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AJ Patangray
Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

NG Patil
ICAR-National Bureau of Soil Survey and Land Use Planning, Nagpur, Maharashtra, India

AR Pagdhune
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

SK Singh
ICAR-National Bureau of Soil Survey and Land Use Planning, Nagpur, Maharashtra, India

VN Mishra
Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Correspondence
AJ Patangray
Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Vertical distribution of soil nutrients and its correlation with chemical properties in soils of Yavatmal district, Maharashtra

AJ Patangray, NG Patil, AR Pagdhune, SK Singh and VN Mishra

Abstract

The application of fertilizers in site-specific crop production systems requires a detailed knowledge of the soil nutrient status. A detailed soil survey at 1:10000 scale in a Kupti micro-watershed (District Yavatmal, Maharashtra) revealed a considerable spatial variation of the nutrient levels. Ten soil series were tentatively identified after the survey and analysis. A representative pedon in soil series was analyzed for pH, electrical conductivity, organic carbon, calcium carbonate, cation exchange capacity, available nitrogen, available phosphorus, available potassium, available sulphur and DTPA-extractable micronutrients (Fe, Mn, Zn & Cu) using standard analytical methods. Based of fertility ratings, pH of soils was slightly acidic to strongly alkaline. Electrical conductivity was normal (<1.0 dS/m). Soil organic carbon was low to high and showed decreasing trend with depth. All soils are calcareous. Zinc was found below critical level whereas; iron, manganese and copper were estimated to occur above critical level. The pH of soil showed non-significant and negative correlation with nitrogen (r = -0.36), non-significant and positive correlation with phosphorus (r = 0.06), potassium (r = 0.11), sulphur (r = 0.25) and significant and negative correlation with iron (r = -0.96), manganese (r = -0.97), zinc (r = -0.71) and copper (r = -0.89). Soil organic carbon shows significant and positive correlation with nitrogen (r = 0.63), zinc (r = 0.61) and copper (r = 0.51) whereas it was non-significant and positive with all other nutrients. Calcium carbonate content of soil showed significant and negative correlation with nitrogen (r = -0.65), iron (r = -0.61), manganese (r = -0.61), zinc (r = -0.60) and copper (r = -0.63).

Keywords: Macronutrients, micronutrients, soil fertility, correlation etc

Introduction

Crop production primarily depends on the soil fertility. Crops do not only take nutrients from surface layer but also draw a part of their nutrient requirement from subsurface layer of the soil. Therefore, the knowledge of vertical distribution of nutrients is very important in recommending management practices (Sankar and Dadhwal, 2009). By accurately mapping variations in nutrient contents, fertilizer expenditure can be reduced while increasing yields and minimizing environmental impact.

In India, about one-half of all soils are low in zinc (Katyal and Vlek, 1985; Welch *et al*., 1991) [15, 52], with as much as 74% of the rice-growing soils of the Andra Pradesh (a southern state in India) being zinc deficient and 69% of the wheat-growing soils (Rathore *et al*., 1980) [38]. Soil properties influence distribution of available Fe, Mn, Cu and Zn in cultivated soil (Yi *et al*., 2012; Belanovic *et al*., 2012; Kumar *et al*., 2011; Milivojevic *et al*., 2002) [56, 3, 11]. It was often confirmed that the DTPA extractable Cu, Zn, Mn and Fe were significantly and positively correlated among themselves and with soil organic matter (OM) content. The availability of nutrients in soil depends upon soil pH, organic matter, adsorptive surfaces and other physical, chemical and biological conditions in the rhizosphere (Jiang *et al.* 2009) [13]. Some micronutrients are related in parent materials, and these relations may persist in soils. Bradford *et al*. (1996) [5] found that nickel and chromium, magnesium and nickel, cobalt and copper, and chromium and magnesium were correlated in California soils.

Rational management of soil micronutrient fertility and toxicity requires an understanding of how total and plant-available soil micronutrients vary across the land. Surveys and maps illustrating the geographic distribution of soil micronutrients and micronutrient availability can contribute to the improvement and sustainability of agriculture and livestock production, to improvements in diet quality, and to a better understanding of the nature and extent of micronutrient deficiencies and toxicities in plants, humans, and livestock (White *et al*., 1997). Maps and surveys of total soil micronutrient content can show where low micronutrient concentrations may cause deficiencies in plants and in the humans and livestock who subsist on them. Therefore soil micronutrient availability to plants would be an extremely useful parameter to map.

The reported study was conducted in a representative micro-watershed to map the micro-nutrient distribution for better management of fertilizer inputs.

