Research Communication

Sci. and Cult. 85 (7–8) 281-290 (2019)

Vertical Distribution of DTPA-Extractable Micronutrients and its correlation with soil properties in selected Soil Profiles of Birbhum District of West Bengal

Abstract **: The present study was undertaken to assess the vertical distribution of DTPA-extractable micronutrients viz. zinc, copper, iron and manganese in relation to soil properties in five selected soil profiles, one each from Sainthia, Suri II, Rampurhat II, Md Bazar and Nalhati I block of Birbhum district of West Bengal. Collected soil samples were analysed for pH, electrical conductivity, organic carbon, textural class (% sand, silt, clay) and DTPA- extractable micronutrients using standard analytical methods. The soil texture varied from silt loam to silt. Based on the fertility ratings, pH of the profile soils was strongly acidic to neutral, showing increasing trend with depth. Its value ranged from 5.012- 7.121. Electrical conductivity was found in normal range. Low to medium organic carbon content was found and its distribution was found decreasing with increasing depth. Iron, manganese and copper were estimated to occur above critical level, whereas low to medium available zinc was found. The available zinc, iron, manganese and copper contents in soils ranged from 0.264 - 1.618 mg/kg, 5.158- 51.820 mg/kg, 1.788- 20.720 mg/kg and 0.324- 3.364 mg/kg respectively. In general, all the micronutrients show decreasing trend with increase in depth. The pH of the collected soil samples showed significant and negative correlation with available iron (r= -0.603*) and manganese (r= -0.524*) whereas pH correlated non-significantly and negatively with available zinc (r= -0.343) and copper (r= -0.484). Soil organic carbon showed significant and positive correlation with all the micronutrients. Non-significant and negative correlation was found between electrical conductivity and available micronutrients except available iron which showed significant and negative correlation with electrical conductivity (r= -0.560*).**

Keywords : Rice fields, Correlation studies, Micronutrient status, physico-chemical properties, Birbhum District, West Bengal

Micronutrient deficiency is a well-documented public health problem in the developing world. Currently, 2 billion people are facing micronutrients deûciency, globally [1]. When micronutrient deficiency is concerned, zinc deficiency comes next after iron deficiency. These micronutrients play important physiological functions, hence their deficiency appears to be a threat to world's population. This can be prevented if the cereals , taken up as dietary intake contains sufficient amount of micronutrients. Hence determining the micronutrient status of soil has become the high priority research area. Along with macronutrients (nitrogen, phosphorus, potassium, sulphur), micronutrients (zinc, iron, manganese, copper) are of immense importance in order to maintain soil health, hence by increasing productivity of crops. Crops not only take nutrients from surface layer but also from sub- surface layer of the soil. Therefore, the knowledge of vertical distribution of nutrients is very important in recommending management practices [2] . The present paper reveals an attempt to understand the vertical distribution of DTPA-Extractable micronutrients and its correlation with soil properties in selected soil profiles of Birbhum district of West Bengal.

Materials and Methods : The geographical area of the district is 4545 sq. Km with 5.12% of the total area of the state. It is the 9th biggest district by area in the state. The district is situated between 23^{0} 32 ' 30" (right above the tropic of cancer) and 24^{0} 35' 0" north latitude and 87^{0} 5' 25" and 88^{0} 1' 40" east longitudes. During summer, the temperature can shoot well above 40^{0} C (104^{0} F) and in winters it can drop to around 10^{0} C (50^{0} F)[3] . The main vegetation of the district is rice. Five selected soil profiles, one each from Sainthia, Suri II, Rampurhat II, Md Bazar and Nalhati I block of Birbhum district of West Bengal were collected from rice growing areas of the district at a depth of 0- 15 cm, 15- 30 cm and 30- 60 cm (Table- 4). These soils were stored and labelled properly in polythene bags, then taken to the laboratory for physico- chemical analyses. The soils were air dried, grinded using porcelain mortar and pestle, sieved through 2 mm sieve. Particle size distribution (relative distribution of sand, silt and clay in soils) and textural class was determined by the method proposed by Bouyoucos[4]. pH, electrical conductivity, organic content of the collected soil samples were determined using standard procedure given by Jackson [5] .

The journal is in the UGC approved list on broad subject category of Multidisciplinary, Science and Social Sciences.

Available zinc, iron, manganese, copper were determined using the method described by Lindsay and Norwell [6]. DTPA extractant (0.005 M Diethylene Triamine Penta Acetic acid + 0.1 M Triethanol amine + 0.01 M $CaCl_2$) were taken in 1:2 soils to extractant ratio, shaken for two hours and filtered. The filtrate was then used for determining zinc, iron, manganese and copper using Atomic Absorption Spectrophotometer (AAS). The relationship between various soil properties and macro- nutrient distribution were established by using simple correlation coefficient. For statistical analysis of data, Microsoft Office Excel 2007 (Microsoft Corporation, USA) and a statistical software IBM SPSS 25.0 (windows version 8.0) packages were used. The level of significance in the results is $P<0.05$. Classification of the soil samples depending on soil pH values and Electrical Conductivity values are given in Table-1 and Table-2 respectively. The rating chart of the micronutrient status of the soil samples are represented in Table- 3.

Results and Discussion: Physico- Chemical Properties of Soil:

Particle size distribution study revealed that among sand, silt and clay, silt was found to be the major fraction in all five locations. Percentage of silt varied from 75.00- 84.00, whereas sand and clay fractions contributed 3.00- 13.50% and 11.50- 15.50% respectively. The textural class was found to be silt loam, silt, silt, silt loam and silt for Suri II, Rampurhat II, Md Bazar, Nalhati I and Sainthia respectively at surface level (Table- 5). With the increase of depth finer fractions (silt and clay) increased whereas % of sand decreased. Similar results were given by Begum *et al*. [7]. Sankar and Dadhwal [2] reported that clay content increased with increasing depth whereas silt and sand distribution pattern observed was irregular. The clay and clay plus silt content increased with depth in pedons showing the migration of finer particles in the pedons in the soils of Cumbum valley, Tamil Nadu[8].

