: Society and Environment* **5**: 1-15.

Vatsavai RR and Bhaduri B 2011. A hybrid classification scheme for mining multisource geospatial data. *GeoInformatica* **15**(1): 29-47.

Received 29 June, 2020; Accepted 26 August, 2020

Indian Journal of Ecology (2020) 47(3): 849-853

Manuscript Number: 3094
NAAS Rating: 4.96

Collection and Utilization Pattern of Non Timber Forest Products in Nagaland, an Eastern Himalayan State of India

Sanjoy Das, Narokumla Longkumer, N.K. Patra, Nchumthung Murry and Mukesh Yadav

Nagaland University, School of Agricultural Sciences and Rural Development
Medziphema Campus, Nagaland-797 106, India
E-mail: das_san1@rediffmail.com

Abstract: The study was conducted to assess the collection and utilization pattern of Non Timber Forest Products in Nagaland, a North Eastern State of Eastern Himalayan region of India. The study was conducted in two blocks, namely Changtongya Block and Ongpangkong N Block of Mokokchung district, Nagaland comprising of 100 respondents from 10 selected villages. Study identified 5 major groups of NTFPs viz. wild fruit, wild vegetable, medicinal plants, fuel wood and other category collected by the respondents from the jungle. Majority of the respondents went for collection of wild vegetables (97%) followed by others category viz, broom grass, wild meat, fish, etc., (87%). Among the different types of NTFPs available, maximum consumption was in fuel wood and for selling purpose others category viz, broom grass, fish, wild meat. were seen more popular among the tribal population. Most of respondents sell the NTFPs mostly to local consumers. Although NTFPs were significant contributors towards rural income and employment, most of the respondents were in the category of monthly collection and only a few percentages of respondents were involved in daily collection of NTFPs from the forest.

Keywords*:* Types of NTFP, Collection, Utilization

Non Timber Forest Products (NTFPs) encompass all biological materials other than timber, which are actively extracted from forest for human use. They are the constituents of the forest system that truly exist in nature and are normally not cultivated. Herdon and butler (2010) concluded that about 80% of the population of the developing countries depend on NTFPs for their primary health and special nutritional needs According to World Bank (2002), throughout the world more than 1.6 billion people dependent on forests for their livelihoods. In around 60 developing countries, over a fifth of people's requirements are supplied by hunting and fishing on forested land (Mery et al 2005). India is the seventh largest country in the world and is a large developing country known for its diverse forest ecosystem and mega biodiversity and ranks 10th amongst the most forested nation of the world with 21.54% of land area under forest, according to India State Forest Report 2017 (ISFR).

Nagaland is situated in one of the identified global biodiversity hotspots and ecologically vulnerable areas of Eastern Himalayan Region of India. The forest cover in the state is 12,489 sq. km, which is 75.33% of the states geographical area (ISFR 2017). According to Department of Environment, Forest and Climate Change, Government of Nagaland, Zunheboto district was the highest collection of revenues from NTFPs in the year 2016-17 and mentioned that there are about 53 important NTFPs species and used extensively in Nagaland. However, because of increase in population levels, per capita availability of agricultural land is declining and dependence on forest is increased over the years to supplement their income. Trees and other products are being discarded from the forest faster mainly due to diminishing of raw materials, soil erosion, and limiting in agricultural yields and variation in microclimate and resource exhaustion. The basic objective of the present study was to assess the collection and utilization pattern of various non-timber forest products by the people of Nagaland State.

MATERIAL AND METHODS

The study was conducted in Mokokchung District of Nagaland. Out of 6 Rural Development Blocks in the district, two blocks namely, Changtongya block and Ongpangkong N block were chosen purposively for the study. From each village 10 respondents were sampled which resulted to a total of 100 respondents. Data were collected from primary as well as secondary sources. The primary data were obtained from the sample households by using well structured questionnaire/schedules and personal interview. Secondary data were collected from secondary sources such as Department of Environment, Forest and Climate Change (Government of Nagaland), journals, handbooks, articles, Statistical Handbook of Nagaland.

RESULTS AND DISCUSSION

Collection of NTFPs by rural households: Majority of the

respondents went for collection of wild vegetables (95.7%), followed by broom grass, wild meat, fish, wild fruits and fuel wood in Changtongya block. Similar trend was observed in Ongpangkong N block also. Present study identified nearly 23 numbers of NTFPs (Table 7) in Mokokchung district of Nagaland that were broadly grouped into wild fruits, wild vegetables, medicinal plants, fuel wood and others category.

Intensity of collection of NTFPs by sample households: Only 8% of the sample households were involved in daily collection of NTFPs in the district, 62% of the households in monthly collection and 15% both weekly and occasionally collection of NTFPs. It indicated that although NTFPs play an important role towards income and employment, daily collectors were very less in number and majority were monthly collectors of NTFPs from forest.

Table 4. Consumption of NTFPs by sample households

Types of NTFPs	Changtongya block	Ongpangkong N block	Total
Wild fruits	22 (31.0)	14 (46.7)	36 (36.0)
Wild vegetables	30 (43.0)	10 (33.3)	40 (40.0)
Medicinal	17 (24.3)	9 (30.0)	26 (26.0)
Fuel wood	57 (81.4)	24 (80.0)	81 (81.0)
Others	30 (43.0)	16 (53.3)	46 (46.0)

The figure in the parenthesis indicates percentage to the total

Table 1. NTFPs collected by sample respondents (per annum)

Block	Types of NTFPs/ No. of respondents				
	Wild fruits	Wild vegetables	Medicinal plants	Fuel wood	Others
Changtongya	51 (71.0)	67 (95.7)	29 (41.4)	49 (70)	62 (88.6)
Ongpangkong N	17 (56.7)	30 (100)	13 (43.3)	19 (63.33)	25 (83.3)
Total	68 (68.0)	97 (97.0)	42 (42.0)	68 (68.0)	87 (87.0)

The figure in the parenthesis indicates percentage to the total

Table 2. Intensity of sample households in collection of NTFPs in a year

Block	Daily	Weekly	Monthly	Occasionally
Changtongya	5 (7.14)	10 (14.29)	45 (64.29)	10 (14.29)
Ongpangkong N	3 (10.0)	5 (16.67)	17 (56.67)	5 (16.67)
Total	8 (8.0)	15 (15.0)	62 (62.0)	15 (15.0)

The figure in the parenthesis indicates percentage to the total

Quantity of NTFPs collected by sample households: In Changtongya Block, 79.6% of total quantity collected by sample household was fuel wood (i.e. 105000 kg) with an average of 3620.69 kg, 10.14% wild vegetables, 2.35 % wild fruits, 0.72 % was medicinal plants and 7.19% was others category. Total quantity of NTFPs collected by male was 106510 kg with an average of 591.72 kg and by women was 25392 Kg with an average of 325.54 Kg. Similar trend was visible in Ongpangkong N block also. It can be concluded that male people were involved more in collection of NTFPs from forest and that resulted the more average collection of NTFPs by male than female. Out of different types of NTFPs, annual average collection was more in case of fuel wood followed by others category and wild vegetables.

Pattern of utilization of NTFPs by rural households: In Changtongya Block, majority of the sample households (81.4%) utilized fuel wood, followed by wild vegetables and

Table 3. Details of quantity collected annually by sample households in Changtongya and Ongpangkong N block

Types of NTFPs	Changtongya Block						Ongpangkong N Block					
	Total quantity collected (Kg)			Average quantity (kg)			Total quantity collected (Kg)			Average quantity (kg)		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
Wild fruits	2261 (2.12)	839 (3.3)	3100 (2.35)	64.6	52.4	60.8	310 (0.79)	240 (3.19)	550 (1.18)	31	34.3	32.4
Wild vegetables	11112 (10.43)	2258 (8.89)	13370 (10.14)	222.2	132.8	199.6	3290 (8.34)	350 (4.65)	3640 (7.78)	164.5	35	121.3
Medicinal plants	656 (0.62)	300 (1.18)	956 (0.72)	14.6	17.7	15.4	340 (0.87)	120 (1.59)	460 (0.98)	22.7	12	18.4
Fuel wood	84500 (79.33)	20500 (80.73)	105000 (79.6)	5633.3	1464.3	3620.7	33500 (85.34)	6500 (86.32)	40000 (85.46)	4187.5	1300	3076.9
Others	7981 (7.5)	1495 (5.9)	9476 (7.19)	228.0	106.8	193.4	1830 (4.66)	320 (4.25)	2150 (4.6)	122	80	113.2
Total	106510 (100)	25392 (100)	131902 (100)	591.7	325.5	402.1	39270 (100)	7530 (100)	46800 (100)	577.5	209.2	450.0

others category, wild fruits and medicinal plants (24.3%) Similarly in Ongpangkong N block, same trend was observed (Table 4). Majority of sample respondents in the district utilized fuel wood as a source of cooking that is collected from the forest and significant portion of the respondents also utilized different types of NTFPs viz, others category, wild vegetables, medicinal plants, wild fruits etc. for their livelihood.

Selling of NTFPs by sample households: In Changtongya Block, highest no. of sample households (57%) involved in selling of both wild fruits and others category *viz*. broom grass, wild meat, fish, followed by 50% for selling of wild vegetables, 19% for selling of medicinal plants and only 4% for selling of fuel wood. Under marketing channel, most of the households sold their products to their local consumers in case of medicinal plants and fuel wood followed by others category, wild fruits and wild vegetables and only a few of them sold it to the middlemen which include for wild vegetables, others category and fruits. In Ongpangkong N block, 53% of the households sold wild vegetables followed by 47% for others category *viz*. broom grass, wild meat, fish etc., 20% for wild fruits, 13% for medicinal plants and 3% for fuel wood. Maximum of the household sold their products to their local consumers only and in case of medicinal plants and fuel wood, all of them sold only to local customers followed by wild fruits and vegetables. It can be concluded that majority of respondents collect and utilize NTFPs for their livelihood management and a good section of them tried to sell to others. Because of non availability of middlemen, they tried to sell within the local customers only.

Processing of NTFPs collected by sample households: Processing of NTFPs was very limited and it was visible only in few households. In Changtongya Block, processing was done for wild fruits and vegetables (7%) and medicinal plants (10%). Similarly, in Ongpangkong N Block similar trend was visible. Due of non-availability of scope, processing was found very limited among the respondents in the district.

Table 6. Processing of NTFPs collected by sample households

Types of NTFPs	Changtongya block	Ongpangkong N block	Total
Wild fruits	5 (7.0)	2 (7.0)	7 (7.0)
Wild vegetables	5 (7.0)	4 (13.0)	9 (9.0)
Medicinal	7 (10.0)	4 (13.0)	7 (7.0)
Others	0	0	2 (2.0)

The figure in the parenthesis indicates percentage to the total

Nature of collection and utilization of individual NTFPs: The nature of collection of NTFPs, including season of collection and utilization in details *i.e*. parts used, general usage of NTFPs and mode of utilization of NTFPs collected by the respondents given in Table 7. Most of the NTFPs collected were utilized for food purpose except broom grass and broom weed used for cleaning purpose. NTFPs are collected in almost all seasons depending upon their types of plants/trees/animal origin etc. For mushroom, broom grass, broom weed and fuel wood, whole plant is utilized. For wild fruits like gooseberry, mulberry, bay berry and nightshade plant, part used was berry for food purpose. For wild vegetables like glory bower, chinese pepper, vegetable fern, plant part used is leave. Animal origin NTFPs like fish, wild meat etc. whole body is utilized for food purpose.

Table 5. Selling of NTFPs by sample household

Types of NTFPs	Changtongya block			Ongpangkong N block			Total of district		
	No. of respondents selling NTFPs	Marketing channel		No. of respondents selling NTFPs	Marketing channel		No. of respondents selling NTFPs	Marketing channel	
		Local consumers	Middle-men		Local consumers	Middle-men		Local consumers	Middle-men
Wild fruits	40 (57.0)	30 (75.0)	10 (25.0)	6 (20.0)	5 (83.0)	1 (17.0)	46 (46.0)	35 (76.0)	11 (24.0)
Wild vegetables	35 (50.0)	20 (57.0)	15 (43.0)	16 (53.0)	12 (75.0)	4 (33.0)	51 (51.0)	32 (63.0)	19 (37.0)
Medicinal plants	13 (19.0)	13 (100)	0	4 (13.0)	4 (100)	0	17 (17.0)	17 (100)	0
Fuel wood	3 (4.0)	3 (100)	0	1 (3.0)	1 (100)	0	4 (4.0)	4 (100)	0
Others	40 (57.0)	35 (81.0)	5 (13.0)	14 (47.0)	10 (71.0)	4 (29.0)	54 (54.0)	42 (78.0)	12 (21.0)

The figure in the parenthesis indicates percentage to the total

Details of NTFPs gathered in the study area

A. Wild Fruits


Gooseberry


Night shade


Bayberry


Toko-patta


Burmese grape


Mulberry


Black dammar


Fragrant caper vine

B. Wild vegetables


Mushroom


Vegetable fern


Glory bower


Chinese pepper


Tree bean


Bamboo shoot


Banana inflorescence

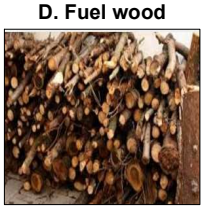
C. Medicinal Plants


Harar


Honey


Nut gall

D. Fuel wood



E. Others Category


Broom grass


Toko-patta


Betel leaf


Wild meat


Fish

Table 7. Nature of collection and utilization of NTFPs

NTFPs	Season of collection	Parts used	General utilization	Mode of utilization
Wild gooseberry	Summer	Berry	Food	Ripe berries are eaten fresh as well as in dried and liquid form.
Burmese grape	Summer	Fruit	Food	Ripe fruits are eaten fresh.
Black dammar	Summer, Autumn	Fruit	Food	Matured fruit are eaten fresh.
Fragrant caper vine	Autumn	Fruit	Food	Ripe fruits are eaten.
Bayberry	Spring	Berry	Food	Ripe fruits are eaten fresh.
Mulberry	Spring	Berry	Food	Ripe berries are eaten fresh.
Toko patta	Mid-Autumn, Early Winter	Fruit, leaves with stalk	Food, Outdoor broom	Fleshy fruit is eaten and also leaves with stalk are used as outdoor broom.
Night shade	All season	Berry	Food	Berries are eaten fresh.
Bamboo shoot	Summer	Shoot	Food	Freshly shoots are used as vegetable and also in the form of liquid & dried form.
Mushroom	All Season	Whole plant	Food	Eaten after cooking as vegetable.
Banana inflorescence	All season	Flower, stem	Food	Flowers are eaten after cooking as vegetable.
Tree bean	Mid-Winter, Spring	Pod	Food, Medicinal	Young fruits and seeds are eaten as vegetable either as raw or after cooking. Used as medicine for stomach pain.
Vegetable fern	All season	Leaves	Food	Leaf is used as vegetable.
Glory bower	Spring	Leaves	Food	Leaf is used as vegetable.
Chinese pepper	Spring	Leaves, Fruit	Food	Leaf is used as vegetable and berries.
Hillika	Autumn	Fruit	Food, Medicinal	Berries are eaten fresh and are used as medicine for diarrhea.
Honey	All season	Syrup	Food, Medicinal	Used as medicinal properties.
Nut gall	Winter	Fruit	Food, Medicinal	Ripe berries are used as medicine for stomach pain, dysentery, etc .
Betel leaf vine	Winter, Early Spring	Leaves	Tobacco	Leaves are eaten fresh.
Broom grass	Winter, Early spring	Whole plant	Indoor broom	Used as indoor broom.
Fuel wood	Winter	Whole plant	Firewood	Used for own consumption or for sale.
Wild meat	Winter, Spring	Whole body	Food	Used for own consumption or for sale.
Fish	All season	Whole body	Food	Used for own consumption or sale.

CONCLUSION

Non Timber Forest Products play a beneficial role towards rural poor and these are utilized and collected by a large section people in large quantity for their sustenance and livelihood in the State. The NTFPs collected are either consumed or sold directly in the local markets and very less or a non-significant part of these are processed at their level. Because of less exposure, respondents were unable to sell their products in outside market. The importance of value addition of NTFPs should be encouraged by training and demonstrations. With less market information at hand and no proper marketing channels, the rural people are bounded by limitation of selling their products only in the local market with the target being the local consumers and very few whole sellers. Efforts should therefore be made on how to bring their products from the local to the commercial markets.

Received 25 May, 2020; Accepted 26 August, 2020

REFERENCES

Anonymous 2002. World Bank annual report: Main report (English), Washington DC.

Anonymous 2006. Food and Agriculture Organisation (FAO). The state Food and Agriculture. Agricultural and Development Economics Division. Rome. www.fao.org/icatalog/inter-e-htm

Anonymous 2017. India State of Forest Report (ISFR). Forest Survey of India. Ministry of Environment, Forests and Climate Change, India, Dehradun. www.fsi.nic.in

Herdon CN and Butler RA 2010. Significance of biodiversity to human health. *BIOTROPICA* **42**(5): 558-560.

Mery G, Alfaro RI, Kanninem M and Steven Bernstein 2005. *Forest in the Global balance-changing Paradigms*. International Union of Forestry Research Organizations (IUFRO), Vienna, Australia, p 318.

Shackleton S and Shackleton C 2004 The importance of NTFP in rural livelihood security and as safety nets: A review of evidence from South Africa. *South African Journal of Science* **100**(11): 658-664.

Indian Journal of Ecology (2020) 47(3): 854-857

Manuscript Number: 3095
NAAS Rating: 4.96

Study on Mangroves of Zuari Estuary: Remote Sensing and GIS Approach

R.U. Sawaiker and P.M. Gaonkar[1]

Department of Botany, PES's RSN College of Arts and Science, Farmagudi Ponda Goa-403 401, India
[1]Department of Botany, Goa University, Taleigao Plateau-403 001, India
E-mail: ranjitasawaikar@gmail.com

Abstract: Goa being a coastal state supports rich diversity of mangrove vegetation. Documentation of this vegetation can be done by ground truthing or using remotely sensed data. Remote sensing is useful in monitoring changes in land use land cover. Vegetation Indices (VI) have been used in mangrove mapping and change detection worldwide. NDVI is calculated from the Red and Near Infrared spectral bands. Present study aimed to document mangrove species; to detect changes in the mangrove vegetation using LULC maps and to calculate NDVI in the upstream region of Zuari estuary. For LULC map, Primary data was collected by ground truthing while secondary data by LAND SAT MODIS and was analyzed using ERDAS 14 Software. Layer stacking was done to get false colour composite (FCC). All satellite images were culminated to get Mosaic image. For NDVI data was taken from LISS III. Mangroves like *Avicinia, Sonneratia, Acanthus, Kandelia, Rhiziphora* along with two associates *Clerodendron and Acrosticum* were recorded. LULC map indicated decline in mangrove vegetation and NDVI with increase in grassland, cropland, woody savannas and total eradication of evergreen needle leaf vegetation. Remotely sensed data plays pivotal role in detecting changes and beneficial in restoration of mangrove vegetation in affected areas.

Keywords: Land use Land cover (LULC), Normalized Difference Vegetation Index (NDVI), *Avicinia, Sonneratia, Acanthus, Kandelia, Rhiziphora, Clerodendron, Acrosticum*

Mangrove ecosystems are referred to as tidal forests that are considered to be highly productive wetland ecosystems of the world acting as buffers between near shore and estuarine environments. India is blessed with vast coastline from the east to west with high mangrove biodiversity. In Goa, Mandovi and Zuari rivers form important estuarine complex supporting dense and diverse flora of mangroves. Worldwide decline in mangroves is due to overexploitation, deforestation, anthropogenic activities and urbanization (Giri et al 2008). Land use changes and use of mangroves as fodder, fuel wood, fiber, timber, alcohol, paper, charcoal and medicine exerts pressure on these ecosystems (Kathiresan and Bingham 2001). They are also affected by the coastal environmental change and sea level rise. Despite their importance, mangroves are disappearing at a global loss rate of 1-2% per year (Polidoro et al 2010). Recent developments in geographical information system (GIS) and Remote Sensing Technologies provide valuable tools in monitoring, inventory making and management of natural resources (Merina 2017, Nayak and Bahuguna 2001, Das et al 2015, Telave and Ghodake 2016, Merina 2017). Utilizing the advantages offered by satellite remote sensing, significant progress has been achieved (Desai 1992, Pandi et al 2018). Present study aimed to document the mangrove species from selected study area; to compare and detect change in the mangrove vegetation of study area by generating LULC map of 1999 and 2019; to calculate NDVI for the study area.

MATERIAL AND METHODS

Description of study area: Zuari estuary is different from other estuaries of Goa, as it has more fresh water influence. Its mouth is nearly 5km wide while in upstream, width narrows down to 1km. The estuarine environment extends upstream upto Savordem (28 km). The selected study area of this estuary lies between latitude 15^0 20"0' N and $74^0$8"0 E longitude (Old Borim bridge to Curchorem) covering a stretch of nearly 20 km in the upstream region. Salinity is very low towards upstream region.

Data Characteristics

Spatial Coverage: Old Borim to Curchorem;

Spatial Resolution: 500 x 500 m;

Temporal Resolution: Two Decadal;

Temporal Coverage: 1999 to 2019;

Study Area: latitude $15^0$20"0' N and $74^0$8"0 E longitude

Analysis and processing of the data was carried out as shown in Figure 1 and 2 respectively.

Land use land cover (LULC): Satellite remote sensing has been widely used for change detection purposes (Sulaiman et al 2013). Over the last two decades, vegetation indices like NDVI have been used for estimating the density of the Mangrove forests (Kanniah et al 2015). For LULC map, primary data was collected by ground truthing whereas secondary data was collected by LAND SAT MODIS and was analyzed using ERDAS 14 Software for upstream region of estuary (Old Borim bridge-Curchorem). Layer stacking was

done to get false color composite (FCC). All satellite images were culminated into one mosaic image to get projection accuracy nearly 1km towards landward side. The land use maps thus generated were used to compare the change in vegetation cover over two decades. For thematic accuracy at each reference location, the respective land cover class and mangrove density was visually estimated, and GPS coordinates were recorded. IGBP-Global vegetation classification scheme was used to do level 1 classification.

Normalized difference vegetation index (NDVI): Spectral signatures are used to differentiate between the objects that reflect differently at different wavelengths (Kiefer 2000). The spectral properties of canopies are produced by the combination of optical properties of individual vegetative components, its effect on growth forms, density, height, tidal stage and soil type (Bahuguna and Nayak 1998). Vegetation has different optical properties in visible, near infrared and mid-infrared region. Due to pigment absorption there is low reflectance in the blue and red region of the EMR. The near-infrared region has got the highest reflectance. Infrared bands reflect well off of healthy vegetation so are useful in detecting changes in vegetation. For calculating NDVI values, data was taken from LISS III and the index was calculated using formula:

NDVI= (NIR band- Red band) / NIR band + red band)

Maps were generated to display the change in vegetation characteristics from 1999 and 2019.Accuracy assessment is an important part of the image classification procedure.