Materials and Methods

1. Study area

The study was taken up in a Kupti watershed (Fig.1) located at 20° 15” 47” to 20° 20” 42” N latitude and 77° 35” 27” to 77° 42” 54” E longitude, covering an area of 11257.1 ha and elevation varying from 340 m to 470 m above the mean sea level (MSL). The study area falls under the Survey of India toposheet of 55 L/11 (1:50,000) and agro-ecologically it is placed in 'hot moist to semi-arid AESR 6.3. Geologically, the area is mainly occupied by the Deccan trap formation known as basalt flows, which belongs to Sahyadri group of Ajanta and Chikhli formations. (District Resource Map, Yavatmal District, Maharashtra of Geological survey of India, 2001). The average annual rainfall of (2005-2015) is about 798 mm, temperature rises rapidly after February till May which is the hottest month of the year with mean daily maximum temperature 42.8° C during May and the mean daily minimum 21.2° C. After October, the day and night temperatures decrease rapidly. January is usually the coldest month with the mean daily maximum temperature at 29.6° C and the mean daily minimum at 13.9° C. The relative humidity ranges from 44.3 % to 54.6 %.

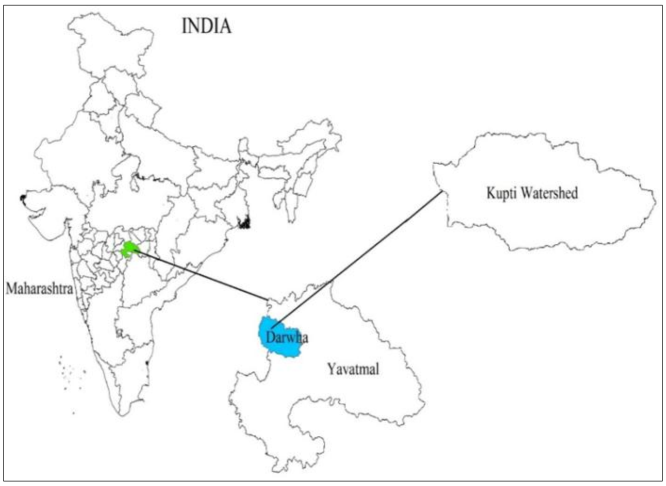

Fig 1: Location map of Kupti watershed

2. Laboratory analysis

Soil pH was measured in 1:2 soil water suspension using class electrode pH meter. Electrical conductivity was measured in 1:2 soil water supernatant solutions with the help of Conductivity Bridge. The organic carbon was determined by rapid titration method (Walkely and Black, 1934) [51]. The available fractions of Fe, Mn, Zn and Cu were extracted with DTPA-TEA buffer (0.005M DTPA + 0.01M $CaCl_2$ + 0.1 M TEA, pH 7.3) as per the method of Lindsay and Norvell (1978) [23] and the concentration of Fe, Mn, Zn and Cu in the DTPA- extracts was determined using atomic absorption spectrophotometer (AAS). Available nitrogen and potassium were estimated by alkaline permanganate and neutral normal ammonium acetate method, respectively. Available phosphorus was estimated by using 0.5M $NaHCO_3$ extractant for alkaline condition (Olsen *et al*., 1981) [30] whereas under acid condition Bray (0.03 N NH_4F+0.025 N HCL) extractant was used (Bray and Kurtz, 1945) [6].

3. Statistical Analysis

Correlation analyses were carried out to detect functional relationship between soil physico-chemical properties and micronutrients. The data analyses were done using a statistical software IBM SPSS 20.0 and Microsoft Office Excel 2016.

Result and discussion

1. Chemical properties

The pH of Kupti micro-watershed soils ranged between 6.7 to 8.7, with a general trend of increase down the profile. The slightly acidic pH may be attributed to the reaction of applied nitrogenous fertilizer material in abundance (Kumar *et al.* 2009) [22]. The EC of all the pedons is much less than 1 dSm^{-1}, indicating no salinity hazards (Table 1). All the soils are calcareous in nature and the $CaCO_3$ content varied from 4.30 to 19.85 per cent in different horizons with a tendency to increase with depth. It was observed that calcium carbonate is low in soils developed on plateau top whereas it was high in the soils of pediments and alluvial plains. This may be due to the leaching of calcium salts from up-slope and its deposition down the slope. Similar results were observed by Pal *et al.* (1999) [32], Challa *et al.* (2000) [7] and Kuchanwar *et al.* (2017) [19]. The 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.* (2001) [39], Nayak *et al.* (2001) [27] and Rao *et al.* (2008) [37]. Organic matter acts as a major factor regulating the availability of organic forms of nitrogen, phosphorus, sulphur and trace elements in the soils, as well as to improve soil structure, infiltration rate, nutrient retention and to reduce soil erosion (Smith and Elliott, 1990) [46]. The cation exchange capacity of the soils was high and it varied from 26.33 to 53.35 Cmol (p+) kg^{-1}. It was high due to predominance of smectitic mineralogy of these soils. Similar findings were reported by Kadam *et al.* (2013) [14], Nimkar *et al.* (1992) [29] and Thumbal and Patil (2015) [48].