TABLE 1: Classification of Soil pH values

Strongly Acid	Moderately Acid	Slightly Acid	Neutral	Moderately Alkali	Strongly Alkali	Reference
<5.5	5.5- 6.0	6.0- 6.5	6.5- 7.5	7.5- 8.5	>8	Muhr *et al.*[9]

TABLE 2: Classification of total soluble salts (EC dSm^{-1})

No deleterious effect on crop	Critical for germination	Critical for Salt Sensitive Crop	Injurious to most crops	Reference
<1.0	1.0- 2.0	2.0- 3.0	>3.0	Muhr *et al.*[9]

TABLE 3: Rating Chart of Micronutrients in soil required for Plant growth

Parameters	Low	Medium	High	Reference
Organic Carbon (%)	<0.50	0.5- 1.0	>1.0	Muhr *et al.*[9] 1965
Zinc (mg/kg)	<0.8	0.8- 2.0	>2.0	Lindsay and Norvell[6]
Iron (mg/kg)	<4.5	4.5- 10.00	>10.00	Lindsay and Norvell[6]
Manganese (mg/kg)	<5.0	5.0- 10.00	>10.00	Lindsay and Norvell[6]
Copper (mg/kg)	<0.2	0.2-1.0	>1.0	Lindsay and Norvell[6]

TABLE 4: Geographical Locations of the Collected Profile Soil Samples

Serial No	Depth of Soil (cm)	Block	Mouza	Latitude	Longitude
S1	0- 15				
S2	15- 30	Suri II	Purandarpur	23^0 51′	87^0 35′
S3	30- 60				
S4	0- 15				
S5	15- 30	Rampurhat II	Morgram	24^0 80′	87^0 52′
S6	30- 60				
S7	0- 15				
S8	15- 30	Md Bazar	Md Bazar	23^0 58′	87^0 32′
S9	30- 60				
S10	0- 15				
S11	15- 30	Nalhati I	Nalhati I	24^0 16′	87^0 58′
S12	30- 60				
S13	0- 15				
S14	15- 30	Sainthia	Sainthia	23^0 58′	87^0 40′
S15	30- 60				

TABLE 5: Particle Size Distribution and Textural Class of the Profile soils of the Selected Blocks of Birbhum District

Serial No.	Soil Depth (cm)	% Sand	% Silt	% Clay	Textural Class
		Profile 1 (P_1) Suri II			
S1	0- 15	13.50	75.00	11.50	Silt Loam
S2	15- 30	4.50	82.00	13.50	Silt Loam
S3	30- 60	4.00	80.50	15.50	Silt Loam
		Profile 2 (P_2) Rampurhat II			
S4	0- 15	8.10	80.00	11.90	Silt
S5	15- 30	6.30	81.00	12.70	Silt
S6	30- 60	3.40	83.00	13.60	Silt
		Profile 3 (P_3) Md Bazar			
S7	0- 15	6.80	81.20	12.00	Silt
S8	15- 30	5.00	82.50	12.50	Silt
S9	30- 60	3.00	83.00	14.00	Silt
		Profile 4 (P_4) Nalhati I			
S10	0- 15	11.00	76.50	12.50	Silt Loam
S11	15- 30	10.30	76.50	13.20	Silt Loam
S12	30- 60	10.00	76.50	13.50	Silt Loam
		Profile 5 (P_5) Sainthia			
S13	0- 15	5.50	82.60	12.00	Silt
S14	15- 30	4.10	83.00	12.90	Silt
S15	30- 60	3	84	13	Silt

TABLE 6: Chemical Characteristics of the Profile Soils of Selected Blocks at different Depths of Birbhum District

Serial No.	Soil Depth (cm)	pH (1:2.5)	EC (mS/m)	OC (%)	Available Zn (mg/kg)	Available Fe (mg/kg)	Available Mn (mg/kg)	Available Cu (mg/kg)
				Profile 1 (P_1) Suri II				
S1	0- 15	5.012	0.056	0.78	0.618	37.860	7.366	1.808
S2	15- 30	5.462	0.083	0.39	0.332	8.308	6.118	0.468
S3	30- 60	6.035	0.100	0.31	0.264	7.674	3.570	0.332
				Profile 2 (P_2) Rampurhat II				
S4	0- 15	6.461	0.092	0.76	0.726	41.020	10.880	2.484
S5	15- 30	6.788	0.100	0.61	0.704	6.954	2.584	0.604
S6	30- 60	7.067	0.123	0.30	0.426	5.884	1.788	0.452
				Profile 3 (P_3) Md Bazar				
S7	0- 15	5.034	0.054	0.81	1.618	51.820	18.070	3.364
S8	15- 30	5.647	0.067	0.49	0.352	12.616	3.636	0.702
S9	30- 60	6.981	0.075	0.30	0.292	5.158	2.270	0.324
				Profile 4 (P_4) Nalhati I				
S10	0- 15	6.421	0.112	0.82	1.028	32.420	14.924	2.532
S11	15- 30	6.892	0.121	0.45	0.540	6.596	2.202	0.596
S12	30- 60	7.121	0.133	0.20	0.530	5.796	2.118	0.582
				Profile 5 (P_5) Sainthia				
S13	0- 15	5.794	0.071	0.55	0.632	40.280	20.720	3.061
S14	15- 30	6.017	0.086	0.47	0.480	12.754	10.084	0.878
S15	30- 60	6.537	0.100	0.23	0.384	11.632	7.564	0.768

The pH of soils was found to be strongly acidic to neutral as per the limits suggested by Muhr *et al.* [9] . Its value ranged from 5.012- 6.035 in profile 1 (P_1); 6.461- 7.067 in profile 2 (P_2); 5.034- 6.981 in profile 3 (P_3); 6.421- 7.121 in profile 4 (P_4); 5.794- 6.537 in profile 5 (P_5), showing increasing trend with depth (Fig.1; Table- 6). The results are in conformity with the findings of Durak *et. al.* [10] that soil pH increases with depth. The soil pH was found increasing with increasing depth in the red soils of Tamil Nadu [2] .

Electrical conductivity of the topsoil is found to be less probably due to leaching of salt present in the surface layer. Hence, with the increase in depth, electrical conductivity value was found to be higher [10]. Dubey *et al.* [11] ; Katti and Rao [12] reported that the higher electrical conductivity of soils is due to accumulation of salts in the soils. Electrical conductivity value ranged from 0.056- 0.100 mS/m in profile 1 (P_1); 0.092- 0.123 mS/m in profile 2 (P_2); 0.054- 0.075 mS/m in profile 3 (P_3); 0.112- 0.133 mS/m in profile 4 (P_4); 0.071- 0.100 mS/m in profile 5 (P_5), indicating no salinity hazards (Fig.2; Table- 6).