RESULTS AND DISCUSSION

Five dominant mangrove species like *Avicinia marina, Sonneratia caseolaris, Acanthus ilicifolius, Kandelia candel, Rhiziphora mucronata,* alongwith two mangrove associates like *Clerodendron inerme* and *Acrosticum aureum* were recorded during study period. Using satellite data, LULC and NDVI maps were generated (Fig. 3-6, Table 1). The data derived from LANDSAT MODIS was analyzed by ground truth surveys, and visual interpretation. LULC maps were classified according to the International Geosphere-Biosphere Programme (IGBP) classification system up to level I.

Out of five true mangroves and two associates of mangroves recorded from the study area showed variation in density and distribution. When the results were compared with IGBP land cover system of classification, it showed six different types of vegetational covers in 1999 and five different vegetational covers in 2019. This ascertained that mangrove cover is degraded in study area due to anthropogenic stress. Aquaculture, deforestation and increase settlement area were main reasons for this degradation. LULC map analysis for the year 1999 revealed that, there were natural vegetation mosaics(lands with a mosaic of croplands, mangrove forests, shrub lands and grass lands less than 60% each), croplands (temporary crop area), grasslands (herbaceous cover), savannas (herbaceous and understory system with canopy cover of 10-30%) woody savannas (herbaceous land and understory system and canopy cover from 30-60%) growing in the region where as in 2019, LULC map analysis showed besides the above mentioned classes there was increase in cropland area to a certain extent while significant increase was observed in woodland savannas. The evergreen needle leaf forest was totally eradicated over two decades. NDVI values declined from 0.16 to 0.14; 0.18 to 0.16;0.22 to 0.19; 0.20 to 0.14; 0.09 to 0.07 from station I to V respectively over a period of twenty years. NDVI is a robust, remote-sensing indicator of healthy vegetation; deterioration of vegetation phenology, indicated by a decrease in greenness, is reflected in a decrease in the NDVI (Alatorre et al 2015). NDVI values also decrease as plant cover diminishes and evaporation increases the salinity of soils (Alatorre et al 2011a). The time series of the two decadal averages of NDVI values showed a marked difference between distinctive land covers in the study area.

Table 1. NDVI values for the year 1999 and 2019

Station	1999	2019
Station I (Old Borim bridge)	0.16	0.14
Station II (Shiroda - Raia ferry)	0.18	0.16
Station III (Panchawadi Musher)	0.22	0.19
Station IV (Digashe)	0.20	0.14
Station V (Curchorem)	0.09	0.07

CONCLUSION

The analyses of mangrove vegetation in selected areas have shown that over two decades there were considerable variations in the study area due to anthropogenic activities. Classification of Landsat images and cross verification by ground truth traverses overall accuracy of the image interpretation. The results show that the LULC and NDVI very efficient tools in detecting the surface features of the visible area which are extremely beneficial for policy makers in decision making. The relationship between changes in remote sensing indices and environmental variables allows an efficient evaluation of environmental impacts, which can be used for planning and management of mangrove vegetation; restoration and management, by involving community participation.

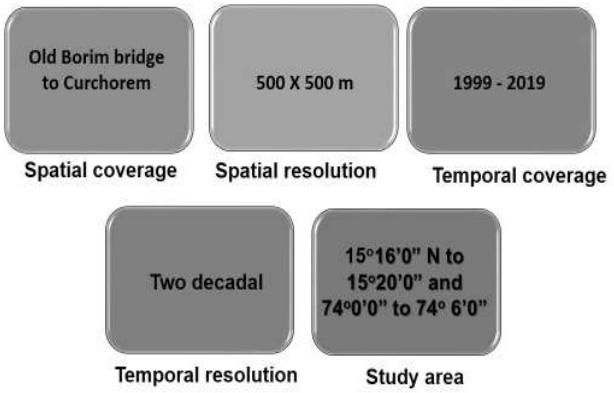


Fig. 1. Data analysis

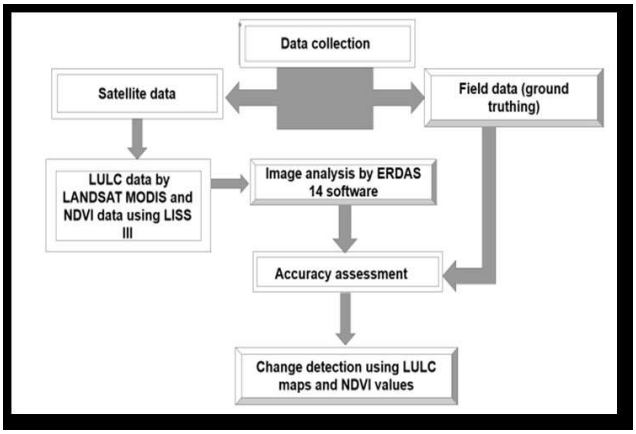


Fig. 2. Data processing

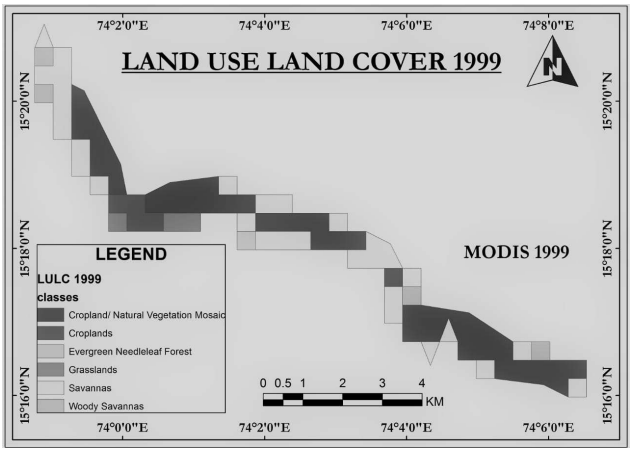


Fig. 3. LULC 1999

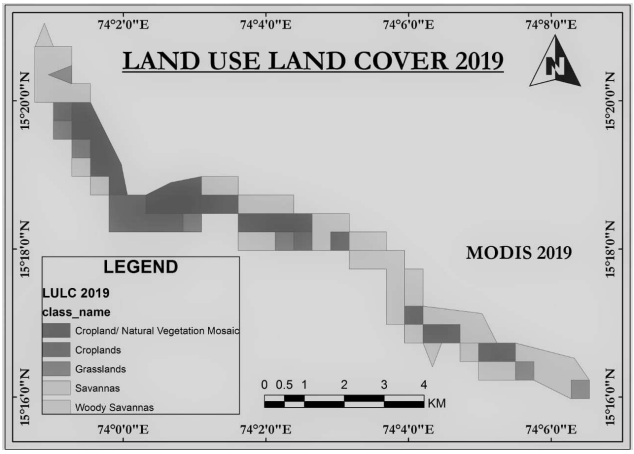


Fig. 4. LULC 2019

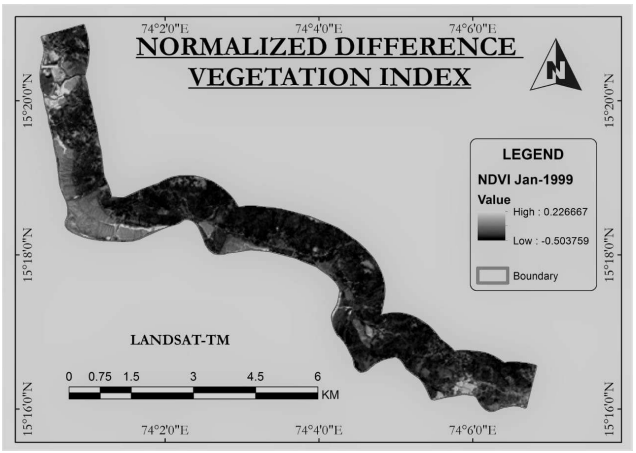


Fig. 5. NDVI 1999

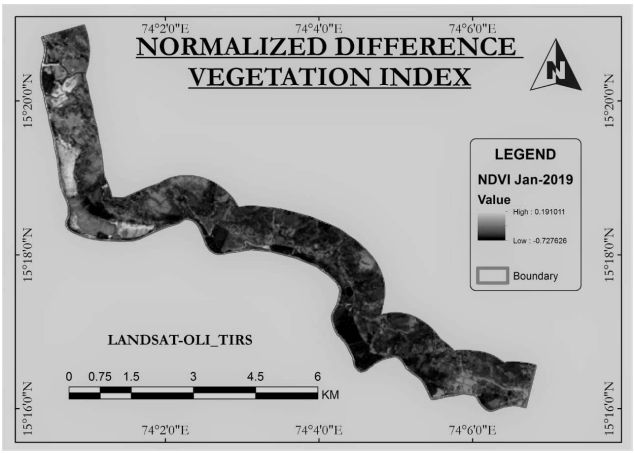


Fig. 6. NDVI 2019

REFERENCES

Alatorre LC, Sanchez E Amado JP Wiebe LC Torres ME Rojas HL Bravo LC and Lopez E 2015. Analysis of the temporal and spatial evolution of recovery and degradation processes in vegetated areas using a time series of Landsat TM images (1986e2011): Central region of Chihuahua, Mexico. *Open Journal Forestry* **5**(2): 162-180.

Bahuguna A and Nayak S 1998. *Coral reefs of Indian coast*, Scientific Note SAC/RSA/RSAG/DOD- COS/SN/16/97 (Space application centre Ahmedabad) 56pp.

Das NK, Verma VK and Meenakshi 2015. Land use and land cover change anal of Hussainiwala wetland ecosystem using remote sensing and GIS. *Indian Journal Ecology* **42**(2): 306-310.

Desai P 1992. *Coastal environment of Gujarat: Special reference to the Gulf of Kachchh*. (Remote Sensing Application Mission). Coastal Environment, Space Application Centre, Ahmadabad.129-146pp.

Ellison JC and Stoddart DR 1991. Mangrove ecosystem collapse during predicted sea level rise: Holocene analogues and implications. *Journal Coastal Research* **7**: 151-165.

Giri C and Muhlhausen J 2008. Mangrove forest distributions and dynamics in Madagascar (1975–2005). *Sensors* **8**: 2104-2117.

Kanniah KD, Sheikhi A Cracknell AP Goh HC Tan KP Ho CS and Rasli FN 2015. Satellite images for monitoring mangrove cover changes in a fast growing economic region in southern Peninsular Malaysia. *Remote Sensors* **7**(11): 14360-14385.

Kiefer RW 2000. *Remote sensing and Image Interpretation*, John Wiley & Sons, New York.

Kathiresan K and Bingham BL 2001. Biology of mangroves and mangrove ecosystems. *Advance Marine Biology* **40**: 81-251.

Merina NR 2017. Evaluation of sediment using GIS approach in Southern Tamilnadu, India. *Indian Journal of Ecology* **44**(2): 179-184.

Nayak S and Bahuguna A 2001. Application for remote sensing data to monitor mangrove and other coastal vegetation of India. *Indian Journal Marine Science* **30**: 195-213.

Pandi SP, Anna Gejo, Purvaja R and Ramesh R 2018. Spatial assessment of net canopy photosynthetic rate and species diversity in Pichavaram Mangrove Forest, Tamil Nadu. *Indian Journal of Ecology* **45**(4): 717-723.

Polidoro BA 2010. The loss of species: mangrove extinction risk and geographic areas of global concern. *PLoS ONE* **5**: 10095.

Sulaiman NA, Ruslan FA Tarmizi NM Hashim KA and Samad AM 2013. Mangrove forest changes analysis along Klang coastal using remote sensing technique. In *System Engineering and Technology (ICSET), IEEE, 3rd International Conference*, pp. 307-312.

Telave AB and Ghodake SD 2016. Mangroves species composition in Rajpuri creek of Maharashtra, India. *Indian Journal of Ecology* **43**(1): 308-310.

Received 22 May, 2020; Accepted 26 August, 2020

Indian Journal of Ecology (2020) 47(3): 858-862

Manuscript Number: 3096
NAAS Rating: 4.96

Design, Development and Performance Evaluation of Manually Operated Groundnut Planter

B.S. Madhusudan and M. Naga Sasi Preetham

Vignan's Foundation for Science, Technology and Research
Vadlamudi, Guntur-522 213, India
E-mail: bsmgowda0078@gmail.com

Abstract: A single row manually operated groundnut planter is developed and evaluated at actual field condition. The developed planter consists of the main frame, adjustable handle, furrow opener, seed hopper, drive wheels, seed tube and seed metering device. Most of this component are fabricated by using locally available material such as mild steel bars, acrylic sheet and pair of ball bearings. During field evaluation it was found that, the field capacity of the planter was 0.0675 ha/hr at average operating speed of 2.1 km/hr. The field efficiency of planter was 80.3 % and average depth of seed sowing was 55 mm. The maximum seed missing index and seed damage was found to be 4.6 % and 4 % respectively. The manually operated groundnut planter is precise in sowing, lower in weight, easy to use and maintenance free.

Keywords: Planter, Seed metering device, Field capacity, Missing index

The area under production of groundnut (*Arachis hypogaea* L.) in India is estimated as 4.012 Mha and production is estimated as 3.77 Mt (Solvent Extractors Association 2018-19). The sowing is one of the major labour intensive operations associated with groundnut crop production (Nwokwu 2018). The objective of sowing operation is to place the seed in required depth and provide required spacing between the seeds and cover them with the soil (Marode et al 2013). The sowing is mostly done manually which results in low field capacity, spacing efficiencies and serious back pain for the farmer which limits the size of the area to be planted (Patro et al 2014). The mechanization of sowing operation is one of the major solutions to overcome the above limitations. The groundnut is planted at a depth of 50 mm and spaced at 300 mm of plant to plant and 40-60 cm of row to row respectively (Papastylianou 1995, Ntareetal 2008). To accomplish the best performance and overcome the above limitations the manually operated planter is developed by adopting proper design procedure and using locally available material to suit the needs of crops.

MATERIAL AND METHODS

The manually operated groundnut planter was designed as functional unit based on seed characteristics, plant to plant spacing for design of seed metering unit, angle of repose of groundnut seed with hopper surface, rack angle of the furrow opener and volume of seed to be carried by the hopper.

Design and Development of Planter

Planter frame: The frame is a rigid structure, which provides support to all components of the groundnut planter. A piece of angle iron of dimension 40 mm × 40 mm × 5 mm was used for fabrication of frame with a dimension of 750 mm length, 450 mm width and 400 mm height (Fig. 1).

Design of seed hopper: The comportment which carries and regulates the movement of the seed is known as seed hopper. The seed hopper is trapezoidal in shape and was made from 5mm acrylic sheet (Fig. 2). The angle of inclination of the hopper is based on the angle of repose of the seed with hopper surface. The angle of repose of groundnut seeds ranges from 17.1-19.8^0 (Mpotokwane et al 2008, Oajide and Igbeka2003).

The volume of the seed hopper is as.

$$V_h = \frac{1}{2} \times (a+b) \times h \times l \qquad (1)$$

Where, V_h = Volume of the hopper, cm^3
a = Top width of the hopper, cm
b = Bottom width of the hopper, cm
h = Height of the hopper, cm
l = Length of the hopper, cm
V_h = ½ × (15 + 10) × 14 × 15.5
V_h = 2712.5 cm^3

Therefore the dimension of the hopper is taken for bottom width, top width, height and length is 10 cm, 15 cm, 14 cm and 15.5 cm respectively. The volume of the seed hopper is calculated as 2712.5 cm^3.

Design of seed metering device: Seed metering device is to distribute seeds uniformly at the required application rates. The number of cells on the seed metering device is obtained

from the following equation (Deorge et al 2002, Saharawat et al 2010).

$$n = \frac{\Pi D}{iX} \quad (2)$$

Where, n = number of cells on seed metering device

D = diameter of the ground wheel, mm, X = spacing between seeds, mm

i = transmission ratio

$$i = \frac{T_1}{T_2} \quad (3)$$

Where, T_1 = Number of teeth in ground wheel shaft, T_2 = Number of teeth in metering shaft

$$i = \frac{12}{24} = 0.5$$

The diameter of the ground wheel were taken as 600 mm. The standard spacing between the seeds are 300 mm (Ntare et al 2008). Substituting the above values in equation 2, the number of cell on the metering device is determined.

$$n = \frac{3.142 \times 600}{0.5 \times 300} \quad n = 12.5 \sim 12$$

The number of cells on the periphery of the seed metering device was selected as 12. The seed metering device was made by using nylon sheet with 12 cells on the circumference (Fig. 3).

Adjustable furrow opener: The shovel type furrow opener is selected because of its easy fabrication and suitability. The furrow tine with the rack angle of 45^0 will experience low soil resistance and draft requirement (Xiangcai 2016). The shovel type furrow opener with rack angle of 45^0 is fabricated using mild steel sheet (Fig. 4).

Design of power transmitting system: The chain and sprocket system is selected for transmitting power between ground wheels to seed metering unit. The gear ratio between ground wheel and seed metering device is determined as 0.5. To provide the gear ratio of 0.5, the chain sprocket of 12 teeth and 24 teeth for ground wheel shaft and metering device respectively is selected. The length of the chain is calculated by using the following formula (Khurmi 2012).

$$L = \frac{p}{2}(T_1 + T_2) + 2x + \frac{\left[\frac{p}{2}\cos ec\left(\frac{180^0}{T_1}\right) - \frac{p}{2}\cos ec\left(\frac{180^0}{T_2}\right)\right]^2}{x} \quad (4)$$

Where, L = Length of chain, mm, P = Pitch of chain, mm, T_1 = Number of teeth on larger sprocket, (T_1 = 60), T_2 = Number of teeth on smaller sprocket, (T_2 = 10), X = Centre to centre distance between two sprockets, mm (x = 330 mm)



Fig. 1. The planter frame

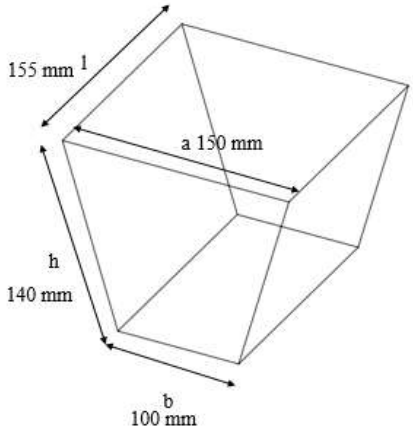


Fig. 2. Seed hopper

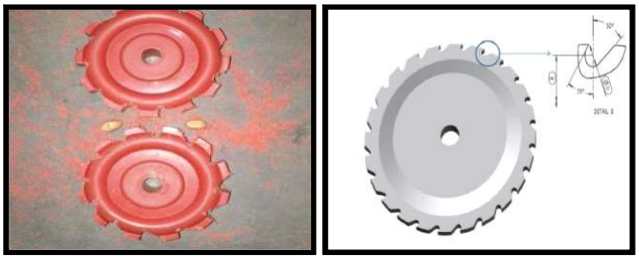


Fig. 3. Seed metering device



Fig. 4. Furrow opener

Therefore,

$$L = \frac{9}{2}(24+12)+2(600)+\frac{\left[\frac{9}{2}\cos ec\left(\frac{180^0}{24}\right)-\frac{9}{2}\cos ec\left(\frac{180^0}{12}\right)\right]^2}{600} \quad (5)$$

L = 1362.5 mm ~ 1.365 m

In order to transmit power from ground wheel shaft to seed metering shaft, 1.365 m chain is required, with above furnished sprockets (Fig. 5).

Performance evaluation of groundnut planter: To evaluate the performance of designed and developed groundnut planter, the following procedure was followed.

Missing index (MI): The missing percentage of seed is represented by an index called the missing index. It was measured by counting the number of seeds missed in a row of 10 m length to the actual number of seed could be dropped in 10 m row. The missing index is calculated by using the following equation.

$$MI = \frac{n}{m} \times 100 \quad (6)$$

Where, *n* = Number of seeds missing during pickup by metering wheel into seed tube; *m* = Number of seed dropped by the metering wheel if no missing occurred and not more than one seed per cell.



Fig. 5. Power transmission system

Theoretical field capacity (TFC): The theatrical field capacity is the rate of field coverage that would be obtained if the planter was operated continuously without any interruptions at turning at the end and filling of hopper. The theoretical capacities of the groundnut planter were determined by the following equation.

$$TFC\ (ha/hr) = \frac{S \times W}{10} \quad (7)$$

Where, *S*= Operating speed, km, *W* = Sowing width, m

Effective field capacity (EFC): The effective field capacity is the actual rate of area coverage with respect to time. The effective field capacity includes the time lost in filling hopper and turning at the end of the row.

Field efficiency (FE): The field efficiency is the ratio of effective field capacity and theoretical field capacity expressed in percentage. The field efficiency of the groundnut planter were determined by the following equation.

$$FE(\%) = \frac{EFC}{TFC} \times 100 \quad (8)$$

Where, *EFC* = Effective field capacity, ha/hr, *TFC* = Theoretical field capacity, ha/hr

Seed damage percentage (SD): The seed hopper was loaded with half of its capacity and drive wheel was rotated with 2.4 km/h in raised position. Polythene bag were placed at the end of furrow to collect the seeds metered and discharged seeds were examined for identification of external damage. The percentage seed damage is determined by using following equation.

$$SD(\%) = \frac{T_{sd}}{T_{sc}} \times 100 \quad (9)$$

Where, T_{sd} = total number of damaged seeds, T_{sc} = total number of seeds collected

RESULTS AND DISCUSSION

The materials used for fabrication of different components are presented in Table 1.

The groundnut planter is fabricated by using locally available material to reduce the cost of production (Table 2).

Planter Field Evaluation

Field capacity and field efficiency: Well prepared plot of 10 m × 10 m size were is selected for testing the planter in the field of Vignan's Foundation for Science, Technology and Research, Vadlamudi, Guntur. The theoretical field capacity at operating speed of 2.1 km/h was 0.084 ha/h. the effective

Table 1. Material of fabrication for manual groundnut planter

Component	Material
Frame	Angle iron
Ground wheel	Steel hub with rubber tire
Seed hopper	acrylic sheet
Seed metering device	Rubber rolls
Furrow opener	Mild steel
Handle	Mild steel pipe
Adjusting Rods	Galvanized iron
Seed tube	Rubber
Power transmission unit	Steel chain and sprocket



Fig. 6. Manually operated groundnut planter

field capacity of the planter varied from 0.065 to 0.071 ha/h .The field efficiency varies from 77.3 to 84.5 per cent. The average values of effective field capacity and field efficiency were 0.675 ha/h and 80.3%, respectively.