Table 1: Chemical properties of soils of study area

Horizon	Depth (cm)	pH (1:2)	EC (dSm^{-1})	OC (%)	$CaCO_3$ (%)	CEC (Cmol (p+) Kg^{-1})
P1	**Clayey smectitic, hyperthermic, Lithic Ustorthent (Gently sloping)**					
Ap	0-16	6.8	0.11	1.38	3.46	29.79
AC	16-41	6.8	0.20	0.78	4.83	38.80
P2	**Clayey, smectitic, hyperthermic, Vertic Haplustept (Gently sloping)**					
Ap	0-13	6.7	0.15	0.45	3.81	42.13
Bw	13-38	6.7	0.15	0.39	4.19	39.56
P3	**Fine, smectitic, hyperthermic (calcareous) Vertic Haplustept (Very gently sloping)**					
Ap	0-15	8.2	0.27	0.33	6.19	54.75
Bw1	15-39	8.4	0.25	0.31	14.94	54.43
Bw2	39-73	8.3	0.26	0.28	9.44	55.07

P4	**Clayey, smectitic, hyperthermic Lithic Ustorthent (Moderately sloping)**					
Ap	0-18	7.6	0.11	0.39	6.81	35.12
P5	**Fine smectitic, hyperthermic Vertic Haplustept (Gently sloping)**					
Ap	0-20	8.4	0.23	0.62	14.46	29.79
Bt1	20-38	8.4	0.21	0.39	18.08	38.80
Bt2	38-55	8.5	0.21	0.31	16.71	36.72
Bc	55-80	8.7	0.21	0.11	27.58	29.10
P6	**Fine smectitic, hyperthermic (calcareous) Typic Haplustert (Very gently sloping)**					
Ap1	0-17	8.1	0.25	1.15	9.46	50.58
Ap2	17-27	8.4	0.18	0.76	10.96	51.96
Bw	27-42	8.4	0.21	0.79	12.96	53.35
Bss	42-67	8.5	0.21	0.68	20.46	52.66
BC	67-82	8.4	0.21	0.50	27.33	53.35
P7	**Fine, smectitic, hyperthermic Typic Haplustert (Gently sloping)**					
Ap	0-22	8.2	0.19	0.88	9.83	51.27
Bw1	22-39	8.3	0.19	0.65	11.33	49.89
Bw2	39-61	8.2	0.21	0.66	11.46	54.74
Bss	61-94	8.3	0.21	0.63	12.33	49.19
BC	94-114	8.3	0.20	0.18	23.33	39.49
P8	**Fine, mixed, hyperthermic, Typic Haplustept (Very gently sloping)**					
Ap	0-18	8.3	0.20	0.46	5.58	109.87
Bw1	18-39	8.3	0.21	0.19	10.58	91.94
Bw2	39-71	8.4	0.20	0.24	16.08	109.32
Bw3	71-114	8.3	0.22	0.30	16.33	107.08
Bw4	114-145	8.4	0.23	0.16	27.58	134.30
P9	**Fine, smectitic, hyperthermic (calcareous) Typic Haplustert (Very gently sloping)**					
Ap1	0-12	8.3	0.22	0.65	7.96	99.73
Ap2	12-26	8.3	0.17	0.63	8.71	103.09
Bw	26-52	8.3	0.18	0.59	9.96	102.44
Bss1	52-92	8.3	0.20	0.53	14.71	101.40
Bss2	92-132	8.4	0.22	0.59	16.46	99.82
BCk	132-150	8.5	0.21	0.27	28.08	110.39
P10	**Fine, mixed, hyperthermic Lithic Ustorthent (Moderately steep sloping)**					
Ap	0-16	8.1	0.21	0.17	7.81	103.98

2. Depth wise distribution of available macronutrients

Depth wise distributions of available macronutrients (NPKS) in pedons are discussed below and are presented in table 2.