Organic carbon value is found be the highest at surface level and its value decreased with increasing depth [13] . Its value ranged from 0.31- 0.78% in profile 1 (P_1); 0.30-0.76% in profile 2 (P_2); 0.30- 0.81% in profile 3 (P_3); 0.20- 0.82% in profile 4 (P_4); 0.23- 0.55% in profile 5 (P_5) (Fig.3; Table- 6). Patangray *et. al.* [14] reported that organic carbon content decreased gradually with an increase in depth, which is mainly due to the accumulation of plant residues on the soil surface and less movement down the profile due to rapid rate of mineralization at higher temperature and adequate soil moisture level. Similar results were observed by Sarkar *et al*.[15]; Nayak *et al*.[16]; Rao *et al*.[17]. Sankar and Dadhwal [2] reported that the organic carbon content decreased with increasing depth in the red soils of Tamil Nadu. Organic carbon content was low (0.15 to 0.69 %) and decreased with depth in pedons in the soils of Cumbum valley, Tamil Nadu [8].

Micronutrient Status of Soil: Available zinc content of the rice growing soils ranged from 0.264- 0.618 mg/kg in profile 1 (P_1); 0.426- 0.726 mg/kg in profile 2 (P_2); 0.292- 1.618 mg/kg in profile 3 (P_3); 0.530- 1.028 mg/kg in profile 4 (P_4); 0.384- 0.632 mg/kg in profile 5 (P_5) (Fig.4; Table- 6). Singh *et al*.[18] ; Sharma and Lal [19] reported that the higher amount at the surface layer was related to higher organic carbon content of the soils due to regular addition of plant residues. Similar results were obtained by Tiwari and Mishra [20] ; Krishnamurthy and Srinivasamurthy [21] ; Chidanandappa *et al*.[22] . Sen *et al*.[23] reported the available zinc content decreased down the profile. On the basis of the critical limits as suggested by Lindsay and Norwell [6] all the soil samples at surface level were found to contain low to medium available zinc, whereas available zinc was found be low at lower depths. Available zinc value showed decreasing trend with soil depth. Nagendran and Angayarkanni [8] observed that the DTPA extractable zinc content in