Seed missing index: The seed missing index of the planter were observed during evaluation. It was found that, during 10 m distance coverage of the planter at constant depth of operation, with series of field trails the average number of seed missed by the planter was 4.6 in a row at a speed of 2.1 km/h.

Seed damage: The seed damage percentage of the planter was measured under laboratory condition. The average seed damage percentages of the planter were 4%.

CONCLUSION

The seed hopper is fabricated by using acrylic sheet, seed metering mechanism made of rubber roller with 12 cells on the periphery of the seed drum, 600 mm diameter of ground wheel is used for power aid and steering purpose,

Table 3. Field capacity and field efficiency

Field trial	EFC (ha/h)	FE (%)
I	0.071	84.5
III	0.065	77.3
III	0.068	81
IV	0.066	78.5
Average	0.0675	80.3

Table 2. Specification of the fabricated manual planter

Component	Specification
Main frame	• Length : 750 mm • Width : 450 mm • Height : 400 mm
Ground wheel	• 600 mm diameter, 50 mm width
Seed hopper	• Dimensions: bottom width 100 mm, top width 150 mm, height 140 mm and length 155 mm • Volume : 2712.5 cm^3 • Angle of Repose between seed and hopper surface: 20^0
Power transmission system	• Number of teeth's : T_1= Number of teeth on larger sprocket, (T_1 = 60) • T_2= Number of teeth on smaller sprocket, (T_2 = 10) • Length of the chain : 1.365 m
Seed metering device	• Diameter of the metering drum : 70mm • Number of cells on drum: 12
Furrow opener	• Depth adjustment : 50 – 100 mm • Rack angle : 45^0
Handle	• Length: 1200 mm • Palm grip diameter : 125 mm
Overall dimensions	• Length: 1200mm • Width : 600 mm • Height : 800 mm

remaining all the parts are fabricated by using mild steel. The seed metering device is developed to maintain the plant to plant distance of 300 mm. The planter has a field capacity of 0.0675 ha/h with field efficiency of 80.3 % at the operating speed of 2.1 km/h. The maximum seed missing index and seed damage was found to be 4.6% and 4%, respectively.

REFERENCES

Doerge T, Hall T and Gardner D 2002. New research confirms benefits of improved plant spacing in corn. *Crop Insights* **12**(2): 1-5.

Kaur T and Kumar D 2013. Design and development of calibration unit for precision planter. *International Journal of Computer Science, Engineering and Applications* **3**(3): 11.

Khan K, Moses SC and Kumar A 2015. The design and fabrication of a manually operated single row multi-crops planter. *IOSR Journal of Agriculture and Veterinary Science* **8**(10): 147-158.

Khurmi RS and Gupta JK 2012. *Simple Mechanisms*-Theory of Machines.

Kumari R, Sharma B and Singh R 2015. Comparative assessment of yield and water use efficiency of different groundnut varieties (*Arachis hypogaea*) of semi-arid Bundelkhand Region. *Indian Journal of Ecology* **42**(1): 27-30.

Marode RV, Tayade GP and Agrawal SK 2013. Design and implementation of multi seed sowing machine. *International Journal of Mechanical Engineering and Robotics Research* **2**: 422-429.

Mpotokwane SM, Gaditlhatlhelwe E, Sebaka A and Jideani VA 2008. Physical properties of bambara groundnuts from Botswana. *Journal of Food Engineering* **89**(1): 93-98.

Ntare BR, Diallo AT, Ndjeunga J and Waliyar F 2008. *Groundnut seed production manual.* Patancheru 502324, Andhra Pradesh, India. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). pp 20.

Nwokwu GN, Ekwu LG and Utobo EB 2018. Performance of groundnut (*Arachis hypogaea* L) variety as affected by weeding frequencies. *Indian Journal of Ecology* **45**(2): 325-329.

Olajide JO and Igbeka JC 2003. Some physical properties of groundnut kernels. *Journal of Food Engineering* **58**(2): 201-204.

Papastylianou I 1995. Spacing of peanut plants (*Arachis hypogaea* L.) under irrigation. *European Journal of Agronomy* **4**(1): 101-107.

Patro H, Alim A and Dash D 2014. Growth and productivity of groundnut (*Arachis hypogaea*) under different tillage and sowing methods in India. *Applied Biological Research* **16**(2): 209-213.

Saharawat YS, Singh B, Malik RK, Ladha JK, Gathala M, Jat ML and Kumar V 2010. Evaluation of alternative tillage and crop establishment methods in a rice-wheat rotation in North Western IGP. *Field Crops Research* **116**(3): 260-267.

Xiangcai Z, Hongwen L, Ruicheng D, Shaochun M, Jin H, Qingjie W and Zhiqiang Z 2016. Effects of key design parameters of tine furrow opener on soil seedbed properties. *International Journal of Agricultural and Biological Engineering* **9**(3): 67-80.

Received 31 May, 2020; Accepted 19 August, 2020

Indian Journal of Ecology (2020) 47(3): 863-865

Manuscript Number: 3097
NAAS Rating: 4.96

Effect of Different Varieties and Spacings on Growth and Yield Attributes of Garlic (*Allium sativum* L.)

Shatrunjay Yadav, Sanjay Kumar and Shubham Singh

Department of Horticulture
Babasaheb Bhimrao Ambedkar University, Lucknow-226 025, India
E-mail: sanjay123bhu@gmail.com

Abstract: The investigation was undertaken to determine the effect of different varieties and spacing on growth and yield traits in garlic. Four different varieties Yamuna safed-1, Yamuna safed-2, Yamuna safed-3 and Yamuna safed-4 with three spacing viz. 10 x 10 cm, 15 x 10 cm and 20 x 10 cm were evaluated. The spacing (15 x 10 cm) produced higher plant height (48.74 cm), number of leaves (10.30), length of leaves (41.70 cm) of plant. The cloves length (2.52 cm), diameter (1.54 cm) and neck thickness (0.35 cm) showed same trend in widest spacing (15 x 10 cm). The weight of individual cloves of garlic (37.08 g) increased with the wider spacing (10 x10 cm). Yield was the highest (50-70 q ha^{-1}) at closer spacing (10 x 10 cm) and lowest was (40-50 q ha^{-1}) at wider spacing.

Keywords: Garlic, Spacing, Varieties, Growth, Yield

Garlic (*Allium sativum*) is popular condiment crop and is second most widely grown winter crop after onion of family amaryllidaceae is native to arid and semi-arid region of central Asia and domesticated there since 3000 BC (Etoh and Simon 2002). Garlic productivity in India is comparatively low as compared to world. So, in the recent years due to attention has been given to improve the plant growth and yield with application of plant growth regulators as they modify plant characters like plant height, number of leaves per plant, number and size of clove and bulb, biomass and yield, net bulb yield by influencing the physiological processes within the plant which ultimately affect the yield and quality of garlic. As the garlic is reproduced exclusively by vegetative means plant character such as cloves weight or size used for propagation also affect the bulb size, yield and quality of the produces significantly (Memane et al 2008). The use of large sized cloves increases the yield significantly but it also enhanced the cost of production by affecting the seed quantity, whereas small sized bulbs result into lower yield with lesser cost of production (Farooqui et al 2009). There is a great need to standardize the size of garlic cloves used for propagation in order to get cost effective result in garlic production. Therefore, the present study was undertaken to determine the effect of spacing on growth and yield of different varieties of garlic (*Allium sativum* L.)

MATERIAL AND METHODS

The experiment was conducted at Babasaheb Bhimrao Ambedkar University, Lucknow during rabi season of 2017-18. The experimental site is situated at $26^0$50 N latitude, $80^0$52' E longitude and altitude of 111 meter above sea level. The area experiences rainfall from April to October with the many rains from June to early September. The area receives average rainfall between 800-1000 mm with annual and maximum temperature ranging from 15 to 30°C. Four varieties viz. Yamuna safed-1, Yamuna safed-2, Yamuna safed-3 and Yamuna Area-4 and three spacing such as 10 x 10, 15 x 10 and 20 x 10 were used for study. The experiment was laid out in factorial Randomized Block Design with three replications. The observation was made on plant height (cm), bulb weight, bulb diameter, number of scale per bulb, bulb weight and yield of bulbs. All the parameters were collected from three randomly selected plants of each treatment. The maximum growth of garlic plant was obtained with medium spacing and moderate clove size might be due to the fact that, the greater spacing of plant stem to have helped the individual plant to help it to put up better growth. Similarly, initial storage of enough food material might be helpful in vigorous growth of plant.

RESULTS AND DISCUSSION

Effect of varieties on growth and yield of garlic: The growth and yield in different spacing and varieties showed significant effect (Table 1). The highest yield (70 q ha^{-1}) was from Yamuna safed-3 but did not differ significantly from Yamuna safed-1. Similar trend was recorded in plant height, number of leaves per plant, neck thickness of plant, bulb diameter, length of bulb, weight of bulb, and number of scale per cloves. No significant variation between Yamuna safed-1, Yamuna safed-2, Yamuna safed-3 and Yamuna safed-4 with respect to various growth parameters.

Effect of spacings on growth and yield of garlic: There

was significant effect of different spacing on plant height, number leaves per plant, bulb diameter, neck thickness, length of bulb, weight of bulb, number of scale per clove, yield per plot. Significantly, the highest plant height (48.74 cm) and diameter (1.80 cm) was observed from the widest spacing (15 x 10 cm) and followed by 20 x 10 cm. The maximum number of leaves per plant (10.25 cm) was in spacing 15 x 10 cm followed by 10 x 10 cm. The maximum length of leaves (41.70 cm) 20 x 10 cm followed by 10 x 10 cm. The maximum (1.80 cm) width of leaves was 20 x 10 cm and followed by 10 x 10 cm. However, the closer spacing 10 x 10 cm produce higher yield (5.45 kg/plot and 70 q ha^{-1}) followed by 15 x 10 cm. The lowest yield was obtained from the wider spacing 20 x 10 cm.

Interaction effect of spacing and different cultivars on growth and yield of garlic: Significantly, the highest plant height (51.23 cm) was in Yamuna safed-3 with spacing 20 x 10 cm. The maximum (12.23) number of leaves per plant was from Yamuna safed-1 with spacing 20 x 10 cm. The length of leaves (38.17 cm) was maximum in Yamuna safed-2 with spacing 15 x 10 cm. This is accordance with (Singh et al 1995) demonstrated that closer spacing 12 x 5 cm was better for height of the plants, length of leaves, number of leaves per plant, weight of bulbs per plot and yield of garlic bulb per hectare in comparison to wider spacing (12 x 10 cm and 12 x 15 cm). The maximum width of leaves (2 cm) was Yamuna safed-3 with the 20 x 10 cm followed by the variety Yamuna safed-2 and Yamuna safed-4 with spacing of 15 x 10 cm, 10 x 10 cm. The stem diameter (10.66 cm) was maximum in Yamuna safed-4 with spacing 20 x 10 cm followed by the variety Yamuna safed-1 with spacing 20 x 10 cm. The maximum (3.10 cm) length of cloves was Yamuna safed-1 with spacing 20 x 10 cm followed by variety Yamuna safed-4 with spacing 15 x 10 cm. The maximum bulb weight with stem was in Yamuna safed-3 with 20 x 10 and the minimum bulb weight in 10 x 10 cm. The maximum weight of bulb without stem (26.05 cm) was Yamuna safed-1 with 20 x 10 cm followed by Yamuna safed-1 with 10 x 10 cm. The maximum number of cloves per bulb (21.00) was in Yamuna safed-2 with 10 x 10 cm. The lowest number of cloves/ bulb (13.00) was in Yamuna safed-3 with spacing 20 x 10 cm. The maximum length of cloves in Yamuna safed-2 (3.80 cm) with 20 x 10 cm followed by Yamuna safed-4 (3.70 cm) with 20 x 10 cm. The lowest length of cloves (1.43 cm) was in Yamuna safed-3 (1.75 cm) with 15 x 10 cm. The lowest diameter of bulb (1.02 cm) was in Yamuna safed-1 with 15 x10 cm. The maximum neck thickness (0.41 mm) was in Yamuna safed-2 with 10 x 10 cm followed by Yamuna safed-4 (0.31 mm) with 10 x 10 cm. The maximum yield per plot (kg) as 7.22 kg was in Yamuna safed-1 with 10 x 10 cm followed by Yamuna safed-3 (6.40 kg/plot) with 15 x 10 cm. The lowest yield/ plot (2.36 kg/plot) was in Yamuna safed-4 with 15 x 10 cm. This result is in agreement with the finding of (Naruka and Dhaka 2001) that the growth and yield components (plant height, number of leaves, fresh leaf weight, maturity period, neck thickness, bulb diameter, fresh bulb weight, clove weight

Table 1. Effect of varieties on growth and yield of garlic

Variety	Plant height (cm)	Number of leaves	Length of leaves (cm)	Width of leaves (cm)	Weight of bulb with stem (g)	Weight of bulb without stem (g)	Number of cloves/ bulb	Length of cloves (cm)	Diameter of bulb (cm)	Neck thickness (cm)	Diameter of stem (cm)	Yield (kg/plot)
Yamuna safed-1	46.85	10.30	43.84	1.72	35.11	26.05	16.66	2.98	1.41	0.38	8.11	5.20
Yamuna safed-2	45.81	8.91	40.47	1.50	32.44	22.80	19.88	2.67	1.39	0.39	8.98	4.87
Yamuna safed-3	47.07	10.05	41.30	1.80	42.82	24.06	16.33	2.48	1.52	0.34	8.14	4.04
Yamuna safed-4	48.74	8.83	39.81	1.50	38.44	23.72	16.77	2.97	1.28	0.34	9.50	4.24
CD (%)	1.31	0.18	1.048	0.033	1.353	0.77	0.94	0.29	0.160	0.01	1.05	0.160

Table 2. Effect of spacing on growth and yield of garlic

Spacing (cm)	Plant height (cm)	Number of leaves	Length of leaves (cm)	Width of leaves (cm)	Weight of bulb with stem (g)	Weight of bulb without stem (g)	Number of cloves per bulb	Length of cloves (cm)	Diameter of bulbs (cm)	Diameter of bulbs (cm)	Neck thickness (cm)	Yield (kg/plot)
10 x10	48.36	10.05	41.69	1.64	34.83	23.95	19.16	2.71	1.33	8.08	0.38	5.45
15 x 10	45.05	8.52	40.68	1.45	37.08	24.54	15.50	2.52	1.33	9.21	0.35	4.30
20 x 10	47.95	10.00	41.70	1.80	39.75	23.98	17.58	3.10	1.54	8.77	0.36	4.00
CD (%)	1.31	0.157	0.908	0.28	1.172	0.673	0.826	0.259	0.139	0.914	0.010	0.139

Table 3. Interaction effect of spacing and different varieties on growth and yield of garlic

Variety x Spacing	Plant height (cm)	Number of leave	Length of leaves (cm)	Width of leaves (cm)	Diameter of stem (cm)	Weight of bulb with stem (g)	Weight of bulb without stem (g)	Number of cloves per bulb	Length of cloves(cm)	Diameter of bulb(cm)	Neck thickness (cm)	Yield (kg/ plot)
Yamuna safed- 1 x 10 x`10 cm	47.53	10.43	42.23	1.76	8.10	31.00	27.00	18.00	2.96	1.42	0.37	7.22
Yamuna safed- 1 x 15 x 10 cm	45.50	8.23	44.16	1.40	9.22	36.00	23.75	14.00	2.50	1.02	0.41	5.16
Yamuna safed- 1 x 20 x 10 cm	47.53	12.23	45.13	2.00	7.03	38.33	27.40	18.00	3.49	1.80	0.38	3.20
Yamuna safed- 2 x 10 x 10 cm	48.63	8.20	43.13	1.50	8.16	29.00	21.33	20.66	1.76	1.05	0.41	6.13
Yamuna safed- 2 x 15 x 10 cm	44.93	11.23	38.13	1.30	8.46	31.33	26.14	18.00	2.46	1.85	0.36	3.30
Yamuna safed 2 x 20 x 10 cm	43.86	7.30	40.17	1.70	10.31	37.00	20.93	21.00	3.8	1.26	0.41	5.20
Yamuna safed- 3 x 10 x 10 cm	49.13	11.26	41.00	2.00	7.00	41.00	25.40	20.00	2.60	1.26	0.35	3.33
Yamuna safed- 3 x 15 x 10 cm	40.86	7.63	40.76	1.40	10.37	46.00	21.26	16.00	3.43	1.79	0.31	6.40
Yamuna safed- 3 x 20 x 10	51.23	11.26	42.13	2.00	7.06	41.66	25.53	13.00	1.43	1.03	0.36	2.40
Yamuna safed- 4 x 10 x 10 cm	48.16	10.30	40.40	1.30	9.06	38.33	22.06	18.00	3.53	1.75	0.39	5.13
Yamuna safed- 4 x 15 x10 cm	48.90	7.00	39.66	1.70	8.78	35.00	27.03	14.00	1.70	1.05	0.35	2.36
Yamuna safed- 4 x 20 x 10 cm	49.16	9.20	39.36	1.50	10.66	42.00	22.06	18.33	3.70	1.42	0.30	5.23
CD (p=0.05)	2.28	0.31	1.81	0.06	1.83	2.34	1.34	1.65	0.52	0.27	0.01	0.27

and harvest index) increased significantly with increasing level of nitrogen and row spacing of 15 cm. It gave the highest bulb yield (128 q ha^{-1}), net return (Rs.77236 q^{-1}) and benefit: cost ratio (3.06: 1.50) with 200 kg N ha^{-1} at a row spacing of 15 cm.

CONCLUSION

The spacing used in the study showed significant variation among the different treatments. Growth parameters like plant height, number of leaves per plant, leaf length, width of leaves, diameter of stem, weight of bulb without stem were significantly affected due to the different plant spacing. When the distance between plants decreased the growth and yield related parameters were increased. Generally, the closer the plant spacing the better is the performance of the garlic plant. Hence, it can be concluded from the study that the closer spacing of 10 x 10 cm produced significantly the highest plant height, leaf number, leaf length, clove diameter and individual weight of bulb with stem. Highest yield from the closest spacing is mainly due to the high plant density through the bulb size was comparatively smaller.

Received 31 May, 2020; Accepted 31 July, 2020

REFERENCES

Etoh T and Simon PW 2002. Diversity, fertility and seed production in garlic. In: Rabinowitch, H.D., Currah, L (Eds). *Allium Crop Science: Recent Advances* pp. 101-117.

Kotgirwar V V, Chaudhary M H, Damke M M and Jadhao B J 1997. Effect of planting method and clove size on growth, yield and quality of garlic cv. *GODAWARI. Dr. PDKV Research Journal* **21**(2): 182-184.

Kumar SKP, Bhowmik D, Chiranjib, Tiwari P and Kharel R 2010**.** *Allium sativum* and its health benefits. *Journal of Chemical and Pharmaceutical Research* **2**(1): 135-14.

Lawande KE, Pawar RD, Supe VS and Kale PN 1993. Effect of spacing and different levels of npk on yield of garlic var. *Godavari. Maharashtra Journal Horti* **7**(2): 61-64.

Farooqui MA, Naruka IS, Rathore SS, Singh PP and Shaktawa RPS 2009. Effect of nitrogen and sulphur on growth and yield of garlic (*Allium sativum* L.). *Asian Journal Food Agro-Industry., Special Issue* S18-23.

Memane PG, Tomar RS, Kakade DK, Kulkarni GU and Chovatia RS 2008. Effect of clove weight and plant growth regulators on growth and yield of garlic (*Allium sativum Linn*) cv. GG 3. *The Asian Journal of Horticulture* **3**(1): 82-86.

Nakura IS and Dhaka RS 2001Effect of row spacing and nitrogen fertilization on growth, yield and composition of bulb in garlic (*Allium sativum* L.) cultivars. *Journal of Spices and Aromatic Crops* **10**(2) : 111-117.

Singh JV, Kumar A and Sirohi HS 1995. Effect of spacing on the growth and yield of garlic. *Indian Journal of Agriculture Research* **29**: 153-156.

Indian Journal of Ecology (2020) 47(3): 866-868

Manuscript Number: 3098
NAAS Rating: 4.96

Assessment of Yield and Nutrient Uptake of Wheat in Agri-Silvi-Horticulture System under Semi-Arid Region of Haryana

Sonia Devi, K.K. Bhardwaj[1], Garima Dahiya[1] and Manoj Kumar Sharma[1]

Division of Agricultural Physics, IARI, New Delhi-110 012, India
[1]Department of Soil Science, CCS HAU, Hisar-125 004, India
E-mail: soniaverma230894@gmail.com

Abstract: The study was conducted to work out the effect of agri-silvi-horticulture system on yield and nutrient uptake of wheat. Study was conducted on an already established seven year old agri-horticultural (Kinnow + wheat), agri-silvi-horticultural (Kinnow+ *Eucalyptus*+ wheat) systems and control (wheat only). Significantly higher grain and straw yield of wheat was recorded in case of agri-horticultural system as compared to agri-silvi-horticultural system. Significant increase in straw and grain yield of wheat was 21.0 and 29.1%, respectively under Kinnow + wheat over Kinnow + *Eucalyptus* + wheat based agri-silvi-horticulture system. The grain yield of wheat in association with Kinnow alone and Kinnow + *Eucalyptus* was reduced by 67.3 and 58.8%, respectively over sole cropping system. However, nutrient content of wheat grain and straw was not affected by different tree based systems. Concentration of N in wheat grain was highest followed by K and P, whereas the concentration of K was highest in wheat straw followed by N and P in all treatments. Different treatment depicted significant effect on nutrient uptake by wheat. The N, P and K uptake by wheat grain under sole wheat was significantly higher followed by Kinnow + wheat and lowest was found under Kinnow + *Eucalyptus* + wheat. Potassium uptake was also significantly highest under sole wheat, but potassium uptake under Kinnow + wheat and Kinnow + *Eucalyptus* + wheat was statistically similar. Similar pattern was observed for straw and total nutrient uptake by wheat in different system.