Table 2: Nutrients status of soils of study area

Horizon	**Depth (cm)**	**Available Macro-nutrients**				**Available Micro-nutrients**			
		Avail-N	**Avail-P**	**Avail-K**	**Avail-S**	**Avail-Fe**	**Avail-Mn**	**Avail-Zn**	**Avail-Cu**
		(kg ha^{-1})			**(mg kg^{-1})**				
P1	**Clayey smectitic, hyperthermic, Lithic Ustorthent (Gently sloping)**								
Ap	0-16	313.6	50.6	224.1	0.12	19.17	59.23	0.93	8.56
AC	16-41	326.1	22.0	215.3	0.38	16.21	50.68	0.52	7.34
P2	**Clayey, smectitic, hyperthermic, Vertic Haplustept (Gently sloping)**								
Ap	0-13	200.7	6.7	388.1	0.06	15.46	68.52	0.58	6.57
Bw	13-38	175.6	5.8	258.7	0.15	16.97	55.70	0.38	5.56
P3	**Fine, smectitic, hyperthermic (calcareous) Vertic Haplustept (Very gently sloping)**								
Ap	0-15	313.6	33.6	388.1	0.34	7.97	16.91	0.41	3.28
Bw1	15-39	225.8	17.5	284.6	0.30	6.66	9.81	0.29	3.36
Bw2	39-73	163.1	29.6	310.5	0.28	6.04	8.26	0.46	3.41
P4	**Clayey, smectitic, hyperthermic Lithic Ustorthent (Moderately sloping)**								
Ap	0-18	200.7	29.6	211.2	0.21	12.36	22.87	0.36	4.83
P5	**Fine smectitic, hyperthermic Vertic Haplustept (Gently sloping)**								
Ap	0-20	301.1	29.1	565.5	0.26	5.03	9.71	0.36	0.98
Bt1	20-38	175.6	22.4	299.4	0.31	4.54	5.48	0.24	1.55
Bt2	38-55	200.7	20.2	343.7	0.18	4.31	3.88	0.24	1.28
Bc	55-80	125.4	15.7	299.4	0.29	3.42	2.37	0.20	0.69
P6	**Fine smectitic, hyperthermic (calcareous) Typic Haplustert (Very gently sloping)**								
Ap1	0-17	288.5	39.9	399.2	0.35	5.31	11.18	0.53	3.07
Ap2	17-27	225.8	15.7	221.8	0.26	5.04	7.85	0.26	2.70
Bw	27-42	250.9	21.1	232.8	0.25	5.09	4.92	0.23	2.81
Bss	42-67	188.2	25.1	243.9	0.21	4.61	3.77	0.25	2.87
BC	67-82	138.0	29.6	255.0	0.29	4.02	2.76	0.26	2.11
P7	**Fine, smectitic, hyperthermic Typic Haplustert (Gently sloping)**								
Ap	0-22	263.4	13.9	831.6	0.20	5.94	17.47	0.45	2.62
Bw1	22-39	250.9	17.9	487.9	0.27	3.73	8.26	0.33	2.28

Bw2	39-61	188.2	15.7	399.2	0.22	4.45	7.03	0.27	2.28
Bss	61-94	175.6	17.9	277.2	0.14	4.51	7.04	0.23	2.41
BC	94-114	150.5	21.5	321.6	0.30	3.79	4.21	0.22	0.99
P8	**Fine, mixed, hyperthermic, Typic Haplustept (Very gently sloping)**								
Ap	0-18	276.0	35.8	532.2	0.27	4.28	13.01	0.50	1.80
Bw1	18-39	175.6	21.5	299.4	0.33	5.85	7.24	0.17	2.32
Bw2	39-71	188.2	22.0	243.9	0.18	5.54	6.77	0.21	2.14
Bw3	71-114	112.9	24.2	243.9	0.20	5.71	7.82	0.25	2.08
Bw4	114-145	75.3	27.3	277.2	0.23	4.15	4.57	0.24	1.28
P9	**Fine, smectitic, hyperthermic (calcareous) Typic Haplustert (Very gently sloping)**								
Ap1	0-12	213.2	21.1	310.5	0.58	6.12	10.45	0.31	2.47
Ap2	12-26	188.2	21.1	221.8	0.67	7.26	5.32	0.25	2.51
Bw	26-52	163.1	38.1	210.7	0.15	5.55	6.80	0.24	2.67
Bss1	52-92	188.2	24.6	266.1	0.11	5.59	5.67	0.28	3.05
Bss2	92-132	150.5	23.3	310.5	0.17	4.90	3.83	0.22	3.19
BCk	132-150	125.4	33.2	243.9	0.29	4.56	3.63	0.22	1.30
P10	**Fine, mixed, hyperthermic Lithic Ustorthent (Moderately steep sloping)**								
Ap	0-16	188.2	50.2	310.5	0.24	5.02	8.99	0.30	1.36