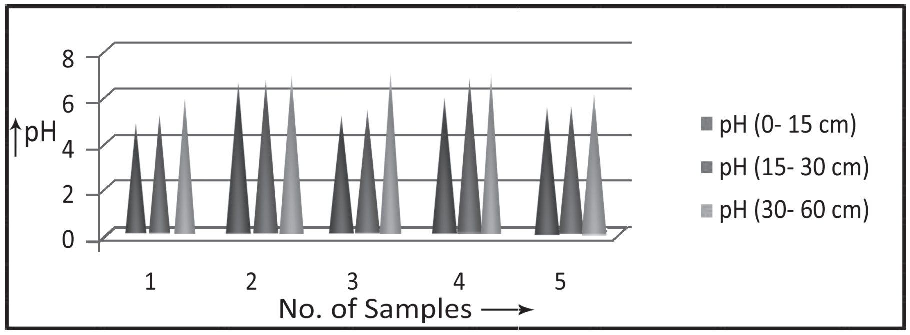

Fig. 1: Soil pH of selected blocks at different depths

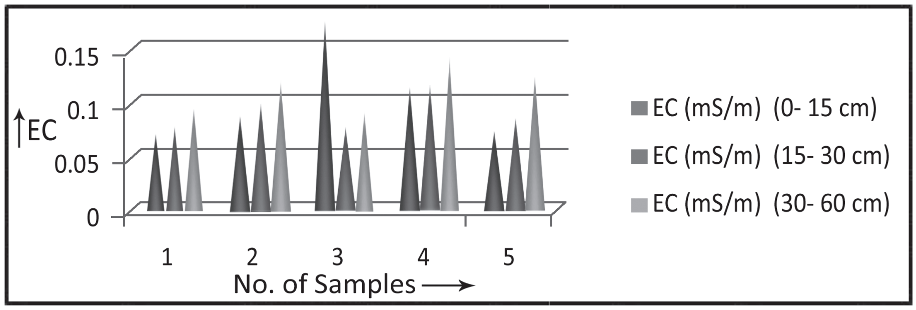

Fig. 2: EC (mS/m) of Soils of selected blocks at different depths

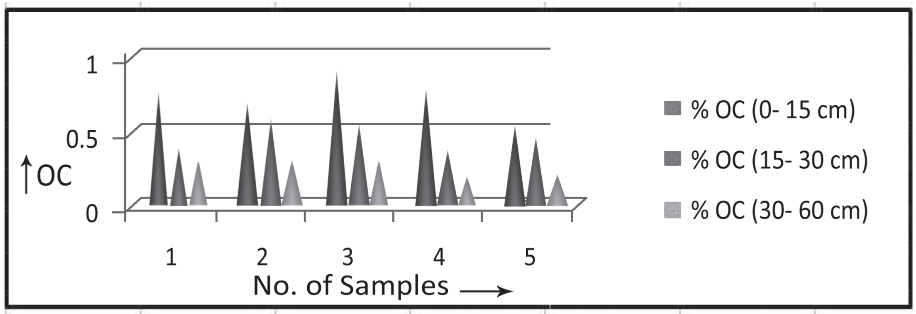

Fig. 3: OC (%) of Soils of selected blocks at different depths

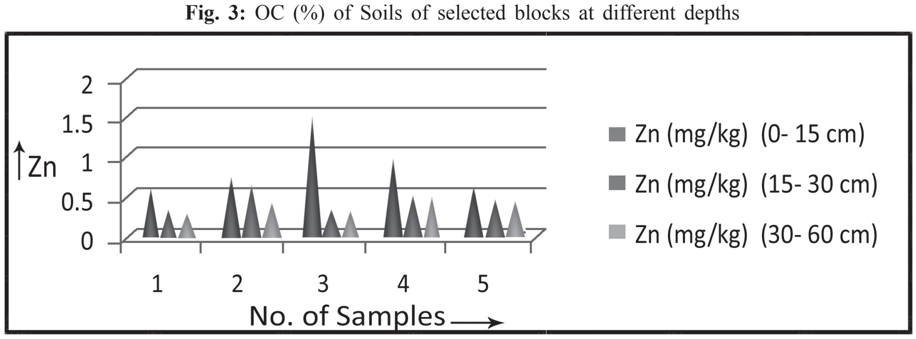

Fig. 4: Available Zinc (mg/kg) of Soils of selected blocks at different depths

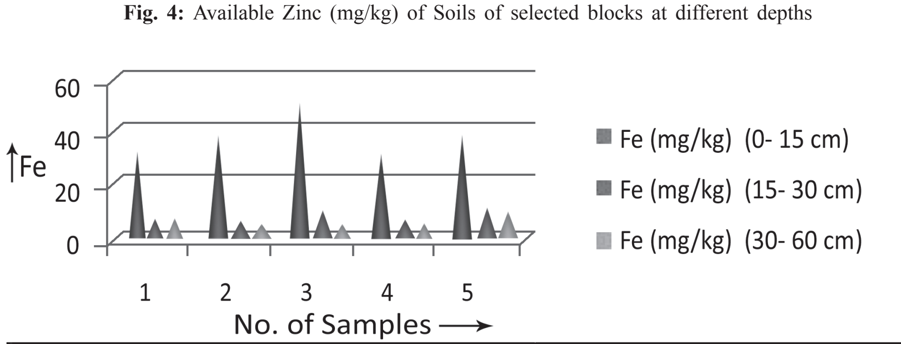

Fig. 5: Available Iron (mg/kg) of Soils of selected blocks at different depths

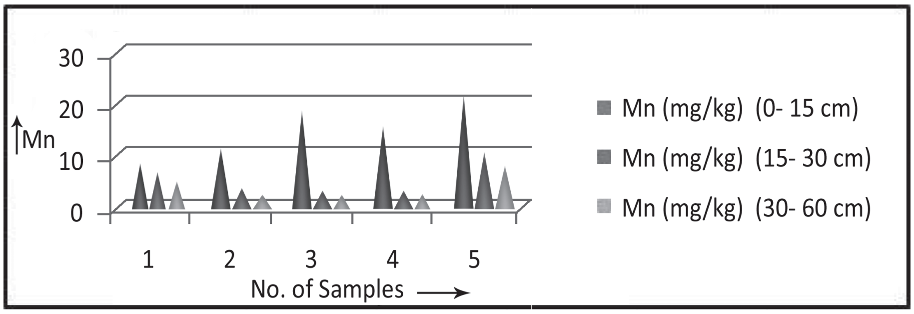

Fig. 6: Available Manganese (mg/kg) of Soils of selected blocks at different depths

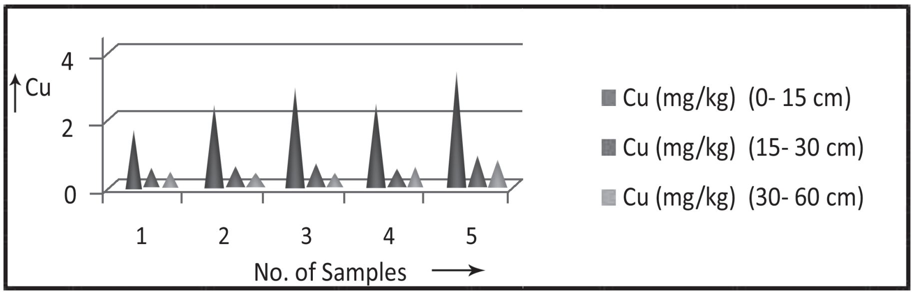

Fig. 7: Available Copper (mg/kg) of Soils of selected blocks at different depths

the pedons of the soils of Cumbum Valley, Tamil Nadu varied between 0.13 and 0.90 mg kg^{-1}. Considering the critical limits of available zinc as suggested by Lindsay and Norwell[6] all the soils were uniformly deficient in subsoil layers. The decreasing zinc content with increase in depth in pedons might be due to the quick fixation of zinc in organo-clay complex in the surface horizons and the slow vertical mobility of this cation down the profile. Similar interpretations were made by Katyal and Sharma[24]. Sharma and Chaudhary [25] reported decreasing trend of available Zn from surface to subsurface horizons. Sharma *et al*. [26] observed that the DTPA-extractable zinc decreased with the depth of pedons in all the plains due to the difference in the distribution of organic carbon down the depth.

The iron content of the soils ranged from 7.674- 37.860 mg/kg in profile 1 (P_1); 5.884- 41.020 mg/kg in profile 2 (P_2); 5.158- 51.820 mg/kg in profile 3 (P_3); 5.796- 32.420 mg/kg in profile 4 (P_4); 11.632- 40.280 mg/kg in profile 5 (P_5) (Fig.5; Table- 6). On the basis of critical limits suggested by Lindsay and Norvell [6] for DTPA extractable iron (4.5 ppm), all the soil samples were found to be having high iron content at surface and sub- surface levels. Although soils were found to be having slightly lower iron value than the critical limit at lower depth. Prasad and Sakal [27] reported that the higher amount of available iron might be due to the presence of organic matter. This indicates that organic matter influenced the solubility and availability of iron which might be due to the chelation of iron which protects itself from oxidation and precipitation of available iron into unavailable form with a consequence of increasing its availability in the soil. Therefore, the distribution pattern of DTPA-extractable iron followed the pattern of distribution of organic carbon which might be attributed to their regular addition through crop residues on the surface [20]. Iron content of the soils were found to decrease with increase in depth of soil (follows the same trend that of organic carbon content of the soil) confirming the fact that micronutrients are more available at surface level. Satish *et al*. [28] reported that the distribution of available iron in all the pedons show a decreasing trend with depth. The surface horizons contain more iron than sub-surface horizons.

Manganese content were also found to decrease with increase in depth of soil. Manganese content of the soils varied from 3.570- 7.366 mg/kg in profile 1 (P_1); 1.788- 10.880 mg/kg in profile 2 (P_2); 2.270- 18.070 mg/kg in profile 3 (P_3); 2.118- 14.924 mg/kg in profile 4 (P_4); 7.564- 20.720 mg/kg in profile 5 (P_5) (Fig.6; Table- 6). All the soil samples at surface level were found to contain high available manganese value[6]. Satish *et al*.[28] reported that all the pedons showed decreasing trend with depth which might be due to higher biological activity and organic carbon in the surface horizons, the higher content of available manganese in surface soils was attributed to the chelating of organic compounds released during the decomposition of organic matter left after harvesting of crop. Athokpam *et al*.[29] reported that the surface soils contain higher manganese value and decreased with increase in depth[30,31,32]. Sharma *et al*.[26] reported that DTPA extractable manganese decreased down the depth of pedons. Variation in manganese down the depth may be attributed to the difference in the distribution of organic carbon, silt plus clay and carbonates in different plains. Sharma and Chaudhary [25] also reported decreasing trend down the depth of available manganese in Solan district of Himalaya.

Copper content ranged from 0.332- 1.808 mg/kg in profile 1 (P_1); 0.452- 2.484 mg/kg in profile 2 (P_2); 0.324-

3.364 mg/kg in profile 3 (P_3); 0.582- 2.532 mg/kg in profile 4 (P_4); 0.768- 3.061 mg/kg in profile 5 (P_5) (Fig.7; Table-6). On the basis of critical limits of copper (0.2 ppm) by Lindsay and Norvell[6], all five soil profiles were found to be sufficient in available copper. The DTPA extractable copper content in the pedons ranged from 0.14 to 1.32 mg kg^{-1} and decreased with depth in all pedons and the soils were found deficient in available copper considering 1.2 mg kg^{-1} as critical limit for copper [8, 9]. Sharma *et al.* [33] reported that the content of zinc and copper were, in general, higher in the surface layers and decreased with depth. Athokpam *et al.* [29] observed that the DTPA-extractable copper content was higher in the surface soils and decreased gradually in all the profiles. Similar results were also reported by Gupta *et al.* [30] and Verma *et al.* [31].