Keywords: Agri-silvi-horticulture, *Eucalyptus,* Kinnow, Nutrient uptake, Wheat, Yield

Increasing demographic pressure has created problem to Indian agriculture and it seems to be challenge to feed the population. This problem can be addressed by adopting different agroforestry models. Agroforestry systems improve degraded land as well as productivity of the site (Kumar et al 2018). The results of different research has indicated that trees like *Eucalyptus* has high level of micronutrients and that results in addition to soil fertility and nutrient content, this has been found to have impacts on topsoil retention and soil erosion reduction (Palma et al 2007). Soil available nutrient particularly N and P are severely deficient in semi-arid region of Haryana and are the two main nutrients that limit crop growth. Furthermore, their requirement is increased due to trees and crops. The trees in an agroforestry system will thus perhaps influencethe performance of intercropped crops. (Chauhan and Ritu 2005, Kaushik et al 2017) observed higher N, P and K content at surface soil than sub-surface under agri-silvi-horticulture system as compared to sole cropping system. The tree roots can often lower the soil nutrient availability of the associated crop species through competition for nutrients. These competitive interactions for resources such as water and N decrease the ability for nutrient uptake by the crops.

Wheat is an important cereal crop of the world and is one of the staple food crop for more than one third of the world population hence, plays a vital role in the development of civilization (Kalhoro et al 2016). In India, it is widely intercropped cereal crop during rabi season with *Eucalyptus* and other fast growing short rotation tree species like poplar in Haryana, Punjab, Uttarakhand, U.P, Bihar, *etc.* (Sarvade et al 2014). In semi-arid region of Haryana, the soils are poor in fertility and on these soils, *Eucalyptus* and kinnow can be planted with different cropping sequence. Thus, agri-silvi-horticulture system has emerged as a prerequisite option for crop diversification in north-west India by enhancing productivity, net profitability and mitigating climate change (Chaudhari et al 2014). But, *Eucalyptus* and kinnow reduce the yield and nutrient uptake of intercrop due to their shading effect and competition for moisture, space and nutrients. Under such conditions, it becomes very important to work out the effect of trees on nutrient uptake by intercropped crops.This study was therefore designed to investigate the effect of agri-silvi-horticulture system on yield and nutrient uptake by wheat.

MATERIAL AND METHODS

The study was conducted during 2017-18 at Chaudhary Charan Singh Haryana Agricultural University, Hisar. The experimental site is located at 29º 09' N latitude and 75º 43' E longitude at an elevation of 215 meters above mean sea level which comes under semi-arid region of North-west India. The average annual rainfall is 350-400 mm and climate is sub-

tropical. An already established seven year old agri-horticultural (Kinnow + wheat) and agri-silvi-horticultural (Kinnow + *Eucalyptus* + wheat) systems was used for conducting this study. Under agri-silvi-horticulture system, plants of clonal *Eucalyptus* (HC-2045) were planted at a spacing of 6×6 m and in-between two *Eucalyptus* plants, one kinnow plant (virus free) was established during September, 2011. In agri-horticultural system, kinnow plants were planted at the spacing of 6x6 m at same time. Wheat crop was taken in association with Kinnow and *Eucalyptus* trees. In the adjacent field wheat crop was grown and considered as control or sole crop. In this experiment the recommended dose of fertilizer was applied. The crop was harvested at maturity and grain and straw yield were determined by recording the weight of net harvested area of wheat in each plot. Nutrient analysis in grain and straw was carried out by taking five plants from each treatment at harvest and then oven dried at 60-65°C to a constant weight. Nitrogen content in grain and straw samples was determined by Macro Kjeldahl method, phosphorous content was determined by Colorimetric method (Jackson 1973) and potassium content was determined by Flame photometer method (Toth and Prince 1949). The uptake of these nutrients was estimated from concentration of nutrients and yield of crop. Randomized Block Design (RBD) having four replications and three treatments *i.e.* Kinnow + Eucalyptus + wheat, Kinnow + wheat and control (devoid of trees) were used to carry out this experiment.

RESULTS AND DISCUSSION

Nutrient content in wheat: Nutrient content in grain as well as straw was found not affected by the different systems *i.e.* agri-silvi-horticulture and agri-horticulture. N, P and K content (%) in wheat grain varied from 1.72, 0.42 and 0.17 to 1.76, 0.46 and 0.22, respectively (Table 1). Similarly N, P and K content (%) in wheat straw varied from, 0.48, 0.16 and 1.16 to 0.52, 0.18 and 1.23, respectively. (Parihar and Tiwari 2003) observed that the concentrations of N and P in different wheat varieties were higher in grain than the straw whereas the concentration of K was higher in straw than their grains.

Nutrient uptake by wheat: Nutrient uptake by wheat grain and wheat straw have significant effect of different systems *i.e.* agri-silvi-horticulture and agri-horticulture system (Table 1). N, P and K uptake by wheat grain under control (N: 80.1 kg/ha and P: 19.1 kg/ha) was significantly highest followed by Kinnow + wheat and lowest was found under Kinnow + *Eucalyptus* + wheat. Potassium uptake was also significantly highest under control (K: 10.0 kg/ha), but potassium uptake under Kinnow + wheat (K: 3.2 kg/ha), and Kinnow + *Eucalyptus* + wheat (K: 2.7 kg/ha), was statistically at par. Similar pattern was observed in nutrient uptake of wheat straw with significantly highest uptake under control (N: 28.3 kg/ha, P: 9.8 kg/ha and K: 66.9 kg/ha) followed by Kinnow + wheat and lowest was found under Kinnow + *Eucalyptus* + wheat. It was also noticed that nitrogen and phosphorus uptake was higher in wheat grain but potassium uptake was higher in straw.

Total uptake of N, P and K by wheat showed the respective sequence under different systems: control > Kinnow + wheat > Kinnow + *Eucalyptus* + wheat. There was reduced uptake of nitrogen by 67.5%, phosphorus by 66.0% and potassium by 68.2% under Kinnow + *Eucalyptus* + wheat by the wheat crop over control. Similarly, reduced uptake of nitrogen by 55.1%, phosphorus by 56.0% and potassium by 68.2% was recorded under Kinnow + wheat system over control (Table 2). Among nutrients, highest uptake by wheat was for nitrogen followed by potassium and lowest uptake of phosphorus by wheat.

Yadav et al (2005) also reported lower uptake of N, P and K by wheat grain and straw under different tree species as compared to wheat in open condition. (Sharma et al 2012) reported minimum concentration of N, P and K as well as their uptake in wheat plants decreased near the tree line and these increased subsequently with increase in distance from tree line. These results also suggest that competition for below and above ground resources often changes with the increase in tree age.

Grain and straw yield: Significantly higher grain and straw yield of wheat was observed in agri-horti (Kinnow + wheat) system as compared to agri-silvi-horticulture (Kinnow +

Table 1. Nutrient content and uptake in wheat under different agri-silvi-horticultural system

System	Nutrient content grain (%)			Nutrient content straw (%)			Nutrient uptake (kg ha^{-1}) in grain			Nutrient uptake (kg ha^{-1}) in straw		
	N	P	K	N	P	K	N	P	K	N	P	K
Control (wheat)	1.73	0.42	0.22	0.52	0.18	1.23	80.1	19.1	10	28.3	9.8	66.9
Kinnow + wheat	1.72	0.45	0.17	0.48	0.16	1.19	32.3	8.5	3.2	12.6	4.2	31.3
Kinnow + *Eucalyptus* + wheat	1.76	0.46	0.18	0.5	0.16	1.16	25.8	6.9	2.7	9.4	3	21.7
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	3.5	0.8	0.5	1.2	0.4	2.8

Table 2. Total uptake by wheat under agri-silvi-horticultural system

System	Total nutrient uptake (kg ha^{-1})		
	N	P	K
Wheat	108.4	28.9	76.9
Kinnow + wheat	45.0	12.7	34.5
Kinnow + *Eucalyptus* + wheat	35.1	9.8	24.4
LSD (p=0.05)	4.6	1.2	3.2

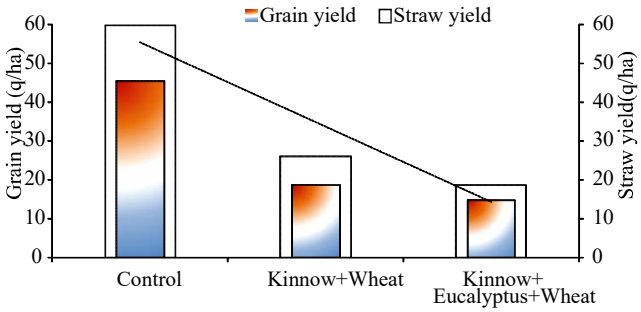


Fig. 1. Grain and straw yield of wheat influenced by agrisilvihorticultural system

Eucalyptus + wheat) system. An increase of 21.0 and 29.1 per cent in straw and grain yield, respectively of wheat was recorded under Kinnow + wheat system as compared to Kinnow + *Eucalyptus* + wheat based agroforestry system (Fig. 1). However, the grain yield of wheat in association with Kinnow and Kinnow + *Eucalyptus* was found less as compared to control (sole wheat). However, grain yield of wheat under agri-silvi-horticulture and agri-horticulture system reduced up to 67.3 and 58.8 per cent, respectively over control (sole wheat without trees). This reduction in yield was due to competition between tree components and crop for moisture, space and nutrients, *etc*. The increased water use of the tree based system causes moisture stress to the crop. Apart from nutrient and moisture, light is a major limiting factor for crop growth and yield under tree species. Being an evergreen tree species, *Eucalyptus* particularly reduces light availability and decreased crop yield. Corroborative results were reported by (Kaushik and Singh 2001, Tripathi et al 2006). Trees grown in an agroforestry system compete with agricultural crops for resources and result in reduction in crop yield. (Dhillon et al 2018) reported that biomass and yield of both the crop was significantly affected due to trees. The magnitude of crop yield losses in agroforestry systems increased with age of the trees. Sharma et al (2000) also reported that close spacing increased amount of leaf litter, which inhibited the crop growth.

CONCLUSION

Reduction in yield of crop component in agroforestry systems was due to immense competition between tree and crop component for light, water, space and nutrients. Shading effect of tree component as well its established stronger root system is a major reason for reduced nutrient uptake and productivity of the sole crop. However, wood yield, fruit yield and fuel from tree components will compensate for yield reduction of crop component and will result in higher production efficiency under tree based system in comparison to sole cropping system.

Received 17 June, 2020; Accepted 12 August, 2020

REFERENCES

Chaudhari SK, Kumar P, Singh K, Mishra AK, Rai P, Singh R and Sharma DK 2014. Aggregate fractions and organic carbon dynamics in partially reclaimed sodic soils growing *Eucalyptus tereticornis*. *Journal of Soil Salinity and Water Quality* **6**: 96-100.

Chauhan SK and Ritu 2005. Towards agro-ecological health: diversifying traditional crop rotation through agroforestry in Punjab, India. *Asia-Pacific Agroforestry News* **27**: 3-4,6.

Dhillon RS, Chavan SB, Bangarwa KS, Bharadwaj KK, Kumari S and Sirohi C 2018. *Eucalyptus*-based agroforestry System under semi-arid condition in North-Western India: An economic analysis. *Indian Journal of Ecology* **45**(3): 470-474.

Jackson ML 1973. *Soil chemical analysis*, Prentice Hall of India, Pvt. Ltd., New Delhi, 498p.

Kalhoro NA, Rajpar I, Kalhoro SA, Ali A, Raza S, Ahmed M, Kalhoro FA, Ramzan M and Wahid F 2016. Effect of salts stress on the growth and yield of wheat (*Triticum aestivum* L.) *American Journal of Plant Sciences* **7**: 2257-2271.

Kaushik N and Singh J 2001. Performance of pearl millet-wheat in Poplar based agri-silvicultural system in sandy soils of Southern Haryana. *Indian Journal of Agroforestry* **3**: 51-54.

Kaushik N, Tikkoo A, Yadav PK, Deswal RPS and Singh S 2017. Agri-silvi-horti systems for semiarid regions of North-West India. *Agricultural Research* **6**: 150-158.

Kumar P, Mishra AK, Chaudhari SK, Basak N, Rai P, Singh K and Sharma DK 2018. Carbon pools and nutrient dynamics under *Eucalyptus*-based agroforestry system in semi-arid region of North-west India. *Journal of the Indian Society of Soil Science* **66**: 188-199.

Palma J, Graves A, Burges P, Van Der Werf W and Herzog F 2007. Integrating environmental and economic performance to assess modern silvo-arable agroforestry in Europe. *Ecological Economics* **63**: 759-767.

Parihar SS and Tiwari RB 2003. Effect of irrigation and nitrogen level on yield, nutrient uptake and water use of late-sown wheat (*Triticum aestivum)*. *Indian Journal of Agronomy* **48**: 103-107.

Sarvade S, Mishra HS, Kaushal R, Chaturvedi S, Tewari S and Jadhav TA 2014. Performance of wheat (*Triticum aestivum* L.) crop under different spacings of trees and fertility levels. *African Journal of Agricultural Research* **9**: 866-873.

Sharma NK, Singh HP and Dadhwal KS 2000. Effect of poplar (*Populus deltoides*) on wheat growth at an early stage. *Indian Journal of Soil Conservation* **28**: 221-225.

Sharma NK, Singh RJ and Kumar K 2012. Dry matter accumulation and nutrient uptake by wheat (*Triticum aestivum* L.) under Poplar (*Populus deltoides*) based agroforestry system. ISRN Agronomy. doi:10.5402/2012/359673

Toth SJ and Prince AL 1949. Estimation of cation-exchange capacity and exchangeable Ca, K, and Na contents of soils by flame photometer techniques. *Soil Science* **67**(6): 439-446.

Tripathi MK, Saini BC and Chaturvedi S 2006. Growth and yield of intercropped wheat under Salix-Dalbergia agroforestry system. *Annals of Biology* **22**(2): 189.

Yadav RS, Yadav BL, Chhipa BR, and Keshwa G L 2005. Nutrient removal and yield of wheat (*Triticum aestivum Linn*.) as influenced by different tree species in agroforestry under semi-arid condition of Rajasthan. *Indian Journal of Agroforestry* **7**(1): 21-24.

Indian Journal of Ecology (2020) 47(3): 869-871

Manuscript Number: 3099
NAAS Rating: 4.96

Diversity and Distribution of Odonates in Alagar Hills of Southern India

T. Sivaruban, S. Barathy[1], Pandiarajan Srinivasan and Rajasekaran Isack

Department of Zoology, The American College (Autonomous), Madurai-625 002, India
[1]Department of Zoology, Fatima college, Madurai-625 018, India.
E-mail: sivaruban270@gmail.com

Abstract: Order odonata includes important aquatic insect groups such as dragonflies and damselflies. They help to assess the ecosystem health and serves as pollution indicators. Studies of Odonata were conducted in Alagar hills of South India state of Tamilnadu from August 2018 to January 2019. Odonate species abundance was high in October to November (7 to 8 species) and their abundance was low in the January and December (6 species.) Among all months, the abundance of libellulid species was comparatively high. Shannon index values were between 1.6094-1.9792 and it shows that these sites had critical position and they might have sensitive habitat status. The results of Simpson index complement with the results of Shannon index. Higher air and water temperature was in August and causes less diversity of organisms. DO was low in January (1.65) and it directly influences the abundance. This study interpreted that diversity of Odonates was directly and indirectly influenced by climatic change and anthropogenic impacts.

Keywords: Temperature, Diversity, Shannon index, Simpson index, DO

Dragonflies and damselflies are among the most attractive creatures on earth and occur in all types of freshwater and nearby habitats (Springate-Baginski et al 2009) from the largest lakes and rivers to tiny wetlands. Globally 5,952 species of odonates are known and out-off these 474 species in 142 genera and 18 families have been recorded in India (Subramanian and Balu 2014). The Western Ghats are known to support a number of species of Odonata: 176 species have been recorded from the Western Ghats, including 68 species endemic to the region. Odonate larvae occupy a variety of running and standing freshwater environments such as rivers, lakes, ponds, wetlands and, to a lesser extent, phytotelma, brackish waters and rithral areas of river. Vegetation provides adults with perching structures for thermoregulation, foraging, territory defense, mate attraction, copulation, nocturnal roosting and protection from adverse weather (Rouquette and Thompson 2007). The life history of odonates is closely linked with water bodies as they use a wide range of flowing and stagnant water bodies. Even though most species of odonates are highly specific to a habitat, some have adapted to urban areas and make use of man-made water bodies. Habitat specificity has an important bearing on the distribution and ecology of odonates. The species of hill streams tend to be narrowly distributed when compared to pool breeders, which are wide spread. Diversity of tropical odonates is partly explained by the high diversity of aquatic habitats in tropical forests (Orr 2006), especially in montane areas (Oppel 2005). The insect order Odonata is divided into three suborders-damselflies (Zygoptera), dragonflies (Anisoptera), and primitive dragonflies (Anisozygoptera) (Mitra 2006). Recent studies on dragonfly ecology from Western Ghats indicate families like Bamboo tails, Reed tails, Glories, Torrent darts, Torrent Hawks and Club tails will be good indicators of health of riverine ecosystem.

MATERIAL AND METHODS

Study area: Collection of Odonata were conducted in Alagar hills of South India state of Tamil Nadu from August 2018 to January 2019.The reserve forest of Alagar hills is 20km north east of city and elevation reaches 830mts.The hill area occupies 6813hectares. The sampling area were divided into three stations which were site 1 (77°50E and 10°05N), site 2 (77°90E and 10°08N), site 3 (78°20E and 10°10N). Three sites differ from one another by their forest vegetation and altitude. The sampling sites were selected based on the presence of microhabitats preferred by the odonata and also specific hydrological characteristics such as current velocity and light intensity.

Sampling and collection of Odonates: The study was conducted twice at monthly interval during morning and evening in all habitats with the help of specially design sweep net.

Water samples collection: Water samples were collected in the three sites and water temperature, air temperature and dissolved oxygen were analyzed using APHA manual (APHA, 2005).

Identification of Odonates: Odonates were observed, captured, identified and released immediately at the spot of capture. The odonates which were difficult to identify in the field were collected as voucher specimens using a hand net. Identification was done by observing wing venation, color pattern, and genitalia described in standard taxonomic literature and field guide (Subramanian and Balu 2017).

Data analysis: This was done with the help of the PAST software to measure the Shannon, Simpson and Brillouin's indices (Hammer et al 2001).

RESULTS AND DISCUSSION

Adults were collected using line transact method resulted in the 87 odonate individuals of 8 species belonging to 2 families, of which 80 anisopterans (7 species, 1 family) and 7 zygopterans (one species and family each) were recorded (Table 3). Libellulidae (sub order anisoptera) was the major component of Odonates community in Alagar hills.

Biotic components: The percent of biotic components includes *Orthetrum sabina* (24), *Tramea limbata* (18), *Trithemis aurora* (16), *Diplacodes trivialis* (13), *Tramea lacerate* (8), *Orthetrum glaucum* (8), *Copera marginipes* (7) and *Brachythemis contaminate* (6) (Table 3).

From the study it was seen that the abundance was high during October to November (7-8 species) and was low in the January and December (6 species.) Among all months, the abundance of family libellulidiae was comparatively high. The distribution and abundance of zygopteran species were most affected by reeds. However, anisopteran species were most affected by shade. The findings here in suggest that open tracts of land, which only had few shady trees, are preferred only by zygopteran species of which 1 species were recorded therein, whereas they were not found in ponds or rivers. In this study Shannon index values were between 1.6094-1.9792 (Table 2) and it shows that these sites had critical position and they might have sensitive habitat status more especially in August and January, due to anthropogenic disturbances and climatic change which makes the pond water scarce of water and causes less diverse organisms. The Shannon index values are normally between 0.0-5.0 and results are generally 1.5-3.5 and it exceeds 4.5 very rarely (Kocatas 1992). The values above 3.0 indicate that the structure of habitat is stable/or balanced. The values under 1.5 indicate that ecosystem balance is broken or there is degradation in habitat structure. During the pre-monsoon period due to lack of rainfall the organisms were tough to survive without much stagnant water. Simpson index values are between 0.8444-0.9272 and the results are complements with the results of Shannon Index. The Brillouin's index value was highest in October 2018 (1.7524) and it was lowest in August 2018 (1.5047) because this index is strictly applicable only to entire populations rather than to finite samples (Table 2). The Brillouin Index also supports the Shannon and Simpson Indices. Water temperature directly affects both the nature of aquatic fauna and species diversity. It also affects organisms indirectly as a consequence of oxygen saturation levels. In the present investigation, the air and water temperature was recorded between 30-37˚C and 20-26˚C. Higher air and water temperature in August cause less diversity of organisms. The normal DO levels in the running

Table 1. Physico-chemical parameters of 3 sites in Alagar hills

Parameters		August	September	October	November	December	January
Air temperature (°C)	Site 1	37	37	36	34	32	34
	Site 2	35	35	35	32	30	33
	Site 3	35	35	35	32	30	33
Water temperature (˚C)	Site 1	26	26	24	25	22	23
	Site 2	25	23	23	20	20	22
	Site 3	25	23	23	20	20	22
DO (mg/l)	Site 1	2.06	2.47	2.06	2.06	1.65	1.65
	Site 2	2.06	2.47	2.06	1.65	2.06	1.65
	Site 3	2.47	2.47	2.06	1.65	2.06	1.65

Table 2. Diversity indices of Alagar hills

Indices	August	September	October	November	December	January
Brillouin	1.5047	1.6854	1.7524	1.6656	1.5911	1.5104
Simpson	0.8538	0.8750	0.8888	0.9242	0.9272	0.8444
Shannon	1.7041	1.8239	1.8790	1.9792	1.8938	1.6094

Table 3. Taxonomic inventory of odonates in different months

Species	August	September	October	November	December	January	Species percentage (%)
Family Libellulidae- Group Anisoptera							
Orthetrum Sabina	4	4	4	3	2	4	24%
Diplacodes trivialis	4	3	2	1	1	0	13%
Brachythemis contaminata	1	1	0	1	1	2	6%
Trithemis aurora	4	2	3	1	2	1	16%
Tramea limbata	4	4	3	2	2	1	18%
Tramea lacerate	2	2	1	1	2	1	8%
Orthetrum glaucum	0	0	3	1	0	0	8%
Family Coenagrionidae - Group Zygoptera							
Copera marginipes	0	1	2	2	1	1	7%

water are 4.6 to 8.6 mg/l. In the present study the DO was low in January (1.65) (Table 1). DO plays a vital role in aquatic insect's life cycle. The lowest DO which might cause by contamination from community waste water, anthropogenic impacts and due to lack of rainfall and it directly influences the abundance of aquatic insects.

CONCLUSIONS

The results of this study give more knowledge about the diversity and distribution of Odonata in Alagar hills. From the results it reveals that Alagar hills supports family Libellulidae of Anisoptera compare to Coenagrionidae of Zygoptera and it indicates that more organic pollution were present because Libellulidae is more tolerant to pollution than Coenagrionidae. The main reason for the pollution is the regular visit by the pilgrims to the temple. In comparison with Western Ghats, low number of diversity works was done in Eastern Ghats and we lack knowledge about the diversity of odonates in that area and the anthropogenic impacts over the odonates. Hence this work suggests the taxonomists to pay more attention for the conservation of aquatic and terrestrial habitats in Eastern Ghats. Then only the most attractive creatures of the sites can be conserved and protected.

Received 16 July, 2020; Accepted 19 August, 2020

REFERENCES

APHA (American Public Health Association) 2005. *Standard methods for the examination of water and wastewater*. 21st Edition, Washington D.C.

Hammer O, Harper DAT and Ryan PD 2001. PAST(Paleontological Statistics software package for education and data analysis). *Palaeontologia Electronica* **4**(1): 9.

Kocataş A 1992. *Ekoloji ve Çevre Biyolojisi*, Ege Üniv, Matbaası, İzmir, 564pp.

Mitra A 2006. Current status of the Odonata of Bhutan: A checklist with four new records. *Bhutan Journal of Renewable Natural Resources* **2.1**: 136-143.

Oppel S 2005. Habitat associations of an Odonata community in a lower montane rainforest in Papua New Guinea. *International Journal of Odonatology* **8**(2): 243-257.

Orr AG 2006. *Odonata in Bornean tropical rain forest formations: diversity, endemicity and implications for conservation management,* Forest and Dragonflies, Pensoft Publishers, Sofia.

Rouquette JR and Thompson DJ 2007. Patterns of movement and dispersal in an endangered damselfly and the consequences for its management. *Journal of Applied Ecology* **44**(3): 692-701.

Springate-Baginski O, Allen D and Darwall WRT 2009. *An Integrated Wetland Assessment Toolkit: A guide to good practice.* Gland, Switzerland: IUCN and Cambridge. UK: IUCN Species Programme, 144 pp.

Subramanian KA and Babu R 2014. A *checklist of Odonata (Insecta) of India*, Zoological survey of India, Kolkata, WB.

Indian Journal of Ecology (2020) 47(3): 872-874

Manuscript Number: 3100
NAAS Rating: 4.96

Effect of Storage Media and Time on Germination, Vegetative Growth and Survival in Mango (*Mangifera indica* L.)

Anishabahen Manojbhai Gangode, Tanzin Ladon[1*], Ankita Aman[2] and Priyanka Chauhan[1]

Department of Fruit Science, ASPEE College of Horticulture and Forestry
Navsari Agricultural University, Navsari-396 450, India
[1]Department of Fruit Science, College of Horticulture
Dr. YS Parmar University of Horticulture and Forestry, Nauni-173 230, India
[2]Department of Horticulture (Fruit & Fruit Technology)
Bihar Agriculture University, Sabour Bhagalpur, Bihar-813 210 India
**E-mail: tanzinldn92@gmail.com*

Abstract: The seeds were stored in four different storage media (ash, cocopeat, saw dust and gunny cloth) at four different storage time (20, 40, 60 and 80-days) to study the germination and growth. The stones stored in gunny cloth with 20-days storage time recorded significantly higher percentage of seed germination, plant height, stem girth, number of leaves, leaf area, vigour index, fresh weight, dry weight, root length and survival percentage, followed by ash. The stones stored in gunny cloth with 20-daysstorage time, followed by ash found best for vegetative growth of the seedling. However, stones stored in moist ash with 80-days storage time also had acceptable viability with some decrease in vigour of seedlings.

Keywords: Germination, Gunny cloth, Vigour index and Survival percentage

In India storage of mango seed is very serious problem and mango stones are available for only 30-40 days of mango season during which a very small quantity of stones were utilized to raise rootstocks, whereas a major portion will become unusable as seed, due to its short storage period, big size, difficulties in handling and loss of viability due to various reasons. It is of great importance to store mango stones for extended sowing and preparation of rootstocks over a wide period, which then facilitates grafting of mango during major part of the year because raising of mango rootstocks for grafting is a very big concern to increase the quality planting material and maintaining the germplasm. India is the largest producer and consumer of mango with 21.82 million tons of production on an area of 2.258 million hectare with the productivity of 9.66 t ha^{-1} (Anonymous 2018). It is grown in almost all the states of India. In Gujarat, mango is a major commercial crop with the production of mango is 1.207 million tons on an area of 162770 hectare and the productivity is 7.42 t ha^{-1} (Anonymous 2018). Mango (*Mangifera indica* L.) is one of the main fruit crop in tropical and subtropical regions. Mango seed stone are classified as recalcitrant and freshly extracted mango seeds have the viability of almost 100 percent and delay in the duration between extraction and sowing of seeds results in reduction of germination percentage. In general, mango seeds can only remain viable up to 10-20 days after extraction from fruits under natural condition but, if kept under sun they loss viability within 3-7 days. The fresh seeds can remain viable for four to five weeks under moist storage conditions. It is very useful to generate scientific information regarding storage of mango stones in different media for different duration to evaluate their effects on viability of stones and growth of the seedlings after storage. Therefore, this experiment has been proposed to evaluate the use of locally available storage materials for increasing the storage life of mango stones while, maintaining the viability at acceptable level.

MATERIAL AND METHODS

The present investigation was undertaken in polycarbonate house at ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari during June to November, 2016. The stones were obtained from fully ripe “Kesar” mango fruits during June, 2016, and washed with water to remove the adhered pulp and then soaked in solution containing carbendezim @ 1.0 g/ liter for 10 minutes. The treated stones were dried in shade for 2-3 hours and then kept in polystyrene box containing different media as per the different treatments. The observations on germination of mango stones, growth and survival of seedlings were recorded. The moisture content of media was initially kept at about 55-60 per cent. The stones were arranged vertically with stalk end up position in polystyrene box and covered with different media. The stalk end tips of stones were kept uncovered to detect the germination. The

mango stones were sown in polyethylene bags [14x18cm size containing soil: sand (4:1) media mixture] at different intervals as per the different storage duration treatments. In all there were 16 treatment combinations of storage media and storage time each having 4 storage media (ash, cocopeat, saw dust and gunny cloth) and 4 storage time (20, 40, 60 and 80-days) replicated thrice in completely randomized design (factorial).

RESULTS AND DISCUSSION

The different storage media and time exert a significant effect on days required for germination and germination percentage (Table 1). The stones stored in gunny cloth recorded lowest number of days required for germination (7.05), whereas, higher number of days was in ash. The stones stored for 20-days resulted in lowest number of days required for germination (7.43). The interaction between storage media and time exerted a significant effect on days required for germination. The mango stones stored in gunny cloth for 20-daysresulted in lowest number of days required for germination (5.59). This might be due to higher moisture holding capacity of gunny cloth, which created micro-climate resulting in highly favourable for the initiation of the processes of germination during the storage and resulted in early resumption of growth of embryo. Significantly higher number of days for germination in ash media might be due to binding of moisture in ash particles, which is less readily available. As the available moisture is less in surrounding, the stones will be temporarily in a state of resting and the germination processes actually starts after sowing which increased the number of days required for germination. The stones stored for 20-days are having maximum initial moisture content and thereby metabolically very active as compared to the stones stored for longer durations. The highest germination percentage (92.35%) was recorded with gunny cloth, whereas saw dust recorded the lowest germination percentage. Mango stones stored for 20-daysrecorded significantly, the highest germination percentage (90.26%), however the lowest was in stones stored up to 80-days. This might be due to the fact that recalcitrant seeds cannot be stored for longer period even at high moisture content and tend to show short longevity as they are highly susceptible to desiccation injury. The loss of viability could be either due to the moisture content falling below a certain value or simply a general physiological deterioration with time (Umarani et al 2015). The highest germination percentage of 98.67 per cent was in stones stored in gunny cloth along with 20-days storage time. It is obvious that the mango stones stored for 20-days with moisture conserved could have maintained its physical and physiological state and expressed as higher germination percentage. Results are in accordance with the Mahasin and Mustafa (2015), who recorded fewer days to germinate and higher germination percentage in mango stones when stored for 2-weeks than 4 and 8-weeks storage time. Similarly, Kaur and Kaur (2019) and Deepika et al (2016) reported the highest germination percentage when seeds were sown immediately after extraction from fruits in karonda.

In the present study storage media and time exhibited a great effect on seedling height, vigour index, number of leaves, leaf area, stem girth, root length, fresh weight, dry weight and survival percentage (Table 2, 3 and Figure 1). The stones stored in gunny cloth recorded significantly, maximum seedling height, vigour index, number of leaves, leaf area, stem girth, root length, fresh weight, dry weight and survival percentage followed by ash. The maximum seedling height,

Table 1. Effect of storage media and time on days required for germination, and seedling growth

Time media	Days required for germination (Germination percentage in parentheses)				Mean	Seedling height, cm (Vigour index, % in parentheses)				Mean
	20 day	40 day	60 day	80 day		20 day	40 day	60 day	80 day	
Ash	8.83 (94.16)	8.49 (91.11)	9.07 (88.67)	8.81 (77.11)	8.79 (87.76)	54.05 (50.92)	53.67 (48.89)	45.67 (40.50)	42.67 (32.89)	49.01 (43.30)
Cocopeat	7.25 (89.00)	7.57 (85.44)	8.14 (77.11)	7.92 (68.33)	7.72 (79.97)	50.40 (44.86)	45.00 (38.45)	43.39 (33.46)	41.30 (28.22)	45.02 (36.25)
Saw dust	8.03 (79.22)	8.39 (73.44)	8.32 (71.44)	8.08 (68.03)	8.20 (73.03)	46.43 (36.79)	43.00 (31.58)	42.60 (30.43)	40.73 (27.71)	43.19 (31.63)
Gunny cloth	5.59 (98.67)	6.99 (94.61)	6.87 (90.67)	8.77 (85.44)	7.05 (92.35)	56.11 (55.36)	52.33 (49.50)	49.00 (44.43)	46.50 (39.75)	50.99 (47.26)
Mean	7.43 (90.26)	7.86 (86.15)	8.10 (81.97)	8.39 (74.72)		51.75 (46.98)	48.50 (42.11)	45.16 (37.20)	42.80 (32.14)	
CD (0.05)										
Media	0.62 (2.43)	1.24 (1.75)								
Time	0.62 (2.43)	1.24 (1.75)								
Media ×Time	1.23 (4.86)	2.48 (3.50)								

Table 2. Effect of storage media and time on number of leaves (leaf area)

Time media	Number of leaves (Leaf area cm^2)				Mean
	20 day	40 day	60 day	80 day	
Ash	8.85 (87.62)	7.48 (81.68)	9.38 (80.37)	8.75 (77.08)	8.62 (81.69)
Cocopeat	9.34 (86.81)	8.54 (80.75)	8.56 (74.86)	6.69 (71.41)	8.28 (78.46)
Saw dust	8.39 (77.97)	8.11 (75.38)	7.47 (72.33)	6.40 (69.91)	7.59 (73.89)
Gunny cloth	11.42 (97.11)	9.65 (96.02)	8.76 (89.77)	7.67 (89.45)	9.38 (93.08)
Mean	9.50 (87.38)	8.45 (83.46)	8.54 (79.33)	7.38 (76.96)	

CD (0.05)
Media 0.66 (6.56)
Time 0.66 (6.56)
Media ×Time 1.33 (7.70)

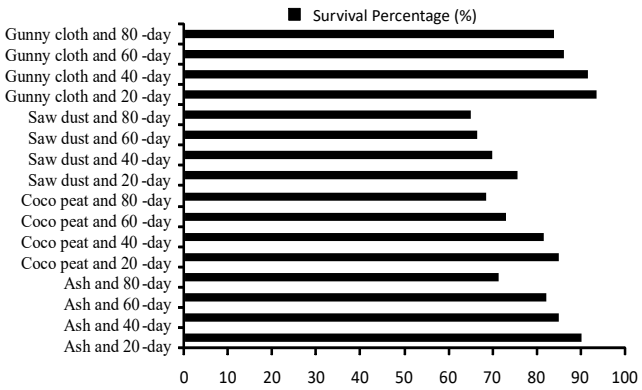


Fig. 1. Effect of storage media and time on survival percentage (%) of seedlings at 60-days after sowing of mango stones

Table 3. Effect of storage media and time on growth and biomass

Time media	Stem girth (mm)(Root length, cm in parentheses)				Mean	Seedling fresh biomass (dry biomass, gm in parentheses)				Mean
	20 day	40 day	60 day	80 day		20 day	40 day	60 day	80 day	
Ash	14.41 (31.40)	13.91 (31.33)	12.30 (29.27)	11.78 (28.47)	13.10 (30.12)	61.86 (25.37)	57.81 (23.49)	50.91 (22.71)	46.78 (20.21)	54.34 (22.95)
Cocopeat	14.19 (30.53)	13.01 (30.17)	12.03 (26.21)	11.44 (25.46)	12.67 (28.09)	55.89 (24.55)	51.96 (23.52)	45.41 (20.57)	41.07 (19.81)	48.59 (22.11)
Saw dust	13.94 (28.40)	12.34 (26.37)	12.27 (25.00)	10.58 (24.67)	12.28 (26.10)	50.18 (21.29)	46.00 (22.52)	42.27 (20.23)	40.14 (19.53)	44.65 (21.64)
Gunny cloth	15.81 (35.53)	15.10 (34.17)	14.12 (32.57)	13.31 (32.50)	14.59 (33.19)	66.33 (25.30)	64.29 (25.30)	62.49 (23.89)	60.70 (22.19)	63.45 (24.37)
Mean	14.59 (31.13)	13.59 (30.35)	12.68 (28.26)	11.77 (27.77)		58.57 (25.07)	55.01 (23.71)	50.27 (21.85)	47.18 (20.44)	

CD (0.05)
Media 0.69 (0.49) 1.40 (0.82)
Time 0.69 (0.49) 1.40 (0.82)
Media ×Time NS (0.98) 2.81 (NS)

vigour index, number of leaves, leaf area, stem girth, root length, fresh weight, dry weight and survival percentage was in 20-days storage time.

The effect of interaction between storage media and time exerted a significant effect on growth of seedling. The maximum height, vigour index, number of leaves, leaf area, stem girth, root length, fresh weight, dry weight and survival percentage was in seedlings with treatment combination of gunny cloth and 20-days storage time.

CONCLUSION

The fresh seeds recorded maximum germination, vigorous seedlings and survival percentage, which declined with the increasing storage duration. Among the storage media best results were with gunny cloth. Therefore, the storage of mango stones in gunny cloth along with 20-days storage time is recommended for commercial multiplication of mango plants in nursery.

Received 24 June, 2020; Accepted 26 August, 2020

REFERENCES

Anonymous. 2018. Indian Horticulture Database. https://www.nhb.org.

Anonymous. 2018. Indian Horticulture Database. https://www.nhb.org.

Deepika, Vanajalatha and Yadav A 2016. Effect of seed storage on seed viability, germinability and morphological characteristics of karonda (*Carissa carandas* L.) seedlings. *Asian Journal of Advanced Basic Sciences* **2**(3): 1-6.

Kaur J and Kaur A 2019. Studies on seed viability, germination and seedling vigour in karonda. *International Journal of Recent Scientific Research* **10**(6): 32742-32745.

Mahasin AD and Mustafa MAE 2015. Evaluation of storage duration, storage containers and storage temperatures on the germination of mango (*Mangifera indica* L.) seed stones.*International Journal of Agriculture Innovations and Research* **3**(5): 1329-1333.

Umarani R, Aadhavan KE and Faisal MM 2015. Understanding poor storage potential of recalcitrant seeds. *Current Science* **108**(11): 2023-2034.

Indian Journal of Ecology (2020) 47(3): 875-877

Manuscript Number: 3101
NAAS Rating: 4.96

Study on Human Wildlife Conflict in Chenab Valley of Jammu and Kashmir India

Kulbhushan Kumar and Satpal Singh Bisht

Department of Zoology, D.S.B. Campus Kumaun University, Nainital-263 002, India
E-mail: kulbhushankumar01041990@gmail.com

Abstract: Study was carried out in Chenab Valley of Jammu and Kashmir India to validate the frequency and attacks of wild animals. Wild animals attack humans and livestock which have negative impacts on people's livelihood. Human Wildlife Conflict usually occurs when wildlife requirements overlap with those of human populations creating costs to residents and wild animals. The aim of present investigation is to extrapolate the existing findings about the losses incurred by local population due to wild animals and also to emphasize on the management of wildlife. The methodology of primary data collection was based on questionnaire survey and collection of secondary data was collected from wildlife department. During present investigation high frequency of human wildlife conflicts were observed in the Chenab Valley particularly in human settlements near to forests. Conflict dynamics in number of human-black bear and human-leopard conflict cases has been observed. Hence effective conservation measures are needed in the region for the management of human wildlife conflict incidences.

Keywords: Livelihood, Conflict dynamics, Management

Human wildlife conflict is becoming one of the most important threats to the survival of many wildlife species in the Chenab Valley such as Himalayan black bear and leopard which are directly associated with the conflict (Dutta et al 2015). In addition endangered wildlife species also get harmed purposely or incidentally because of retaliatory poaching or habitat loss (Anand and Radhakrishna 2017). The cause of human wildlife conflict includes the expansion of human populations into or near to areas inhabited by wildlife and fragmentation and loss of habitat in those areas (Gotelli and Ellison 2004). Additional causes of human wildlife conflict include the designation of protected areas, where human activity is forbidden or strictly limited that the farmers attempt to protect their crops from wildlife by increasing the risks faced by potential predators (Chelliah et al 2010, Constant et al 2015). These defense strategies are designed to exploit an animal's tendency to avoid foraging in risky areas by employing stimuli that increase an animal's fear of the places where crops are planted (Hartter et al 2011). Farmers mark the borders of their fields with specific biological barriers like spiny plants and fencings to avoid the entry of wild animals in the crop field (Hill 2010, Jasmine et al 2015). Human Wildlife conflict has negative impacts on the livelihood of native population which eventually causes retaliatory killings of wild animals (Hill and Wallace 2012, Mukhrjee 2016). Therefore management and conservation of wildlife become an essential aspect in the study area. The aim of study is to demonstrate the extent of human wildlife conflict in the study area and may extrapolate the frequencies of human wildlife incidences and management of wildlife biodiversity from human threat.

MATERIAL AND METHODS

Study Area: Chenab Valley is located in Jammu and Kashmir State of northern India. Study area is situated in the Himalayan Mountains with diverse forests ecosystem and is situated at about 1631 meters from above the sea level. The Chenab Valley mainly consists of two districts Doda and Kishtwar (Fig. 1).

Dominated Wildlife of Chenab Valley: Brown Bear (*Ursus isabellinus*), leopard (*Panthera pardus*), Himalayan musk deer (*Moschus moschiferus*), hangul (*Cervus elaphus hangula*), shrew (*Capricornis sumatraenis*), Kashmiri Flying Squirrel (*Hylepated fimbriatus*), Himalayan Black Bear (*Selenaractos thibetanus*), The Red Fox (*Vulpus montana*), Jackal (*Canis aurcus*), Leopard Cat (*Felis bengalensis*), Common Langur (*Presbytis entellus*), Rhesus Macaque (*Macaca mulata*).

Data collection: The primary data was collected through field visits in the study site by questionnaire survey. 167 villages of study area were visited from last three years. The secondary data so collected from the wildlife department of Chenab warden Kishtwar Jammu and Kashmir India was validated through questionnaire and the location of conflicts was also analyzed. The most common questions asked among the respondents were: Which wild animal was involved in conflict at what location and what was the cause?

RESULTS AND DISCUSSION

The maximum number of mortality of humans was observed during the year 2015-16 and least during the year 2014-15 (Table 1). The frequency of injured cases due to

Himalayan Black Bear was more than Leopard and other animals. The maximum number of injured cases was observed during 2010-11 and least during 2016-17 (Table 2). Wild animals often come in faceoff condition to humans in agricultural farms particularly nearby to forest (Ogra and Badola 2008). As long as man and animals share common habitats, damage to life and property of humans is inevitable (Malaviya and Ramesh 2015). The extent of damage depends upon the density of the problem populations around croplands and human habitations (Sethy and Chauhan 2013). The number of injured cases was more due to Black Bear than leopard which is due to more population of Black Bear. Exceptionally the frequency of incidences due to leopard was more than Black Bear during the year 2012-13, 2014-15 and 2016-17 respectively and most of the conflicts with leopard were reported in forests (Sillero-Zubiri and Laurenson 2001). These incidences in forests reveals the carnivorous feeding behavior of leopard compared to Black Bear (Sitati et al 2003). Conflict issues are mainly related to people's expanding livelihood and settlements near the forests. As during the investigation most of the cases were reported in or near the forests. Cases in agricultural farms were also reported. In Jammu and Kashmir like other states of India, the interface between man and wildlife narrowed down as a result of human population explosion and pushed human settlements deep into the forests (Karanth et al 2012. Nair and Jayson 2016). Human-Wildlife conflict occurs due to sharing of habitat niche between wild animals and the local residents (Kumar et al 2017, Karanth et al 2013, King et al 2009). Conflicts between human and wild animals are also due to the grazing of livestock by the villagers near or in the forests. The location of incidences is randomly distributed among the agricultural farms, forests and other places (Fig. 2). The losses incurred by local communities have antagonistic and intolerant attitude towards wildlife, which can undermine and impede wildlife conservation strategies (Peterson 2005). In study area few number of retaliatory killings of wild animal's has been reported. Wildlife department provide ex-gratia as compensation to the victims of wildlife depending upon the seriousness of the case (Ahsan and Uddin 2014). During the year 2014, 2015 and 2016 maximum ex-gratia was disbursed as the number of wildlife victims was also more in number during these years (Fig. 2). As the number of human wildlife conflict incidences was more during the year 2015 and 2016 therefore maximum



Fig. 1. Study area

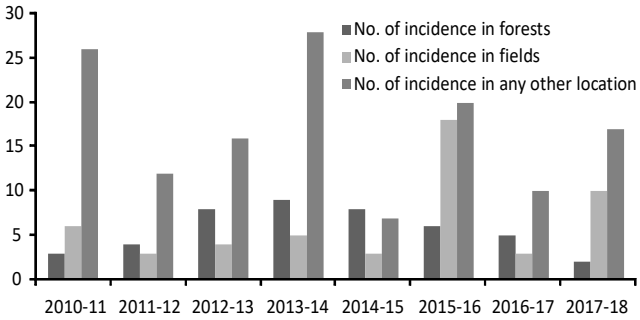


Fig. 2. Frequency of incidences

Table 1. Annual frequency of deaths due to wildlife

Year of incident	No. of cases	Bear attacked victims	Leopard attacked victims
2010-11	1	1	0
2011-12	5	3	2
2012-13	1	0	1
2013-14	2	0	2
2014-15	0	0	0
2015-16	14	9	5
2016-17	5	3	2
2017-18	3	2	1

Table 2. Annual cases of injured victims of wildlife

Year of incident	No. of cases	Bear attacked victims	Leopard attacked victims
2010-11	36	34	2
2011-12	20	18	2
2012-13	29	10	19
2013-14	43	29	14
2014-15	20	8	12
2015-16	45	29	16
2016-17	18	7	11
2017-18	30	18	12

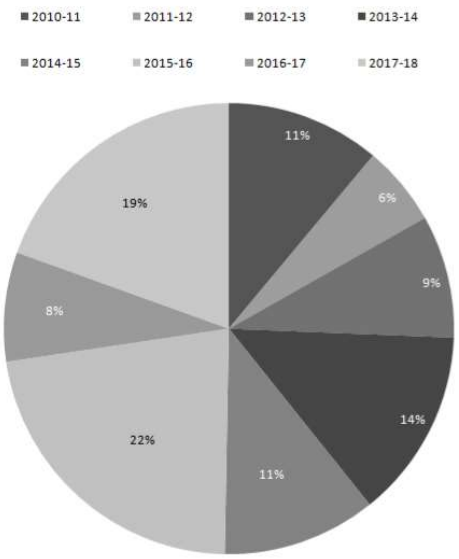


Fig. 3. Percentage of ex-gratia disbursed by wildlife department

amount of compensation was disbursed among the victims of conflicts during 2015-16.