Patangray *et. al.*[14] observed higher content of micronutrients in surface horizons, which may be due to the higher amount of organic carbon content, which is ascribed to increase the solubility of micronutrient cations from soil material. Decomposition of organic material releases micronutrients and reduces pH locally, which assists in mineral solubility[34]. Satish *et al.*[28] reported that the variation observed in available micronutrients within and among the profiles might be the result of variable intensity of different pedogenic processes taking place during soil development. They further reported that, organic matter has been reported to play an important role in controlling the availability of micronutrients in soils. Organic matter and manure applications affect the immediate and potential availability of micro- nutrient cations [35].

Relationship between DTPA extractable zinc and soil properties: Correlation between soil physico-chemical properties and available zinc is listed in Table - 7. Available zinc correlated non- significantly and negatively with pH (r= -0.343). This implies that available zinc decreases with increase in soil pH. This is due to the formation of insoluble zinc hydroxide $Zn(OH)_2$ which is not soluble in soil solution, hence not available for the take up by plants. Patangray *et. al.* [14] reported non-significant and negative correlation between available zinc and soil pH (r= -0.71) in soils of Yavatmal district, Maharashtra. Similar results were given by Meena and Mathur [36] (r= -0.265) in the soils of Ghatol tehsil, Banswara district of Rajasthan, Kumar *et al.* [37] (r= -0.15) in the soils of Chamarajanagar district, Karnataka. Tundup and Akbar [38]; Mandavgade *et al.*[39]; Rai *et al.*[40], ; Kumar *et al.*[41], showed similar relation.

Between available zinc and electrical conductivity, non- significant and negative correlation was observed (r= -0.258). Similar results were given by Aich *et al.* [42] (r= -0.101) in the soils of Pune; Patangray *et. al.* [14] (r= -0.36) in soils of Yavatmal district, Maharashtra. Available zinc showed non- significant, negative correlation with electrical conductivity (r= -0.045) [43]. Meena and Mathur[36] ; Kumar *et al.*[41] reported similar relationship (r= -0.036).

Available zinc showed significant and positive correlation with soil organic carbon (r= 0.744**). This significant and positive correlation can be explained by considering the fact that organic matter reacts with zinc and forms soluble organo- zinc complexes, which are readily plant available. Similar observations were reported by Katyal and Sharma[24]; Chitdeshwari and Krishnaswamy[44]; Chidanandappa[45]. Minakshi *et al.*[46] also found the same findings in soils of Patiala district of Punjab. Nagendran and Angayarkanni[8] reported significant and negative correlation between available zinc and pH (r= -0.41**) and a significant and positive correlation with organic carbon(r = 0.70**) in the soils of Cumbum valley, Tamil Nadu. Athokpam *et al.* [47] reported significant and positive correlation between available zinc and soil organic carbon (r= 0.708**) in the soils of Senapati district,

TABLE 7: Correlation Coefficients between Physico- Chemical Properties and Micronutrient Status of soils

Soil Properties	pH	EC (mS/m)	% OC	Available Zn (mg/kg)	Available Fe (mg/kg)	Available Mn (mg/kg)	Available Cu (mg/kg)
pH	1						
EC (mS/m)	0.821**	1					
% OC	-0.519*	-0.468	1				
Available Zn (mg/kg)	-0.343	-0.258	0.744**	1			
Available Fe (mg/kg)	-0.603*	-0.560*	0.822**	0.759**	1		
Available Mn (mg/kg)	-0.524*	-0.459	0.618*	0.664**	0.854**	1	
Available Cu (mg/kg)	-0.484	-0.442	0.785**	0.799**	0.970**	0.920**	1

*. Correlation is significant at the 0.05 level. **. Correlation is significant at the 0.01 level.

Manipur. Available zinc showed significant and positive correlation with other micronutrient cations. This result is also supported by the finding of Bassirani *et al*. [48]; Tundup and Akbar [38]; Rai *et al*., [40]; Kumar *et al*. [41]. Sharma *et al*. [26] reported the significant positive correlation between available zinc and organic carbon (r= 0.721**).

Relationship between DTPA extractable iron and soil properties: Correlation between soil physico- chemical properties and available iron is listed in Table-7.

Available iron showed significant and negative correlation with soil pH (r= -0.603*). This indicates that with the increase of soil pH, solubility of iron in soil decreases i.e. the precipitation of soluble iron into insoluble products. Similar results were also reported by many workers [46, 49, 50, 51, 52, 53]. High pH is responsible for the oxidation of Fe^{2+} to Fe^{3+}. Reduction in the availability of iron with increasing pH might be attributed to conversion of Fe^{2+} to Fe^{3+} ions. Oxidation causes the precipitation of iron as insoluble $Fe(OH)_3$ (iron hydroxide), hence, reduction in the availability of iron in soil solution. Nagendran and Angayarkanni [8] reported significant and negative correlation between available iron and pH (r= -0.53**). Sharma *et al*. [25] reported significant negative correlation between available iron and pH (r = - 0.420**). Similar results were given by Sharma *et al*. [33] in the soils of Rajasthan. Results given by Reshma et al. [43] revealed that the soil reaction (pH) of Salem district, Tamilnadu had significant negative correlation with availability of iron (r= -0.254**). Kumar *et al*. [37] observed similar result (r= -0.50**) in the soils under paddy land use in Chamarajanagar district, Karnataka. Similar observations have been shown by different scientists [38, 54, 40]. Available iron correlated significantly and negatively with electrical conductivity (r= -0.560*). Similar relationship was obtained by Sharma *et al*. [55] in soils of Leh district of cold arid region of Ladakh.

Available iron correlated significantly and positively with organic carbon (r= 0.822**). This indicates that available iron content of the soil increases with the increase in organic matter of the soil. This can be explained by considering the fact that organic matter in soil prevents the oxidation of ferrous to ferric ion and supply soluble chelating agents which increase the solubility of iron compounds. Yadav and Meena [56] also reported similar relationship in Degana soil series of Rajasthan. These results are in agreement with Khalifa *et al*. [57]. The organic matter reacts with iron and forms soluble organo-iron complexes, which prevent the iron from fixation by soil constituents. Similar observations were noticed by Katyal and Sharma [24]. Satish *et al*. [28] reported significant and positive correlation of available iron with organic carbon (r = +0.477**) and negative and significant correlation with pH (r = -0.345**). These findings were in good agreement with those of Sarkar *et al*. [58]. Athokpam *et al*. [47] reported significant and positive correlation between available iron and soil organic carbon (r= 0.836**), available manganese (r= 0.849**), available copper (r= 0.768**), available zinc (r= 0.720**) in the soils of Senapati district, Manipur.