CONCLUSION

At present minimizing man- animal conflict in the study area is big challenge for wildlife department because of increasing human settlements near the forests, sharing of niche and other resources with wild animals etc. So there is a need to accept the human wildlife conflict and people of valley need to be educated to live with the situation by awareness programmes to deal with the incidences of attack on human beings and livestock. Therefore the need of time is to check and assess the various wildlife effecting factors in order to mitigate the human wildlife conflicts.

ACKNOWLEDGMENT

The author is thankful to department of Zoology, Kumaun University Nainital Uttrakhand India for providing all the facilities and CSIR-UGC for financial assistance. The author is also thankful to department of Wildlife Warden Chenab Division Kishtwar.

REFERENCES

Anand S and Radhakrishna S 2017. Investigating trends in human-wildlife conflict is conflict escalation real or imagined. *Journal of Asia-Pacific Biodiversity* **10**: 154-161.

Ahsan MF and Uddin MM 2014. Human-rhesus monkey conflict at Rampur Village under Monohardi Upazila in Narsingdi District of Bangladesh. *Journal of Threatened Taxa* **6**(6): 5905-5908.

Chelliah K, Kannan G, Kundu S, Abilash N, Madhusudan A, Baskaran N and Sukumar R 2010. Testing the efficacy of a chilli-tobacco rope fence as a deterrent against crop raiding elephants. *Current Science* **99**: 1239-1243.

Constant NL, Bell S and Hill RA 2015. The impacts, characterisation and management of human–leopard conflict in a multi-use land system in South Africa. *Biodiversity and Conservation* **24**(12): 2967-2989.

Dutta H, Singha H, Dutta BK, Deb P and Das A 2015. Human-wildlife conflict in the forest villages of Barak Valley Assam India. *Current World Environment* **10**: 245-252.

Gotelli N and Ellison AM 2004. Patterns and correlates of human-elephant conflict around a south Indian reserve. *Biological Conservation* **148**: 88-95.

Hartter J, Goldman A and Southworth J 2011. Responses by households to resource scarcity and human-wildlife conflict: Issues of fortress conservation and the surrounding agricultural landscape. *Journal of Nature Conservation* **19**: 79-86.

Hill CM 2000. Conflict of interest between people and baboons crop raiding in Uganda. *International Journal of Primatology* **21**: 299-315.

Hill CM and Wallace GE 2012. Crop protection and conflict mitigation reducing the costs of living alongside non-human primates. *Journal of Biodiversity and Conservation* **21**: 2569-2587.

Jasmine B, Ghose D and Das SK 2015. An attitude assessment of human-elephant conflict in a critical wildlife corridor within the Terai Arc Landscape, India. *Journal of Threatened Taxa* **7**: 6843-6852.

Karanth KK, Gopalaswamy AM, DeFries R and Ballal N 2012. Assessing patterns of human-wildlife conflicts and compensation around a central Indian protected area. *PLOS ONE* **7**: 50433.

Karanth KK, Naughton-Treves N, DeFries R and Gopalaswamy A M 2013. Living with wildlife and mitigating conflicts around three Indian protected areas. *Environmental Management* **52**: 1320-1332.

King LE, Lawrence A, Douglas-Hamilton and Vollrath F 2009. Beehive fence deter crop raiding elephants. *African Journal of Ecology* **47**: 131-137.

Kumar A, Bargali HS, David A and Edgaonkar A 2017. Pattern of crop raiding by wild angulates and elephants in Ramnagar forest division, Uttrakhand. *Human Wildlife Interactions* **11**(1): 41-49.

Malaviya M and Ramesh K 2015. Human felid conflict in corridor habitats: Implications for tiger and leopard conservation in Terai Arc Landscape, India. *Human-Wildlife Interactions* **9**: 48-57.

Mukherjee N 2016. A brief appraisal of human wildlife conflict in Jalpaiguri and Alipurduar districts of West Bengal. *International Journal of Scientific and Research Publications* **6**(8): 2250-2253.

Nair RP and Jayson EA 2016. Effectiveness of beehive fences to deter crop raiding elephants in Kerala, India. *International Research Journal of Nature and Applied SCIENCES* **3**: 14-19.

Ogra M and Badola R 2008. Compensating human wildlife conflict in protected area communities ground level perspective from Uttrakhand, India. *Springer* **36**: 717-729.

Panday A, Sharma A and Bhardwaj A 2017. Analysis of human-wildlife conflict management. *Engineering Sciences International Research Journal* **5**: 2320-4338.

Sethy J and Chauhan NS 2013. Human Sun bears conflict in Mizoram, North East India: Impact and conservation management. *International Journal of Conservation Science* **3**(4): 317-328.

Sillero-Zubiri C and Laurenson MK 2001. Interactions between carnivores and local communities: Conflict or co-existence? *Conservation Biology Series-Cambridge* **22**: 282-312.

Sitati NW, Walpole MJ, Smith RJ and Leader-Williams N 2003. Predicting spatial aspects of human-elephant conflict. *Journal of Applied Ecology* **40**: 667-677.

Received 25 June, 2020; Accepted 26 August, 2020

Indian Journal of Ecology (2020) 47(3): 878-880

Manuscript Number: 3102
NAAS Rating: 4.96

Impact of Moisture Content of Different Seed Spices on Damage Caused by Cigarette Beetle, *Lasioderma serricorne* F.

N.J. Chaudhari, C.M. Muralidharan[1] and Manishkumar J. Joshi*

Department of Entomology, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, BK-385 506, India
[1]Date palm Research Station, Sardarkrushinagar Dantiwada Agricultural University, Mundra, Kachchh-370 421, India
**E-mail: mj1107006@gmail.com*

Abstract: Cigarettes beetle, *Lasioderma serricorne* F. is a serious pest of many stored goods causing major economic losses to stored goods. Effect of moisture content on the weight loss of seed spices due to *L. serricorne* has been done in laboratory. The association of initial moisture and wt. loss was highest in fenugreek (r = 0.87) and it was lowest in coriander (r = 0.67). A significant positive association between final moisture and wt. loss was observed in all seed spices and it was maximum in ajwain (r = 0.91) followed by fennel and cumin (r = 0.90), coriander and fenugreek (r = 0.88). The initial and final moisture content of the seed spices established a significantly positive correlation with weight loss due to *L. serricorne* indicating moisture plays a key role in storage.

Keywords: *Lasioderma serricorne*, Survey, Storage losses, Gujarat, Seed spices

In India, the varying climatic conditions provide ample scope for spice cultivation. Nearly all Indian States produce spices; the total area under cultivation is approximately 3.15 million hectares (IBEF 2018). The major seed spices producing states are Rajasthan, Madhya Pradesh, Gujarat, Andhra Pradesh, Tamilnadu, Karnataka, Uttar Pradesh and Orissa. However, Rajasthan and Gujarat are the major seed spices growing states of our country contributing more than 80 per cent of seed spice production in India (Singh and Solanki 2014). Out of the 20 seed spices grown in our country, the most important spices of north Gujarat are coriander (*Coriandrum sativum* L.), cumin (*Cuminum cyminum* L.), fennel (*Foeniculum vulgare* l.), fenugreek (*Tigonella foenumgraecum* L.), carom (*Trachspermum ammi* L.) and chilli (*Capsicum annum* L). Most of the seed spices grown in India are quite susceptible to various insect and diseases which results a high loss of up to 90 per cent (Dahiya and Sehgal 2013). Storage insects cause major losses to farmers as well as traders. Insect infestation on stored spices is a serious problem throughout the world. There are approximately 20 species of insects attacking stored spices (Kumar et al 2014), such as red flour beetle (*Tribolium castaneum*), cigarette beetle (*Lasioderma serricorne*), spider beetle (*Ptinus tectus*), confused flour beetle (*Tribolium confusum*), khapra beetle (*Trogoderma granarium*) and drug store beetle (*Stegobium paniceum*). Among these, cigarettes beetle, *L. Serricorne* is a serious pest of many stored goods and belongs to the order Coleoptera and family Anobiidae. Across tropical and subtropical regions, the cigarette beetle *L. serricorne* is found worldwide, causing major economic losses to stored goods (Rees 2004). Maximum damage to stored goods is done by cigarette beetle larval feeding, while adults do harm by letting holes penetrate or escape packed commodities. Besides the harm done by feeding, the presence of dead insects, casting skin residues from various stages of larval life, pupal cases and fras are pollutants in spices and make them unfit for consumption. Moisture is one of the critical factors in safe storage of grains and seeds. Generally higher moisture of the commodity favours the development of storage insects. Current investigation was therefore undertaken to investigate the effect of moisture content on the weight loss of seed spices due to *Lasioderma serricorne* F.

MATERIAL AND METHODS

The samples collected during survey in different villages were brought to laboratory at S.D. Agricultural University, Sardarkrushinagar and 250g of each seed spices *viz.,* cumin, fennel, coriander, carom and fenugreek were properly labeled and kept in 500g capacity plastic bottle under laboratory (30±2°C). The moisture percentage of each seed sample was calculated using oven dry method before keeping in the plastic jar. Moisture per cent of the seed spices before the experiment and at monthly interval was estimated using oven dry method at 105°C for 20-25 minutes. The samples were observed periodically for weight loss and insect damage. The weight loss (%) was assessed monthly using the method proposed by Tiongson (1992) and computed using the following formula.

$$\text{Weight loss} = \frac{M1-M2}{M1} \times 100$$

Where, M1 = initial weight, M2 = grain weight after damage

RESULTS AND DISCUSSION

Moisture is one of the critical factors in safe storage of grains and seeds. Generally higher moisture of the commodity favors the development of storage insects. The moisture per cent has a significantly positive correlation with weight loss in all the seeds spices under study. In fenugreek the weight loss due to infestation recorded only in samples having initial moisture per cent i.e. 8.61-10.0%. The highest weight loss of 2.97% was in sample having moisture per cent of 9.75 followed 2.93, where the moisture per cent of the samples were 9.82. In cumin, the highest wt. loss of 33.13% was in samples having 10.18% initial moisture and least 30.73 in 9.24% indicating that if the moisture per cent is more than 10, resulted in higher weight loss. The lowest wt. loss of 10.47% was observed in samples having the moisture level of 7.87 %. In coriander, the maximum weight loss of 31.20% was in samples having initial moisture level of 9% and the lowest wt. loss of 13.50% in samples having moisture of 7.95%. Highest weight loss of 37.33% was in sample having an initial moisture level of 10.85% in case of fennel and if initial moisture level is more than 10%, led to a wt. loss of more than 35% in fennel. In carom the initial moisture per cent of the samples varied from 7.50 to 8.54% and the wt. loss due to *L. serricorne* infestation ranged from 11.40 to 24.73%. In coriander, final moisture level has greatly influenced (r = 0.88) the weight loss, as initial moisture has lower regression value (r = 0.67). Compare to initial moisture per cent, the final moisture per cent has highly associated with wt. loss as regression values varied 0.88 (Fenugreek and coriander) to 0.90 (Cumin and fennel) to a highest of 0.91 in case of ajwain (Table 3). Dahiya and Sehgal (2013) observed *L. serricorne* infested coriander even at a low moisture per cent of 7.97 and reported highly significant positive correlation between moisture and infestation in all spices under study.

Table 1. Correlation coefficient between initial moisture per cent and weight loss

Sr. No.	Fenugreek		Cumin		Coriander		Fennel		Carom	
	Moisture %	Loss %	Moisture %	Loss %	Moisture %	Loss %	Moisture %	Loss %	Moisture %	Loss %
1.	9.75	2.97	8.00	18.27	8.14	21.83	9.00	27.13	8.24	16.90
2.	8.20	0.00	8.68	19.07	9.45	23.67	9.35	28.53	7.78	18.53
3.	9.25	2.13	9.02	28.40	9.12	27.27	9.85	32.27	7.92	21.90
4.	9.82	2.93	10.00	31.20	8.87	28.87	10.00	24.67	8.00	23.83
5.	8.00	0.00	9.65	28.73	8.26	25.47	10.50	36.30	7.95	20.20
6.	8.45	0.00	10.18	33.13	8.32	28.30	10.85	37.33	8.36	24.03
7.	8.88	0.00	10.00	25.67	9.28	25.87	10.98	29.00	8.04	21.30
8.	8.84	0.00	8.85	17.10	8.92	21.57	8.68	16.80	7.68	13.23
9.	7.68	0.00	9.48	30.47	9.00	26.40	10.58	34.50	8.12	22.00
10.	9.35	2.83	8.28	20.40	9.16	25.03	9.96	26.63	8.00	17.27
11.	7.95	0.00	8.74	21.87	8.00	19.77	8.45	24.50	7.50	14.80
12.	10.00	2.50	7.87	10.47	7.95	13.50	8.28	11.50	7.50	11.40
13.	7.05	0.00	9.63	28.00	10.32	28.63	10.38	32.43	8.42	24.13
14.	7.38	0.00	9.24	30.73	10.00	29.50	10.00	35.67	8.20	23.50
15.	9.62	2.73	8.92	21.00	8.45	21.87	8.15	13.45	7.84	15.40
16.	9.98	2.77	9.46	32.17	9.00	31.20	9.72	37.10	8.00	24.73
17.	8.10	0.00	9.30	19.20	8.00	18.87	8.62	24.10	7.80	13.77
18.	7.86	0.00	10.00	28.20	9.62	26.67	8.00	8.03	8.54	22.23
19.	8.34	0.00	7.84	17.10	8.67	23.90	8.32	17.07	7.56	14.73
20.	7.72	0.00	8.98	17.13	8.24	17.50	8.64	17.13	7.50	12.73
Average	8.61	0.94	9.10	23.91	8.83	24.28	9.41	25.70	7.94	18.83
t value	7.69*		5.81*		3.83*		6.80*		5.38*	

Table 2. Correlation coefficient between final moisture per cent and weight loss

Sr. No.	Fenugreek		Cumin		Coriander		Fennel		Carom	
	Moisture %	Loss %	Moisture %	Loss %	Moisture %	Loss %	Moisture %	Loss %	Moisture %	Loss %
1.	10.50	2.97	12.20	18.27	12.72	21.83	13.22	27.13	12.16	16.90
2.	8.50	0.00	12.54	19.07	13.00	23.67	13.48	28.53	12.75	18.53
3.	9.85	2.13	13.38	28.40	13.72	27.27	14.05	32.27	13.04	21.90
4.	10.15	2.93	13.67	31.20	13.54	28.87	13.87	24.67	13.00	23.83
5.	8.25	0.00	12.84	28.73	13.24	25.47	15.00	36.30	12.70	20.20
6.	8.85	0.00	14.48	33.13	13.72	28.30	14.38	37.33	13.18	24.03
7.	9.15	0.00	13.74	25.67	13.48	25.87	13.92	29.00	12.86	21.30
8.	9.00	0.00	12.88	17.10	12.86	21.57	12.68	16.80	11.55	13.23
9.	7.92	0.00	13.72	30.47	12.92	26.40	14.08	34.50	12.2	22.00
10.	9.58	2.83	13.00	20.40	13.34	25.03	14.00	26.63	12.72	17.27
11.	8.00	0.00	13.58	21.87	12.82	19.77	13.98	24.50	11.78	14.80
12.	10.22	2.50	10.82	10.47	11.00	13.50	11.08	11.50	11.72	11.40
13.	7.15	0.00	14.00	28.00	13.46	28.63	14.47	32.43	13.00	24.13
14.	7.55	0.00	13.94	30.73	13.94	29.50	14.33	35.67	13.35	23.50
15.	9.80	2.73	13.18	21.00	13.00	21.87	12.12	13.45	12.00	15.40
16.	10.25	2.77	13.76	32.17	13.24	31.20	15.00	37.10	12.95	24.73
17.	8.15	0.00	12.82	19.20	12.64	18.87	14.75	24.10	11.46	13.77
18.	7.95	0.00	13.56	28.20	13.56	26.67	11.08	8.03	12.92	22.23
19.	8.55	0.00	12.64	17.10	13.00	23.90	12.55	17.07	12.00	14.73
20.	7.84	0.00	12.46	17.13	11.33	17.50	12.87	17.13	11.22	12.73
Average	8.86	0.94	13.16	23.91	13.03	24.28	13.54	25.70	12.42	18.83
t value	7.72*		8.46*		6.27*		14.27*		9.28*	

Table 3. Correlation between weight loss (%) and moisture per cent on different spices after one year of storage

Seeds of spices	Moisture (%)		Weight loss (%)	Cal. "r" value	
	Initial	Final		Initial	Final
Fenugreek	8.61	8.86	0.94	0.87*	0.88*
Cumin	9.10	13.16	23.91	0.80*	0.90*
Coriander	8.83	13.03	24.28	0.67*	0.88*
Fennel	9.41	13.54	25.70	0.85*	0.90*
Ajwain	7.94	12.42	18.83	0.78*	0.91*

*Significant at 0.05 per cent (r = 0.38)

CONCLUSION

Highly positive association indicating moisture level of seed spices *viz.,* cumin, fennel, coriander, carom and fenugreek having direct effect on wt. loss due to the infestation of *L. serricorne*. The initial and final moisture content of the seed spices established a significantly positive correlation with weight loss due to *L. serricorne* indicating moisture plays a key role in storage. The farmers and traders intend to store seed spice has to take care of the moisture level to avoid the wt. loss due to *L. serricorne*.

REFERENCES

Dahiya P and Sehgal B 2013. Comparative study between different storage practices on the basis of infestation in spices. *Annals of Biological Research* **4**(5): 16-22.

IBEF 2018. India Brand Equity Foundation. (https://www.teacoffeespiceofindia.com/ spice/spice-statistics)

Kumar SCM, Jacob TK, Jayashree E and Devasahayam S 2014. *Insect Pests of Stored Spices & Their Management,* 17p.

Rees D 2004. *Insects of Stored Products*, CSIRO Publishing, Collingwood, Australia.

Singh B and Solanki RK 2014. Status of research and development of seed spices in India. In: *Proceeding of the 3rd International conference on Agriculture and Horticulture* **2**: 72.

Tiongson RL 1992. Standardized methods for the assessment of losses due to insect pests in storage. *In: Towards integrated commodity and pest management in grain storage. A Training Manual for application in humid tropical storage systems.* Edited by R.L. Semple, P.A. Hicks, J.V. Lozare, and A. Castermans. A REGNET (RAS/86/189) Publication in Collaboration with NAPHIRE, May, 1992.

Received 24 May, 2020; Accepted 26 August, 2020

Indian Journal of Ecology (2020) 47(3): 881-883

Manuscript Number: 3103
NAAS Rating: 4.96

Leaf Litter Degradation by Microbes and Macro Invertebrates in Mid Reaches Stream of Eastern Ghats

S. Barathy, M. Vimali, T. Sivaruban[1] and Pandiarajan Srinivasan[1]

Department of Zoology, Fatima College, Madurai-625 018, India
[1]Department of Zoology, The American College, Madurai-625 002, India
E-mail: sivaruban270@gmail.com

Abstract: The present work implies about the role of microorganisms and macro invertebrates in leaf litter degradation. Five fungal genera and five bacterial genera were isolated from the collected leaf litter samples. *Bacillus* sp and *Aspergillus niger* were as the dominant in bacterial and fungal genera respectively. The leaf litter was associated with the scrapers like *Baetis* sp, *Choroterpes* sp and *Hydropsyche* sp. The decline in microbial population was observed in February and it is due to the increase of the scrapers. The reason for the increase of scrapers is a non-shady environment which normally they tend to live that happens during February. The riparian cover becomes the governing body in controlling the population dynamics of scrapers and microbes. The result implies that fungi were the first one to colonize the leaf litter and it co-exists with bacteria and finally leaf litters are degraded by scrapers.

Keywords: Scrapers, Macro invertebrates, Fungi, Leaf litter

The degradation of leaf litter and other organic matters that falls into streams plays a vital role in the functioning of the ecosystem. Thus, examining factors that influence the degradation of leaf material in streams is critical for understanding ecosystems processes in nature (Sparkes et al 2008). Streams are naturally subjected to great spatial and temporal variability, which is likely to affect the distribution and activity of organisms. Various factors such as quality of leaf litter, pH (Dangles and Chauvet 2003), temperature and nutrient concentration regulating the leaf litter decomposition in fresh water habitat. Macro invertebrates being the secondary producers occupies most important place in regulating the energy dynamics of freshwater habitat. Western Ghats being one of the biodiversity hotspot being vastly studied in all sectors of diversity, distribution, spatio-temporal variation, leaf litter degradation and energy dynamics of benthic macro invertebrate community. Microorganisms like heterotrophic fungi and bacteria play a crucial role in decomposition of aquatic leaf litter and degradation of organic material in the freshwater habitat (Nizamydeen et al 2014), but only a little has been emphasized by the aquatic biologists for the community structure of aquatic fungi and bacteria in running waters. The present study can be used to provide information about the role of microorganisms and macro invertebrates in determining the pattern of leaf litter degradation in Sirumalai stream of Eastern Ghats.