Relationship between DTPA extractable manganese and soil properties: Correlation between soil physico-chemical properties and available manganese is listed in Table-7. It can be observed that like other micronutrients zinc and iron, copper and manganese also decrease with the increase in soil pH. These results are supported by different workers [59, 60, 61, 62]. Manganese correlated significantly and negatively with pH (r= -0.524*), indicating the formation of insoluble higher valent oxides of manganese at higher pH. Kumar *et al* [63] showed negative significant correlation of available manganese with soil pH in Dumka series in soils of Santhal Paraganas region of Jharkhand. Nagendran and Angayarkanni [8] reported significant and correlation between available manganese and pH (r= -0.58**). Patangray *et. al*. [14] reported that with the increasing soil pH Mn^{2+} is converted into its higher oxides (Mn^{3+} and Mn^{4+}) which are insoluble in water, might be the reason for decreasing concentration of available manganese with increasing pH. Similarly the solubility of manganese bearing minerals like Pyrolusite, manganite etc. increase with decreasing pH resulting in greater release of Mn^{2+} in soil solution showed by Das [64]. These results are in agreement with the findings of several scierntists of India[33,56,60,62,65,66,67,68]. Sharma *et al*.[26] reported that, significant negative correlation was found between available manganese and pH (r = - 0.288**). A significant positive correlation was noted between manganese and organic carbon (r = 0.612**). The availability of manganese (r= -0.084**) showed significant negative correlation with soil pH in the soils of Salem district, Tamilnadu[43]. Similar results were also shown[38,40,41,54].

Non- significant and negative correlation was found between available manganese content and electrical conductivity (r= -0.459). Similar result was given by Patangray *et. al*. [14] (r= -0.57) in soils of Yavatmal district, Maharashtra. Availability of manganese (r= -0.006) showed non- significant negative correlation with electrical conductivity [43]. Rai *et al*. [40] and Kumar *et al*. [41] gave similar relationship.

Manganese correlated significantly and positively with soil organic carbon (r= 0.618*). Similar results were obtained by Khattak *et al*. [69] and Chinchmalatpure *et al*.[62].

Available manganese content of the soil showed increase with increase in organic matter of the soil. This might be due to the influence of organic carbon on the solubility and availability of manganese which protects itself from oxidation and precipitation of available manganese into unavailable form. Sharma *et al*. [55] reported that the available manganese was positively correlated (r=0.029) with organic carbon. Athokpam *et al*. [47] also reported significant and positive correlation between available manganese and soil organic carbon (r= 0.788**), available copper (r= 0.826**), available zinc (r= 0.760**) in the soils of Senapati district, Manipur (India). Soil micro-nutrient cations like iron, copper and zinc have significant correlation with available manganese, suggesting variation in their distribution dependent upon common soil factors[70]. Reshma *et al*. [43] reported significant positive correlation between organic carbon and available manganese (r= 0.052*).

Relationship between DTPA extractable copper and soil properties: Correlation between soil physico-chemical properties and available manganese is listed in Table- 7. Copper correlated non- significantly and negatively with pH (r= -0.484). This relationship can be explained by considering the fact that at higher pH, copper precipitates as copper hydroxide $Cu(OH)_2$ which is not readily available to the plants. Patangray *et. al*. [14] reported non- significant and negative correlation between available zinc and pH (r= -0.89) in soils of Yavatmal district, Maharashtra. The availability of copper (r= -0.030) showed non- significant negative correlation with soil pH in the soils of Salem district, Tamilnadu [43]. Meena and Mathur [36] reported similar relationship between pH and available copper (r= -0.056). Results were in conformity with that obtained by others [39, 41].

Available copper and electrical conductivity correlated significantly and negatively (r= -0. 442). Similar results were given by Aich *et al*. [42], (2017) (r= -0.137) in the soils of Pune; Patangray *et. al*. [14] (r= -0.54) in soils of Yavatmal district, Maharashtra. Bharteey *et al*. [71] reported that electrical conductivity correlated non- significantly and negatively with available copper (r= -0.179), available manganese (r= -0.149), available zinc (r= -0.029) in the soils of Narayanpur block, district Mirzapur, Uttar Pradesh. Mandavgade *et al* [39] and Kumar *et al*. [41] gave similar relationship.

Available copper and organic carbon correlated significantly and positively (r= 0.785**). This can be explained by considering that organic matter increases the availability of copper by forming soluble complexing agents which decreases the formation of insoluble copper complexes. Similar relationship was obtained by Minakshi *et al*. [46]. Nagendran and Angayarkanni [8] reported significant negative correlation between available copper and pH (r = -0.33*) and significant and positive correlation between available copper and soil organic carbon (r = 0.44**). These results are in agreement with the observations of Dhane and Shukla [52]; Chattopadhyay *et al*. [59]. Patangray *et. al*. [14], reported non- significant and negative correlation between soil pH and iron (r = -0.96), manganese (r = -0.97), zinc (r = -0.71) and copper (r = -0.89). Sharma *et al*. [33] reported that pH correlated significantly and negatively with available zinc (r= -0.86*), available copper (r= -0.87*), available iron (r= -0.94*), available manganese (r= -0.95*). Organic carbon and all the micronutrients correlated significantly and positively [54] in soils of Jhotwara panchayat samiti of Jaipur district. Tundup and Akbar [38]; Rai *et al*. [40] gave similar relationship. Chandrakar *et al*. [72] reported significant and positive correlation between organic carbon and all the micronutrients.

All the micronutrients correlated significantly and positively with each other. Patangray *et al*. [14] reported non-significant and positive correlation between soil orgnic carbon and available iron (r = 0.34), available manganese (r= 0.33), available zinc (r= 0.61) and available copper (r = 0.51). The non-significant and positive correlation between soil organic carbon and available iron content might be due to formation of iron chelates by organic matter, release of iron from organic complexes, acidulating action of soil organic carbon and decrease in soil pH thus increasing the solubility of iron complexes. The results are in accordance with the observations of Nazif *et al*. [73] and Bhat *et al*.[74].

Conclusion: The fertility status of the collected soil profiles of Birbhum district showed that the pH was strongly acidic to neutral, electrical conductivity was within normal limits, low to medium in organic carbon content, available zinc was low to medium in the surface layer whereas low value was recorded at lower depths, high available iron content was registered at surface and sub-surface level, lower iron content was recorded with increasing depth, high manganese content was noticed at surface level, soil profiles showed low to medium available copper content. The decreasing trend of these micronutrients content down the profile was observed in all soils. From the study conducted in the soils of Birbhum district, it was found that soil pH significantly and negatively correlated with available iron, manganese, copper whereas non- significant and negative correlation was registered between available zinc and pH. Electrical conductivity correlated non- significantly and negatively with DTPA extractable micronutrients except available iron. Significant and negative correlation was found between electrical conductivity and available iron. Organic carbon content correlated significantly and positively with all the available micronutrients. The information of the present study could be useful in micronutrient fertilization strategy for both shallow and deep rooted crops of red and lateritic soils of West Bengal. ❒

SUNANDANA MANDAL, SHREYA MONDAL, ANANYA MUKHERJEE, SOUMI MUKHOPADHYAY AND GOUTAM KUMAR GHOSH

Department of Soil Science and Agricultural Chemistry
Palli Siksha-Bhavana, Visva-Bharati
Sriniketan -731236, West Bengal
Email: sunandana7373@gmail.com

Received : 01 April, 2019

Revised : 14 June, 2019

1. G. Velu, I. Ortiz-Monasterio, I. Cakmak, Y. Hao, and R.P. Singh, *J. Cereal Sci.* **59**, 365–372 (2014).
2. M. Sankar, and K.S. Dadhwal, *Asian Journal of Soil Science*, **4(1),** 118-120 (2009).
3. D. Mondal, Ek Najare Birbhum Jela, Paschim Banga, Birbhum Special Issue (in Bengali, 2006).
4. G.J. Bouyoucos, *Soil Sci*., **23**, 343-353 (1927).
5. M.L. Jackson, Soil Chemical analysis (Prentice Hall of India Pvt. Ltd., New Delhi, 1973).
6. W.L. Lindsay and W.A. Norvell, *Soil Sci. Soc. America J.* **42**, 421–428 (1978).
7. K. Begum, F. Hossain and Z. Parveen, *Dhaka Univ. J. Biol. Sci.* **25(1)**, 19- 25 (2016).
8. T. A. Nagendran and A. Angayarkanni, *Agric. Sci. Digest.,* **30 (2),** 79- 84 (2010).
9. G.R. Muhr, N.P. Datta, H. Sankarasubramoney, V.K. Laley and R.L. Donahue, In Soil Testing in India (USAID Mission to India,2nd Edition, New Delhi, 1965).
10. A. Durak, E. Buyukguner and H.M. Dogan, *Asian Journal of Chemistry,* **22(8)**, 6375-6386.
11. D.P. Dubey, G.P. Verma and O.P. Sharma, *Curr. Agric*., **7**, 129-137 (1983).
12. V.M. Katti and J.S. Rao, *Mysore Agric. J.,* **66**, 192-194(1979).
13. A.O. Oladoye, *Journal of Research in Forestry, Wildlife and Environmental,* **7(1),** 117-125 (2015).
14. A.J. Patangray, N.G. Patil, A.R. Pagdhune, S.K. Singh and V.N. Mishra, *Journal of Pharmacognosy and Phytochemistry*, **7(6)**, 2799-2805 (2018).
15. D. Sarkar, S.K. Gangopadhyay and M. Velayutham, *Agropedology*, **11**, 29-36 (2001).
16. A.K. Nayak, G.C. Sahu, and S.K. Nanda, *Agropedology*, **12**,1-8 (2001).
17. A.P. Rao, V. Prasad, M.V.S. Naidu, N. Ramavatharam and G. Rama, Rao, *J. Indian Soc. Soil Sci*., **56(1),** 23-33(2008).
18. K. Singh, R.L. Ahuja and M. Singh, *J. Indian Soc Soil Sci*., **36**, 828-832 (1988).
19. S.K. Sharma and F. Lal, *J. Indian Soc. Soil Sci.,* **40(2)**, 393-394 (1992).
20. J.R. Tiwari and B.B. Mishra, *J. Indian Soc. Soil Sci*., **38**, 319-321(1990).
21. R. Krishnamurthy and C.A. Srinivasamurthy, *Mysore J. Agric. Sci.,* **39(1)**, 57-63 (2005).
22. H.M. Chidanandappa, G.S. Yogesh, K.T. Gurumurthy and B.L. Shivaprakash, *Mysore J. Agril. Sci*., **42(2),** 247-250 (2008).
23. T.K. Sen, P.N. Dubey, A.K. Maji and G.S. Chamuah, *J. Indian Soc. Soil Science*. **45**, 388-390 (1997).
24. J.C. Katyal and B.D. Sharma, *Geoderma*, **49**, 165-179 (1991).
25. J.C. Sharma and S.K. *J. Indian Soc. Soil Sci.* **55**, 40-44 (2007).
26. R.P. Sharma, R.S. Singh and S. S. Sharma, *International Journal of Pharmaceutical and Chemical Sciences*, **2(3)**, 1377-1389 (2013).
27. R. Prasad and B.P. Sakal, *J. Indian Soc. Soil Sci.,* **39**, 658-661 (1991).
28. S. Satish, M.V.S. Naidu and K.V. Ramana, *International Journal of Chemical Studies* **6(5),** 2916-2925 (2018).
29. H.S. Athokpam, K.S. Singh, N. Chongtham, K.N. Devi, N.B. Singh, A. Sanatomba and P.T. Sharma, *Int. J. Curr. Microbiol. App. Sci.* **7(8),** 4222-4227 (2018).
30. N. Gupta, S.K. Trivedi, K.N. Bansali and R.K. Kaul, *J. Indian Soc. Soil Sci.* **51**, 517-522 (2003).
31. V.K. Verma, R. K. Setia, P. K. Sharma, M.P.S. Khurana and S. Kang, *J. Indian Soc. Soil Sci.* **55**, 515-520 (2007).
32. H.S. Athokpam, V.S. Zimik, N. Chongtham, K.N. Devi, N.B. Singh, L. Watham, P.T. Sharma and H. Athokpam, *International Journal of Agriculture, Environment and Biotechnology,* **9(4),** 691-697 (2016).
33. S.S. Sharma, K.L. Totawat and R.L. Shyampura, *Agropedology*, **15(1),** 51-54 (2005).
34. M.D. Khanday, D. Ram, J.A. Wani and T. Ali, *Int. J. Curr. Microbiol. App. Sci.,* **6(4),** 375-381 (2017).
35. Z. Rengel, Nutrient Cycling in Terrestrial Ecosystem (Springer-Verlag, Berlin, Heidelberg, 2007) p.121.
36. R.S. Meena and A.K. Mathur, *Int. J. Curr. Microbiol. App. Sci*., **6(7**), 102-108 (2017).
37. M. Kumar, C.T. Subbarayappa, and V. Ramamurthy, *Int. J. Curr. Microbiol. App. Sci.,* **6(5),** 1423-1428 (2017).
38. P. Tundup and A. Akbar, *Asian eJournal of Soil Science* , **9(1**), 59-62 | ISSN–0976–7231(2014).
39. R.R. Mandavgade, S.L. Waikar, A.L. Dhamak, and V.D. Pati, *Journal of Agriculture and Veterinary Science*, **8(2),** 38-41(2015).
40. A.P. Rai, P. Tundup, A.K. Mondal, V. Kumar, A. Samanta, M. Kumar, R.K. Arora and M.C. Dwivedi, *Int. J. Curr. Microbiol. App. Sci,* **7(1),** 3596-3602 (2018).
41. M. Kumar, S. Yadav and R. Mangilal, *International Journal of Chemical Studies*, **6(1**), 527-530 (2018).
42. V. Aich, N.B. More, S.K. Udayana and G.D. Patil, *Int. J. Curr. Microbiol. App. Sci.*, **6(8**), 855-861 (2015).
43. M.R. Reshma, V.P. Duraisami, D. Muthumanickam, S. Purma and N. Jayasoorian, *International Journal of Agricultural Science and Research*, **6(1**), 247-252 (2016).
44. T. Chitdeshwari and R. Krishnaswamy, *J. Indian Soc. Soil Sci*., **45(4),** 774-778 (1997).
45. H.M. Chidananadappa, Ph. D. Thesis (UAS, Bangalore, 2003).