MATERIAL AND METHODS

Study area: Sirumalai hills belong to Sholavandhan range of Tamil Nadu forest department of Eastern Ghats (10º 18' N and 78º12'E), which has nine reserve forests extending over an area of 4,4769,74 acres. The main stream is Sathiar which originates from Pidariammanmalai at Manakattur and receives supplies from Sembodai stream and other small streams. Sampling was carried out in Thadaganachi Amman stream, which ultimately joins with Vaigai River (Fig. 1).

Sampling rationale: Leaf litter samples were collected for three months viz., October, December and February during 2018-2019. Leaf litter samples were collected in sterile vials and it is brought up to the laboratory and they were refrigerated. Water samples were also collected and physico-chemical parameters were analyzed using APHA guidelines (APHA 2005).

Microbial analysis: The leaf litter was soaked in water and serially diluted to 10^{-4} dilutions. From this dilution, 0.1ml was transferred to the Petri plates with nutrient agar and potato dextrose agar for bacterial and fungal growth, respectively.

Enumeration of colonies: The number of colonies was enumerated in each plate. The total number of microbes was determined per ml of original culture, multiplying the number of colonies by dilution factor.

Identification of the microorganisms: The isolated bacterial colonies were identified by Gram's staining method and biochemical characterization. Fungi were identified based on their morphology and spores following Lacto phenol Cotton blue staining method.

Sampling of aquatic insects: The most conventional sampling device, kick net of hand screen was used for



Fig. 1. Study site

sampling aquatic insects. The size of the net was $1m^2$ and approximately 100 µm mesh size following the methodology adopted by Burton and Sivaramakrishnan (1993) and macro invertebrates were identified with the help of suitable taxonomic literature.

RESULTS AND DISCUSSION

Five fungal genera and five bacterial genera were isolated from the collected leaf litter samples at 10^{-2} and 10^{-3} dilutions (Table 1). Five bacterial genera include *Bacillus* sp., *Micrococcus* sp., *Staphylococcus aureus*, *Pseudomonas* sp., *Escherichia coli* and five fungal genera's *Aspergillus niger*, *Penicillium* sp., *Rhizopus* sp, *Sacchromyces* sp., *Cladosporium* sp. These were identified from the discrete colony forming units (cfu) obtained on nutrient agar and potato dextrose agar. The cfu was found to be highest during October and the lowest was recorded in February. In bacterial genera, a maximum of 126 x 10^{-3} cfu were produced by *Bacillus* sp in October and minimum of 2.1 x 10^{-3} cfu were produced by *Pseudomonas* sp in February. Among fungal genera, *Aspergillus niger* shows maximum cfu (13 x 10^{-2} cfu/gm) in October and *Penicillium* sp shows a minimum of 0.6 x 10^{-2} cfu/gm. *Aspergillus* and *Penicillium* were the primary colonizers and *Rhizopus* has been reported as one of the colonizers during the advanced stage of decomposition (Shanthi and Vittal 2010). Same trend was also observed in our results, as the *Rhizopus* number started to increase in the December whereas other fungal genera number was highest in October.

The leaf litter was associated with the scraper community macro invertebrates which includes two principal orders of aquatic insects, ephemeroptera and trichoptera of which ephemeroptera includes genera *Baetis* sp. and *Choroterpes* sp, whereas trichoptera includes *Hydropsyche* sp (Table 2), *Baetis* sp. was found to be maximum. The results of the study which also fits in the concept of River Continuum Concept (RCC) because in mid reaches streams,

Table 1. Mean number of colony forming units (cfu) of bacteria and fungi colonizing leaf litter

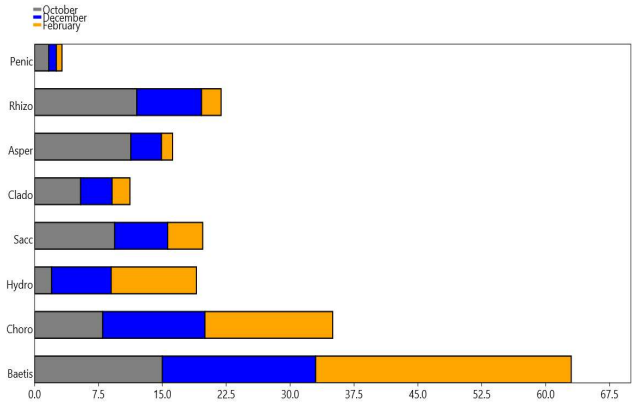
Organism name	October	December	February
Sacchromyces sp.	9.40	6.23	4.11
Cladosporium sp.	5.40	3.70	2.10
Aspergillus niger	11.30	3.60	1.30
Rhizopus sp.	12.00	7.60	2.30
Penicillium sp.	1.66	0.90	0.66
Bacillus sp.	116.33	72.00	62.60
Micrococcus sp.	44.33	22.30	11.66
Staphylococcus aureus	10.40	6.30	4.20
Pseudomonas sp.	7.60	6.10	2.10
Escherichia coli	17.10	14.30	11.11

Table 2. Scraper genera of aquatic insects colonizing leaf litter

Genera	October	December	February
Baetis sp.	15	18	30
Choroterpes sp.	8	12	15
Hydropsyche sp.	2	7	10

due to more influence of allochthonous matter, scraper community was found to be higher than the shredders (Vannote et al 1980). In this study, only scrapers are present so it fits in the concept of RCC as the feeding categorization changes when moves from head water streams to mid reaches streams (Vannote et al 1980). The association by scraper macro invertebrate communities like *Baetis*, *Choroterpes* (Ephemeroptera) and *Hydropsyche* (Trichoptera) along with leaf litter is substantiated by the observation of Anbalagan et al (2012). Fungi are the principal organisms in converting the leaf litter to more palatable form (Pascoal and Cassio 2004). In the present study, bacterial colonies outnumber the fungal colonies. The reduction in the abundance of fungi and increase of bacteria is due to the macro invertebrate interaction. The scraping community is strong enough to control the distribution and abundance of fungi indicating that, the growth of fungal population is inversely proportional to the number of scrapers (Fig. 2)

The decline in microbial population was observed in February and may be due to the end of post monsoon period which made less water flow with low percentage of canopy cover. In contrast to microbial population, macro invertebrate communities are higher in number in February. The reason for the increase of scrapers is because normally they tend to live in a non-shady environment, due to less canopy cover in February (Table 4), which makes suitable for the livelihood of scrapers and this leads to reduction of fungal communities. The riparian cover becomes the governing body in controlling



Penic-*Penicillium* sp, Rhizo-*Rhizopus* sp, Asper-*Aspergillus niger*, Clado-*Cladosporium* sp, Sacc-*Sacchromyces* sp, Hydro-*Hydropsyche* sp, Choro-*Choroterpes* sp, Baetis-*Baetis* sp

Fig. 2. Correlation of fungi and macro invertebrates in different months

Table 3. Mean physico-chemical parameters of Sirumalai hills

Physico-chemical parameters	October	December	February
Water temperature (°C)	30.1	29.5	28.3
pH	7.1	6.9	7.2
Dissolved oxygen (mg/l)	7.2	6.9	7.03
Total dissolved solids (ppt)	0.18	0.17	0.13
Stream width (m)	2.8	1.9	2.1
Stream depth (m)	0.1	0.2	0.5
Stream flow (sec/m)	6.1	8.2	4.2

Table 4. Mean habitat parameters for Sirumalai hill

Parameters	October	December	February
Bedrock (%)	10	8.3	60
Boulders (%)	50	27.4	20
Pebbles (%)	11.7	50	11.7
Gravels (%)	15	3.3	1.3
Sand (%)	13.3	11	7
Riparian cover (%)	80.3	83	60

the population dynamics of scraper community of insects. All other physico-chemical parameters fall within normal acceptable range (Table 3). The result predicts that fungi were the first one to start the leaf litter decomposition and it co-exists with bacteria and finally leaf litters are degraded by scrapers.

Received 20 June, 2020; Accepted 26 August, 2020

CONCLUSIONS

The leaf litter degradation was primarily done by aquatic fungi and bacteria, subsequently macro invertebrates were the last one to colonize. Poor forest management and forecasted climate change in Eastern Ghats were directly and indirectly influence on leaf litter decomposition. The micro and macro taxa along with riparian coverage can influence the decomposition mechanism of leaf litter in Sirumalai forest. In the future, a more detailed study on microbial biomass, chemistry of leaf litter and the physicochemical parameters of the stream will reveal the fate of the allochthonous energy inputs in running waters and the bioenergetics of the system.

REFERENCES

Anbalagan S, Dinakaran S and Krishnan M 2012. Spatio-temporal dynamics of leaf litter associated macro invertebrates in six river basins of peninsular India. *Ecologia* **2***:* 1-11.

APHA (American Public Health Association) 2005. *Standard methods for the examination of water and wastewater.* 21st Edition, Washington D.C.

Burton TM and Sivaramakrishnan KG 1993. Composition of the insect community in the streams of the Silent Valley National Park in Southern India. *Tropical Ecology* **34**: 1-16.

Dangles O and Chauvet E 2003. Effects of stream acidification on fungal biomass in decaying beech leaves and leaf palatability. *Water Research* **37:** 533-538.

Nizamydeen N, Santhiya T, Ambika R and Sengottaiah N 2014. Diversity of aquatic fungi in the Coastal region of Cauvery River. *Advances in Science and Research* **5**(2): 55-58.

Pascoal C and Cassio F 2004. Contribution of fungi and bacteria to leaf litter decomposition in a polluted river. *Applied and Environmental Microbiology* **70**: 5266-5273.

Shanthi S and Vittal BPR 2010. Fungi associated with decomposing le1af litter of cashew (Anacardium occidentale). *Mycology* **1**(2): 121-129.

Sparkes TC, Mills CM, Volesky LA, Talkington JA and Brooke JS 2008. Leaf degradation, macro invertebrate shredders & energy flow in streams: a laboratory-based exercise examining ecosystem processes. *The American Biology Teacher* **70**(2): 90-94.

Vannote RL, Minshall GW, Cummins KW, Sedell JR and Cushing CE 1980. The river continuum concept. *Canadian Journal of Fisheries and Aquatic Sciences* **37**: 130-137.

Indian Journal of Ecology (2020) 47(3): 884-886

Manuscript Number: 3104
NAAS Rating: 4.96

Prevalence of *Phytophthora* Foot Rot in Kinnow Orchards of Punjab State

Anita Arora, Amrinder Kaur[1*] and Amarjit Singh[1]

Department of Fruit Science, [1]Department of Plant Pathology
Punjab Agricultural University, Ludhiana-141 004, India
**E-mail: augaulakh@pau.edu*

Abstract: Foot rot/gummosis caused by *Phytophthora nicotianae* var. *parasitica* (Dastur) Waterhouse has become an important pathogen in the decline of kinnow orchards, Sweet orange and nurseries in the Punjab state. The disease is characterized by rotting of the rootlets, girdling of the trunk, dropping of brightened leaves, canker lesions and gummosis at the base of the trunk, as well as root rot, extending from main roots into feeder roots. Surveys conducted of different agro-climatic zones of Punjab during 2016-19 revealed that *Phytophthora* foot rot/gummosis occurred in trees of all age groups across the agro-climatic zones with maximum incidence of the disease in sub-mountenous zone (28.6%) followed by 26.2% in the arid-irrigated zone in 15-20 years old trees. Population of *Phytophthora nicotianae* showed an increasing trend from July onwards and reached maximum in the month of September when hot and humid temperature prevails due to frequent rains during these months which coincides with the favourable conditions for disease development.

Keywords: *Phytophthora*, Foot rot, Kinnow mandarin, Survey, Punjab

Citrus being highly prized fruit crop is a second largest industry in India with respect to area and third largest in production. In Punjab, citrus is being cultivated over an area of 57,288 hectares with an annual production of 12,81,632 MT. Among the different Citrus fruits, kinnow ranks first with respect to area (53,045 hectares) and production (12,46,821 MT) (Anonymous 2019). The wide geographical diversity and perennial nature of fruit crops also provide almost a permanent niche for many pests and diseases which thus leads to considerable damage to tree health, longevity and productivity and also decrease the quality and value of harvested produce. Under Punjab conditions, among the various diseases infecting the Kinnow plants, Phytophthora foot rot/ gummosis caused by *Phytophthora nicotianae* var. *parasitica* (Dastur) Waterhouse is of major concern causing significant losses in the harvested yield of the kinnow plants (Sharma et al 2010). This pathogen it causes hidden damage by decaying the feeder roots of the plants. Foot rot symptoms are easily recognized as rotting of the bark or crown near the ground level and as the disease progresses, gum starts oozing from the cracks in the bark near the base of the tree (Plate 1). The infection thus spreads around the circumference of the trunk, slowly girdle and kills the tree (Gade and Lad 2018).

MATERIAL AND METHODS

In present study, roving and fixed plot surveys were conducted in citrus growing areas of the three agro-climatic zones of Punjab (south-western arid-irrigated zone, central plain zone and sub-mountainous zone) to record the incidence and severity citrus foot rot/ gummosis. Surveys were carried out in kinnow orchards of various villages during April-June, July-September, October-December and January-March from 2016-2019. Fifty plants from each orchards were observed randomly to record the presence or absence of the disease symptoms. During surveillance, the data were recorded according to different age groups of the plants and per cent disease incidence was calculated by using the following formula:

$$\text{Per cent disease incidence} = \frac{\text{Number of plants infected}}{\text{Total number of plants observed}} \times 100$$

Soil samples were also collected from kinnow orchards at fortnightly interval for monitoring population of *Phytophthora nicotianae* from 2016-2019. The rhizosphere soil from four opposite sides around the infected kinnow mandarin plants was collected and then mixed and from this mixture, 250 grams of soil was taken to form the representative sample.

RESULTS AND DISCUSSION

During the extensive surveys, it was observed that the most widespread and serious diseases prevalent in Punjab was *Phytophthora* foot rot/gummosis and this disease occurred in trees of all age groups in all the three agro-climatic zones. During surveillance moderate to profuse gumming and water- soaked lesions were observed in a considerable number of plants due to foot rot disease.

Maximum incidence of *Phytophthora* foot rot was observed on Kinnow mandarin in sub-mountenous zone (28.60%) followed by 26.20 % in the arid-irrigated zone in 15-20 years old trees (Fig. 1). These orchards were frequently heavily irrigated, weeding operations were done and heavy water requiring crops such as berseem, potato and vegetables were grown as intercrops. In case of central zone, maximum (21.50%) incidence of *Phytophthora* foot rot was recorded in 6-12 years old trees followed by 9.2% in 2.5-5 years old trees (Fig. 1). The present findings are in accordance with Thind and Sharma (1996) and Savita et al (2012) who observed maximum incidence of this disease on kinnow mandarin and sweet orange. The present findings are in agreement with Kaur et al (2009) who observed that disease incidence was 20.42 per cent and 23.58 per cent for 1-6 and 7-12 year age plant respectively and stated that plant age has direct correlation with the disease incidence. Thind et al (2008) also reported the increase in the incidence of citrus foot rot with an increase in age of the plant.

Population of *Phytophthora nicotianae* studied at fortnight interval from the soil samples collected from different locations revealed that it increased rapidly in the second fortnight of July (Fig. 2). The lowest population (8 propagules/cc of soil) was recorded in the first fortnight of May and followed by 9 propagules/cc of soil in second fortnight of May and first fortnight of June. It was observed

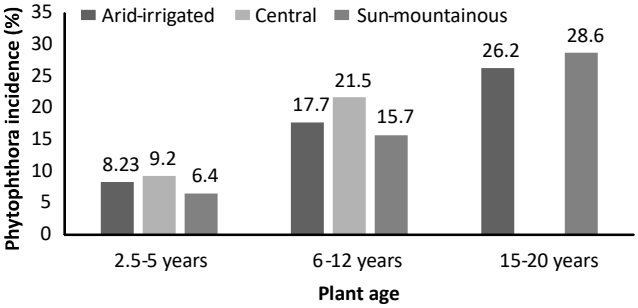


Fig. 1. Incidence of *Phytophthora* foot rot in Kinnow orchards from 2016-2019

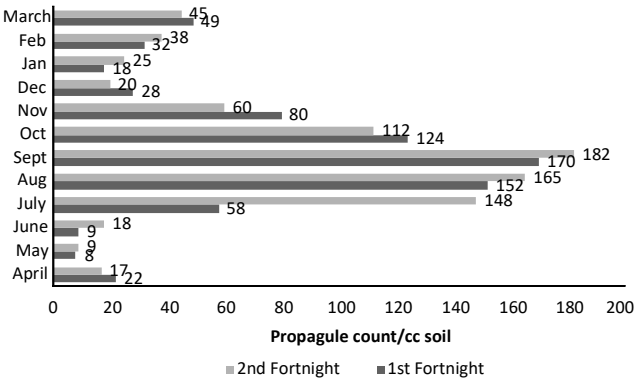


Fig. 2. Periodic population of *Phytophthora nicotianae* var. *parasitica* from 2016-2019

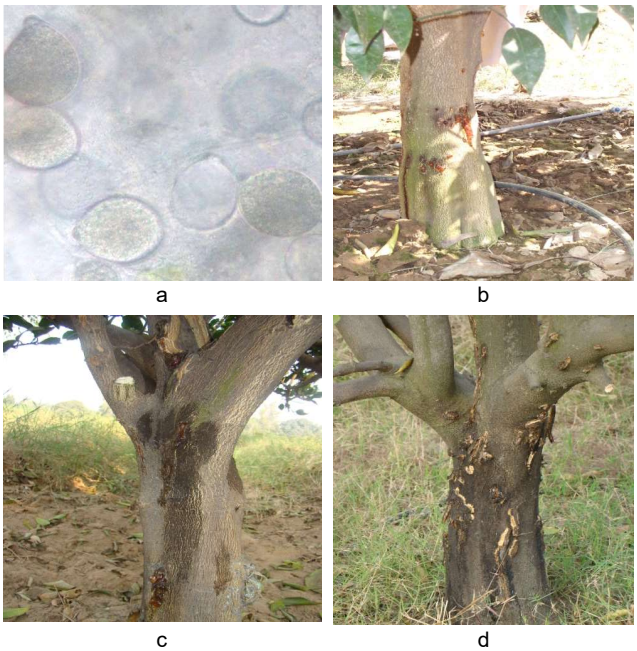


Plate 1. (a) Sporangia of *P. nicotianae* var. *parasitica* (b) Oozing of gummy drops from the infected tree bark (c) Oozing of sap from the infected tree bark (d) bark cracking and death of the tree

that the population of *Phytophthora nicotianae* showed an increasing trend from July onwards and reached maximum in the month of September (182 propagules/cc of soil) and thereafter it again decreased.

These observations are closely related to the findings of Dhakad et al (2015) who have reported that propagule count of *Phytophthora parasitica* in citrus orchards was highest (>300 propagules / cc of soil) in the months of July - August. Lowest population in the months of May-June may be due to hot summer days. Increase in population build up in the months of July-September may be attributed to frequent intermittent rains. Increase in population was also found coinciding with root flush period during January-March.

CONCLUSIONS

The observations revealed that all the agroclimatic zones of the Punjab were observed to be the hot spots for *Phytophthora* foot rot/gummosis. The maximum incidence of the disease was recorded in the Kinnow orchards present in the sub-mountainous and arid irrigated zones of Punjab where heavy irrigation was applied and the orchards were also intercropped with high water requiring crops. The propagule count of this pathogen was at its peak in the month

of August-September when hot and humid temperature prevails due to frequent rains during these months which coincides with the favourable conditions for disease development.

REFERENCES

Anonymous 2019. *Package of practices for cultivation of fruits*. Punjab Agriculturalv University, Ludhiana, p. 164.

Dhakad UK, Kaur S, Thind SK and Badaya VK 2015. Factors favouring the development of foot rot pathogen (*Phytophthora nicotianae* var. *parasitica*) in Punjab. *The Ecoscan* **7**(Sp. issue): 135-138.

Gade RM and Lad RS 2018. Biological management of major citrus diseases in central India: A review. *International Journal of Current Microbiology and Applied Sciences* **6**: 296-308

Kaur A, Verma KS and Thind SK 2009. Citrus *Phytophthora* impact on tree health and fruit quality of kinnow mandarin and its development in irrigation systems. *Agricultural Research Journal* **46**: 166-167.

Thind SK, Arora PK and Aulakh PS 2008. *Symptomatology, epidemiology and management of citrus diseases in orchards and nurseries.* Annual Report, PAU, Regional Research Station, Abohar. p. 32-47.

Thind SK and Sharma JN 1996. Incidence and control of citrus gummosis in kinnow mandarin. *Indian Journal of Horticulture Science* **53**: 118-120.

Savita, Virk SG and Nagpal A 2012. Citrus diseases caused by *Phytophthora* spp. *GERF Bulletin Bioscience* **3**: 18-27.

Sharma DR, Singh A and Arora A 2010. *Plant Protection of Fruit Crops*. Punjab Agricultural University, Ludhiana. pp. 48.

Received 10 July, 2020; Accepted 26 August, 2020

Indian Journal of Ecology (2020) 47(3): 887-888

Manuscript Number: 3105
NAAS Rating: 4.96

First Record of Alexandrine Parakeet *Psittacula eupatria* (Psittaculidae, Psittaciformes) (Linnaeus 1766) in Iraq

Salwan Ali Abed, Mudhafar A. Salim [1] and Saifulden M. Alsaffah[2]

College of Science, University of Al-Qadisiyah, Diwaniyah, Iraq
[1]Arab Regional Centre for World Heritage, Manama, Bahrain
[2]Iraq Organization for Conservation of Nature, Iraq
E-mail: salwan.abed@qu.edu.iq

Abstract: Alexandrine Parakeet *Psittacula eupatria* is a medium-sized parakeet species that inhabits South and Southeast Asia to Pakistan and India. Parakeets, including Alexandrine Parakeet, are well-known cage-bird worldwide, and the escapes form captivity might be the key reason of their recent expansions out of their natural range such as the Middle East and beyond. As part of the Iraqi Organization for Conservation of Nature (IOCN) regular surveys in Iraq, the team was able to find this species in Babylon archaeological site for the first time in the wild in Iraq. This paper confirms the firs record of Alexandrine Parakeet as an addition to Iraq birds checklist.

Keywords: Alexandrine Parakeet, Alien and invasive species, Babylon, Iraq, *Psittacula eupatria*

Alexandrine Parakeet *Psittacula eupatria* is one of the medium-sized parakeets (also called Parrots) that belong to Order Psittaciformes, Family Psittaculidae, of the Genus *Psittacula.* The natural range of this species spreads from feral populations in South and South-East Asia, ranging from Pakistan and India (BirdLife International 2017. Several observations of Alexandrine Parakeet in the wild were made off its natural distribution in different countries like Afghanistan, Bangladesh, Bhutan, Cambodia, India, Myanmar, Nepal, Pakistan, Sri Lanka, Thailand, and Viet Nam, where it is thought that some of these populations were originated from escapes from captivity like Iran, Qatar, Turkey, United Arab Emirates, also this species introduced in Bahrain and Yemen (Porter and Aspinal 2010, Gilbert et al 2012, Del Hoyo et al 2014, IUCN 2017). This species is commonly used as a pet and cage-bird, and this might be the reason behind the decreasing and the continuous decline of its population in its natural range to be ranked as Near Threatened by the IUCN Redlist (IUCN 2017). Recording of Alexandrine Parakeet in Iraq is considered one of the important observations for the ornithology of the country because this species is alien and might be one of the invasive species in future like the case with the Rose-ringed Parakeet that has established several breeding colonies in Iraq now (Salim et al 2006).

MATERIAL AND METHODS

Observation area: The Iraqi Organization for Conservation of Nature (IOCN) team surveyed the natural areas within the archaeological site of Babylon, 80km to the south of Baghdad at mid-October. The archeological city of Babylon is located at the middle of Babil Governorate, east of River Euphrates. The complex of this area consists of different components of which the archeological sites form part of it. Some of the patches within the area consist of gardens covered with dense, large trees and surrounded by date-palm trees, while other areas consist of running River and small ponds and reed-beds (Fig. 2). In order to have better coverage of the surveyed area, the team has spread within the different habitats of the site. The observation of the bird subject of the current paper was made at the coordinates (N: 32°32'26", E: 44°25'3"). The field observations were conducted at the 19th of October, 2019. The binoculars and the professional cameras (Canon and Nikon) with telephotos (50-500mm & 24-2000mm respectively) were used to observe the birds in the wetlands and within the gardens and yards of the site. Small cameras were used for documenting the habitats and the landscapes. The observation of this new species was made through only one visit to the site described above. The site was visited at the 19th of October 2019.

RESULTS AND DISCUSSION

After surveying the birds in the southern pool of Babylon site (N: 32°32'26", E: 44°25'3"), the surveyed parts of the gardens of the site, a green parrot perching on relatively large tree was observed and considered Rose-ringed Parakeet *Psittacula krameri*, but after having closer view, especially to the bill and the shoulders' patches, it was immediately identified as Alexandrine Parakeet *Psittacula eupatria*. The observed individual bird was perching in high spot among the

top parts of the tree, and was shy and restless. It was hiding itself away from the observers each time they find a way among the dense branches to check it carefully.

Based on the status of this species within the Middle East and over the countries around Iraq, it was concluded that this individual might have originated from the escapes from nearby captivity. The alike Rose-ringed Parakeet *Psittacula krameri* has established its breeding populations in different locations in Iraq (Salim, unpublished observations) and it seems that this species might take the same route in case the escapes increased up to the threshold that allows establishing wild groups. However, this assumption might not be very true to this species for several reasons. The key reason that might not make the future case of this bird in Iraq similar to Rose-ringed Parakeet ,*Psittacula krameri* is the high price of Alexandrian Parakeet in comparison with Rose-ringed Parakeet that make the keepers more cautious to prevent escaping of this species to increase the opportunity of the presence of couples together in the wild (IOCN unpublished interviews). However, this stays as assumption, leaving the fate of this near threatened species in the wild in Iraq for future, taken into consideration

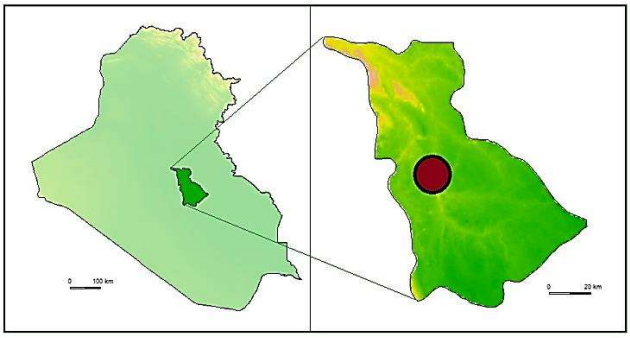


Fig. 1. Map (left) shows the location of Babil Governorate, central Iraq, and the map of Babil Governorate (right) shows the location of Babylon Archaeological site (the red circle) where the Alexandrian Parakeet was first observed in the wild for Iraq



Fig. 2. (Left) Alexandrian Parakeet that was first observed for Iraq in the wild in Babylon archaeological site. (Right) the natural landscape of the gardens of Babylon archeological site. River Euphrates appears at the upper part of the photo. ©IOCN

that the availability of food and habitats for sheltering, and possibly, breeding. Based on the clear observation and documentation, and based on the absence of any previous records of this species in the literature (Allouse 1953, Salim et al 2006, 2012, Porter et al 2010, Salim et al 2012), the current paper confirms the first record of Alexandrine Parakeet *Psittacula eupatria* in the wild for Iraq and adds it to the checklist of the Avifauna of Iraq.

ACKNOWLEDGEMENT

The researchers are sincerely grateful for the assistance provided by the Iraqi Organization for Conservation of Nature (IOCN), the Arab Regional Center for World Heritage (ARC-WH), and College of Science, University of Al-Qadisiyah for the continuous support and encouragement. Sincere thank goes to the Management staff of Babylon archaeological site for their kind cooperation.

REFERENCES

Allouse BE 1953. *The Avifauna of Iraq*. Publication. No. 3. Iraq. Natural History Museum. Baghdad, Iraq: Al-Rabita Press.

Ancillotto Leonardo, Strubbe Diederik, Menchetti Mattia and Mori Emiliano 2015. An overlooked invader?. Ecological niche, invasion success and range dynamics of the Alexandrine parakeet in the invaded range". *Biological Invasions* **18**(2): 583-595.

Bird Life International 2017. *Psittacula eupatria* (amended version of 2016 assessment). The IUCN Red List of Threatened Species 2017: e.T22685434A110985466. Downloaded on 25 October 2019.

Del Hoyo Josep, Nigel J, Collar, David A Christie, Andrew Elliot and Lincoln DC Fishpool 2014. HBW and birdlife *International Illustrated Checklist of the Birds of the World*. Volume 1: Non-passerines. Barcelona: Lynx Edicions. ISBN 978-8496553941.

Gilbert M, Sokha C, Joyner PH, Thomson RL and Poole C 2012. Characterizing the trade of wild birds for merit release in Phnom Penh, Cambodia and associated risks to health and ecology. *Biological Conservation* **153**: 10-16.

IOCN, unpublished interviews and reporting with birds hunters and keepers in different bird-markets in Iraq.

IUCN 2017. The IUCN Red List of Threatened Species. Version 2017-1. Available at: www.iucnredlist.org. (Accessed: 27 April 2017). https://www.iucnredlist.org/species/22685434/110985466#bibliography.

Lantermann W and Vriends MM 1986. New parrot handbook. Barron's Educational Series, New York.

Porter R and S Aspinall. 2010. Birds of the Middle East. Christopher Helm, London.

Porter RF, Salim M, Ararat K and Fadhel O 2010. A provisional checklist of the birds of Iraq. *Marsh Bulletin* **5**(1): 56-95.

Salim MA, Al-Sheikhly OF, Majeed KA and Porter RE. 2012. An annotated checklist of the birds of Iraq. *Sandgrouse* **34**: 4-43.

Salim MA, Porter RE, Schiermacker-Hansen P, Christensen S and Al- Jbour S 2006. *Field guide to the birds of Iraq*]. NI/Bird Life International, Baghdad. [In Arabic]. Salim (unpublished manuscript), *Birds observations in Iraq* since early 1990s.

Received 11 July, 2020; Accepted 12 August, 2020

OBITUARY

Dr Kirti Dua



Dr Kirti Dua was Officer In-charge, Centre of Wild Life and Professor, Veterinary Medicine in College of Veterinary Sciences, Guru Angad Dev Veterinary & Animal Sciences University (GADVASU), Ludhiana, Punjab, India. He was born on 14th Oct 1960 at Delhi. He did his schooling from Bhartiya Vidya Mandir, Ludhiana and went to Govt. College for Boys, Ludhiana, before joining Punjab Agricultural University (PAU), Ludhiana in 1978. He did his B.V.Sc. and M.V.Sc. in 1983 & 1985 respectively. In 1989, he was awarded Commonwealth Fellowship by UK Government to pursue Ph.D at University of Wales.

He joined the University service as Assistant Professor in Department of Veterinary Medicine in 1987. In 2008, he joined as Head, Department of Clinical Veterinary Medicines Ethics & Jurisprudence and in 2013 he was appointed as In charge, Centre of Wild Life Studies & Research Centre at GADVASU, Ludhiana.

He was a very good 'Teacher' and 'Scientist' of national repute. For his professional accomplishments, he received Young Scientist Award, D.C. Blood Gold Medal in Bovine Medicine and Fellowships of National Academy of Veterinary Sciences and Indian Society of Veterinary Medicine. He was also one of the founder members of the Indian Society for Veterinary Medicines & served the society as various capacities. In 2001, he was nominated by Govt of India as an ITEC expert in large animal veterinary medicines to Mauritius.

In addition to many referred publications in journals of national & international repute, he also authored three books in Veterinary Medicines viz *Infectious diseases of Farm animals, Animal Welfare, Ethics and Jurisprudence* and *Infectious Diseases of Farm Animals*, which are part of the course curriculum not only in the veterinary colleges of India but are also frequently referred in other Asian countries.

Dr Dua was a very popular personality among Veterinary Fraternity of the country. He was a lively and adventurous person, good orator, artist, writer and above all a generous man. He started a 'Farmer Welfare Society' for providing free food to the poor farmers visiting University hospital and free medicines for their sick animals. Nature's biodiversity and resilience in mankind especially in rural sector amazed him. His written columns had appeared in many newspapers. Dr Dua was widely travelled and was a good photographer. He had written and made documentary films of animals from Leh-Ladhak to deserts of Rajasthan. During the recent floods in Punjab, he extensively toured the flood affected areas, documented the problems of farmers and livestock of that area. His Youtube channel 'BRILLIANT MOMENTS WITH KIRTI DUA' has his videos of his travels, PAU/GADVASU events, veterinary related, socio-cultural events etc.

Dr Dua was due to retire on 31st October, 2020. But his untimely demise on 1st June 2020 had led a great loss to the Veterinary Profession as well as society.

Dr Asha Dhawan
Dean (Retired)
College of Fisheries
GADVASU, Ludhiana-141 004

CONTENTS

3089	Do Exotic Trees Threaten Southern Arid Areas of Tunisia? A Case Study *Zouhaier Noumi*	808
3090	Assessment of Tree Species Diversity and Their Carbon Sequestration Potential in Tumkur University Campus, Tumkur *H.B. Lakshmi and Vinod Kumar*	815
3091	Floristic Diversity Assessment of Dhauligiri Hill and its Adjoining Areas of Bhubaneswar City, Odisha, India *Sanjeeb Kumar Das, Padmini Bisoyi, Ashutosh Subudhi, Samarendranath Naik and Sourav Ranjan Pradhan*	821
3092	Vegetation Analysis in Chora and Joyalbhanga Forest Area of Raniganj Coal Field, West Bengal, India *M. Saikat, P. Debnath and C. Pinaki*	831
3093	Heterogeneous Landscape Assessment using Multi-Temporal LISS and Hybrid Approach: A Case Study in Barak Valley, India *Demsai Reang, Aparajita De and Ashesh Kumar Das*	842
3094	Collection and Utilization Pattern of Non Timber Forest Products in Nagaland, an Eastern Himalayan State of India *Sanjoy Das, Narokumla Longkumer, N.K. Patra, Nchumthung Murry and Mukesh Yadav*	849
3095	Study on Mangroves of Zuari Estuary: Remote Sensing and GIS Approach *R.U. Sawaiker and P.M. Gaonkar*	854
3096	Design, Development and Performance Evaluation of Manually Operated Groundnut Planter *B.S. Madhusudan and M. Naga Sasi Preetham*	858
3097	Effect of Different Varieties and Spacings on Growth and Yield Attributes of Garlic (*Allium sativum* L.) *Shatrunjay Yadav, Sanjay Kumar and Shubham Singh*	863
3098	Assessment of Yield and Nutrient Uptake of Wheat in Agri-Silvi-Horticulture System under Semi-Arid Region of Haryana *Sonia Devi, K.K. Bhardwaj, Garima Dahiya and Manoj Kumar Sharma*	866
3099	Diversity and Distribution of Odonates in Alagar Hills of Southern India *T. Sivaruban, S. Barathy, Pandiarajan Srinivasan and Rajasekaran Isack*	869
3100	Effect of Storage Media and Time on Germination, Vegetative Growth and Survival in Mango (*Mangifera indica* L.) *Anishabahen Manojbhai Gangode, Tanzin Ladon, Ankita Aman and Priyanka Chauhan*	872
3101	Study on Human Wildlife Conflict in Chenab Valley of Jammu and Kashmir India *Kulbhushan Kumar and Satpal Singh Bisht*	875
3102	Impact of Moisture Content of Different Seed Spices on Damage Caused by Cigarette Beetle, *Lasioderma serricorne* F. *N.J. Chaudhari, C.M. Muralidharan and Manishkumar J. Joshi*	878
3103	Leaf Litter Degradation by Microbes and Macro Invertebrates in Mid Reaches Stream of Eastern Ghats *S. Barathy, M. Vimali, T. Sivaruban and Pandiarajan Srinivasan*	881
3104	Prevalence of *Phytophthora* Foot Rot in Kinnow Orchards of Punjab State *Anita Arora, Amrinder Kaur and Amarjit Singh*	884
3105	First Record of Alexandrine Parakeet *Psittacula eupatria* (Psittaculidae, Psittaciformes) (Linnaeus 766) in Iraq *Salwan Ali Abed, Mudhafar A. Salim and Saifulden M. Alsaffah*	887

CONTENTS

3070	Assessment of Changes in Observed Rainfall and Prediction of Future Conditions Using Quantile Delta Mapping Bias Correction Technique over Cauvery River Basin, India *Parthiban Loganathan and Amit Baburao Mahindrakar*	708
3071	Nutrient Management of Garlic (*Allium Sativum* L.) cv. Bhima Purple in an Integrated Way *K. Singh, S. Maji, D.H. Dwivedi and M. Prasad*	712
3072	Evaluation of Strawberry Cultivars Under Sub-Mountane Zone of Punjab *Bikramjit Singh*	716
3073	Growth Performance and Health Status of Pangas catfish (*Pangasianodon hypophthalmus* Sauvage, 878) Fingerlings Fed on Fish Silage and Linseed Oil Supplemented Diets *Injeela Khan, Vaneet Inder Kaur and Surjya Narayan Datta*	720
3074	Runoff Estimation of Machhu and Watrak Rivers Basins of Gujarat India using SCS-CN Method and GIS *Darji Kishanlal, Indra Prakash and Binh Thai Pham*	726
3075	Rapid Exploration of Insect Pests and their Ecology along Chitwan Annapurna Landscape, Nepal *Daya Ram Bhusal, Shivish Bhandar, Tara Maya Gurung and Kishor Chandra Ghimire*	733
3076	Status of Zooplankton Diversity, Abundance in Relation to Hydrography of Ganga River and its Tributaries at Rishikesh *D.S. Malik, Amit Kumar Sharma and Arvind Kumar Sharma*	739
3077	Seasonal Variation of Physicochemical Parameters of Aquaculture Ponds in District Karimganj, Assam *Piyali Das and Mithra Dey*	746
3078	Isolation and Characterization of a Biosurfactant Producing *Pseudomonas* and *Bacillus* from Hydrocarbon-Contaminated Site *Preeti N. Gajghate, Pranali A. Shete and Vishal R. Dhundale*	751
3079	Algal Diversity and Physio Chemical Qualities of Achankovil River in Monsoon seasons *Meera Krishnan, T. Praveen Dhar, R. Sreejai and Sreeja Thankappan*	755
3080	Ecological Future Scenario of Marine Macro Algal Flora of Karwar Coastal Area, Arabian Sea, India *Gulnaz Qureshi and J.L. Rathod*	759
3081	Effect of Physico-Chemical Properties of Water on Macrophyte Diversity with Special Reference to Bhoj Wetland *Prerna Gupta, Sadhna Tamot and Vinoy K. Shrivastava*	764
3082	Seasonal Aggregate Effects of Water Bird Populations on Tropical Rural Lake *M. Saravanaraja, P.S. Aruna Devi and K. Nagarajan*	769
3083	Issues and Problems of Small-Scale Fishing (SSF) Communities in South Asia: A Comprehensive Overview *Mohammed Mamun Rashid, Azlinda Azman, Paramjit Singh Jamir Singh and Md Isahaque Ali*	775
3084	Study of Environmental Conditions, Morphometric and Meristic of Mudskipper (*Periophthalmus*) from Ambon Island Coastal Waters, Indonesia *D. Rumahlatu, K. Sangur, A.P. Leuwol, Y.N. Apituley, S.I.A Salmanu and I. Arini*	782
3085	Comparison of Performance of Trimedlure and Enriched Ginger Root Oil (*Zingiber officinalis*) in Attracting Males of Mediterranean Fruit Fly (*Ceratitis capitata*) *Jamal Ben Yazid, Zouheir Chafik, Imane Bibi and Ez-Zahra Kharmach*	788
3086	Litter Mass Loss Rate Changes as Function of Soil Microbial Diversity and Litter Chemical Quality in Tropical and Sub-Tropical Forest of Mizoram: A Microcosm Study *Ngangbam Somen Singh and S.K. Tripathi*	792
3087	Delineation of the Major Soil Nutrients in Seabuckthorn (*Hippophae* sp.) Stand and its Comparison to Other Land uses from Extreme Landscape of Trans-Himalaya *Praveen Kumar, Pardeep Kumar, Munish Sharma, Nagender Pal Butail, Virendra Singh and Arvind Kumar Shukla*	799
3088	Impact Analysis of Anacardiaceae family against *Dociostaurus maroccanus* Locust in Inventories of Algeria South-West Region *M. Bereksi Reguig, I. Abdelli and F. Hassani*	803

Indian Journal of Ecology (2020) 47(3)

Indian Journal of Ecology

CONTENTS

3052 Effect of Chemical Characteristics of Soil on Orange Productivity: A Case Study of Nghe An Province, Vietnam 607
Nguyen Thi Hoai, Takahashi Kazuya, Hoang Thi Thuy, Nguyen Thi Thuy Hà, Nguyen Thi Trang Thanh, Hoang Phan Hai Yen, Nguyen Thi Viet Ha, Nguyen Nam Thanh, Vo Thi Thu Ha, Phan Thi Quynh Nga, Hoang Anh The, Binh Thai Pham, Indra Prakash, Tran Thi Tuyen

3053 Comparative Study of Sugarcane Agro-Industrial Waste Raw Pressmud and Composted Pressmud: A Case Study 614
Amol Chougule, P.R. Bhosale and P.D. Raut

3054 Influence of Various Doses of Fertiliser and Crop Geometry on Growth Parameters and Productivity of Late Sown Indian Mustard (*Brassica juncea* L.) 619
Naveen Rathi, Bikram Singh, V.S. Hooda, Harender, and Mohammed Mohsin

3055 Economic Efficiency of Applying Environmentally Friendly Fertilizers in Production Technologies in the South of Ukraine 624
Ye. Domaratskiy, O. Kozlova and A. Kaplina

3056 INM in Rice Based Integrated Farming System Model for Food Security and Enhanced Productivity 630
B. Sudha, J. John, A.V. Meera and A. Sajeena

3057 Effect of Integrated Nutrient Management on Nutrient Uptake by Lowland Cassava and Soil Physico-chemical Properties 634
A.P. Pooja and O. K. Swadija

3058 Water Erosion of the Slopes of Tayyar Drainage Basin in the Desert of Muthanna in Southern Iraq 638
Bashar F. Maaroof and Hashim H. Kareem

3059 Daily Gauge-Discharge Estimation using ANN and Wavelet-ANN Models for Muri Station, Jharkhand 645
Anuradha Kumari, Manish Kumar, Abhishek Kumar and Anupam Amitabh

3060 Annotated Checklist of Brachyuran Crabs of Karwar Mangroves, West Coast of Karnataka, India 650
Pradnya D. Bandekar and V.S. Kakati

3061 Influence of Organic and Inorganic Farming Practices on Production Potential and Soil Health under Different Cropping Systems in Mid Himalayan Region 655
Ashish Kumar, J.P. Saini, Arvind Chahal and Pankaj Chopra

3062 Use of Immobilized Polyphenol Oxidase in Removal of Phenol from Some Aqueous Solutions 663
M.A. Alsoufi and R.A. Aziz

3063 Effect of Conservation Tillage on Soil Quality of Southern Russia 668
Kamil' Sh. Kazeev, Tatiana V. Minnikova, Gregory V. Mokrikov and Sergey I. Kolesnikov

3064 Hyper Spectral Imaging Technology for Seed Quality Identification 676
D. Madhusudhana Rao, B. Naga Sudheer, K. Sarada and A. Ramarao

3065 Growth, Yield and Nutrient Uptake of Knol-Khol (*Brassica oleracea* Var. *gongylodes*) as Influenced by Organic Manures, Inorganic Fertilizers and Biochar 681
Ashaq Hussain, Manzoor A. Ganai, Mudasir A. Shan, Intikhab Aalum Jehangir, Shabir H. Wani and Aziz M.A.

3066 Productivity of Spinach Beet as Influenced by Varieties and Nutrients in Humid Tropical Conditions of South Kerala 686
Vinod Alur and Sheeba Rebecca Isaac

3067 Comparison of CERES-Wheat and InfoCrop Model to Predict the Phenology and Yield of Wheat 690
Amarinder Singh, Gurbax Singh and Prabhjyot Kaur

3068 Structural Analysis of Shade Nets for Construction of Low-Cost Shade Net Houses in A Semi-Arid Climate of Trichy District, Tamil Nadu, India 697
G. Gopi, K. Shanmugasundaram and B.S. Madhusudan

3069 Impact of Drip Irrigation on Soil Biological Activity, Symbiotic Traits and Yield in Summer Mungbean 703
Harpinder Singh, Mukesh Siag, Nilesh Biwalkar, Poonam Sharma and Rakesh Sharda

Date of Publication 15.09.2020