46. N.S. Minakshi, V.K. Tur, P. Nayyar, K. Sharma and A.K. Sood, *J. Indian Soc. Soil Sci.,* **53(3**), 324-329 (2005).

47. H. Athokpam, S.H. Wani, D. Kamei, H.S. Athokpam, J. Nongmaithem, D. Kumar, Y.K. Singh, B.S. Naorem, T.R. Devi and L. Devi, *Afr. Jour. Agric. Res.,* **8,** 4932-4936 (2013).

48. N. Bassirani, M. Abolhassani and M. Galavi, *Afr. Jour. Agric. Res*., **6**: 4239-4242 (2011).

49. G.C. Hazra, and B. Mandal, *J. Indian Soc Soil Sci*., **36**, 169-179 (1988).

50. R.M. Yerriswamy, M.Sc. Thesis (UAS, Dharwad, 1988).

51. A.K. Sahoo, K.D. Sah and S.K. Gupta, *Indian Agriculturist*, **33(3**), 141-146 (1989).

52. S.S. Dhane and L.M. Shukla, *J. Indian Soc. Soil Sci*., **43(4**), 597-600 (1995).

53. S. Vadivelu and A.K. Bandyopadhyay, *J. Indian Soc. Soil Sci*., **43(1**), 133-134 (1995).

54. K.K. Choudhary, B.L. Yadav, K.K. Sharma, R.D. Jat and S.K. Kakraliya, *Int. J. Curr. Microbiol. App. Sci.,* **6(3**), 88-96 (2017).

55. V.K. Sharma, S.K. Dwivedi, D. Tripathi and Z. Ahmed, *J. Indian Soc. Soil Sci*., **54(2**), 248-250 (2006).

56. R.L. Yadav and M.C. Meena, *J. Indian Soc. Soil Sci*., **57(1),** 90-92 (2009).

57. E.M. Khalifa, M.A. El-Desoky, M. A. Gameh and M.E. Faragallah, *Assiut J. Agric. Sci.,* **27(3)**, 107-127 (1996).

58. D. Sarkar, A. Haldar, A. Majumdar and M. Velayutham, J. *Indian Soc. Soil Science,* **48**, 202-205 (2000).

59. T. Chattopadhyay, A.K. Sahoo, R.S. Singh, and R.L. Shyampura, *J. Indian Soc. Soil Sci.*, **44(4),** 678-681 (1996).

60. G.R. Rajakumar, C.V. Patil, S.S. Prakash, N.A. Yeledhalli and K.K. Math, *Karnataka J. Agric. Sci.,* **9(2),** 231-235 (1996).

61. S. Chatterji, D. Sarkar, T.H. Das and A.K. Haldar, *J. Indian Soc. Soil Sci*., **47(3**), 463-465 (1999).

62. A.R. Chinchmalatpure, R. Brijlal, O. Challa and J. Sehgal, *Agropedol*., **10(1),** 53-58 (2000).

63. R. Kumar, A.S. Sarkar, K.P. Singh, B.K. Agarwal and S. Karmakar, *J. Indian Soc. Soil Sci.,* **57(3**), 366-369 (2009).

64. D.K. Das,, Micronutrients: their behavior in soils and plants (Kalyani publishers, 2000).

65. R.P Sharma, M. Singh and J.P. Sharma, *J. Indian Soc. Soil Sci*., **51(4**), 522-527 (2003).

66. B.K. Yadav, *Academic J. Plant sciences*, **8**, 29-51 (2011).

67. G.S. Sidhu and B.D. Sharma, *Communications in soil science and plant analysis*, **41(1**), 29-51 (2010).

68. D. Khadka and S. Lamichhane, *Int. J. Agri. Innov. Res*., **4(5**), 2319-1473 (2017).

69. J.K. Khattak, M. Sharif, and S. Naz, *Sarhad J. Agric.,* **10(4),** 451-460 (1994).

70. R.H. Follect and W.L. Lindsay, *Tech. Bullet. Colorado*, **110**, 79 (1970).

71. P.K. Bharteey, Y.V. Singh, P.K. Sukirtee, M.K. Sharma and A.K. Rai, *Int. J. Curr. Microbiol. App. Sci.* **6(7),** 2829-2837 (2017).

72. K. Chandrakar, L.K. Srivastava and D. Devdas, Asian J. of Soil Science. 8: 416-418 (2013).

73. W. Nazif, S. Perveen and I. Saleem, *J. Agricul. Biol. Sci*.; **1(2),** 35-40 (2006).

74. Z.A. Bhat, S.A. Padder, A.Q. Ganaie, N.A. Dar, H.U. Rehman and M.Y. Wani, *Journal of Pharmacognosy and Phytochemistry*, **6(2),**181-185 (2017).