The available nitrogen content (kg ha^{-1}) varied from 313 to 326 in pedon 1, 175 to 200 in pedon 2, 163.1 to 313.6 in pedon 3, 192 in pedon 4, 125 to 301 in pedon 5, 138 to 288 in pedon 6, 150 to 263 in pedon 7, 75 to 276 in pedon 8, 125 to 213 in pedon 9 and 50 in pedon 10. It was observed to be low at rooting depth (upto 50 cm) in all the pedons perhaps due to rapid decomposition of organic matter and low nitrogen supplying power of the soils. Available nitrogen content was the maximum in surface horizon and found to decrease with increasing depth, which could be due to decreasing content of organic carbon with depth. Thangasamy *et al.* (2005) [47], Sharma and Bali (2000) [41] and Todmal *et al.* (2008) [49] have reported similar findings. The available phosphorous (P) content (kg ha^{-1}) varied from 5.8 in pedon 2 to 50.6 in pedon 1. It was high at rooting depth of pedon 1, 3, 4, 6, 8 and 10 and medium in pedon 5, 7 and 9 and low in pedon 2. The depth wise distribution of available P showed an irregular trend in all the pedons except pedon 1, 2 and 5, which show decreasing trend with depth that may be due to higher fixation of available P by clay. Such irregular trend has also been reported by Todmal *et al.* (2008) [49] and Sankar and Dadhwal (2009). Potassium content ranged from 210 in pedon 9 to 831 in pedon 7. It was high in rooting depth and its depth wise distribution was observed irregular in all the pedons except pedon 1, 2 and 7, which shows increasing trend with depth. The potassium content also increased with the clay content. This may be attributed to the K-rich minerals occurring in the soil (Pal, 1985) [31] and the relative immobility of this element because of fixation by clay. Most of the surface soils had higher available potassium content which might be due to more intense weathering of potash bearing minerals, generation of leaf litter from different crops in cropping systems, release of labile K from organic residues, application of K fertilizers and upward translocation of K from lower depth with capillary rise of ground water (Hirekurbar *et al.* 2000 and Patil *et al.* 2008) [12, 34]. Available sulphur (S) content (Kg ha^{-1}) in the soils varied from 0.06 mg kg^{-1} in pedon 2 to 0.67 mg kg^{-1} in pedon 9, with the average sulphur content of 0.25 mg kg^{-1} (Table 2). It also showed similar trend as in other major nutrients that it is lower in soils at higher elevation and slope as compared to those located on lower elevation and slope. The depth wise distribution of available S in crop rooting zone also showed an irregular trend in all the pedons except pedon 3 and 6, which show decreasing, trend with depth.

3. Depth wise distribution of available micronutrients

The critical limits of Zn used for this study was 0.6 mg Zn kg^{-1} soil however it varies with soil and crop type. For clear prediction of possible deficiencies, the critical limit has to be refined with reference to the soil characteristics and plant parts for individual crops as the soils and crops vary widely in their nutrient supplying and utilization efficiency (Shukla *et al*, 2014) [43]. Available zinc (Zn) content (mg kg^{-1}) varied from 0.17 in pedons 8 to 0.93 in pedon 1. It was found above critical level at rooting depth in pedon 1 and below critical level in all other pedons. It also showed irregular trend with increasing depth except pedon 1, 2 and 7.

In Indian soils, Fe is another limiting micronutrient for crops as plant Fe deficiency is known to occur since long in many parts of the country. Available iron (Fe) content (mg kg^{-1}) ranged from 3.42 in pedon 5 to 19.17 in pedon 1. It was observed above critical level at rooting depth in all the pedons and its content decreased with depth in pedon 3, 5 and 6 whereas in other pedons, irregular trend with increasing depth was noticed. *Mn* content ranged from 2.37 in pedon 5 to 68.52 in pedon 2. It was observed above critical level at rooting depth and showed decreasing trend with depth in all the pedons except pedon 8 and 9, which shows irregular trend with increasing depth. Appavu and Sree Ramulu (1990) [1] reported similar findings. Available copper (Cu) content (mg kg^{-1}) varied from 0.69 in pedon 5 to 8.56 in pedon 1. It was above critical level at rooting depth and its distribution showed irregular pattern with increasing depth in all the pedons except pedon 1, 2 and 7 which decreasing trend with depth. The data indicate that the average contents of all micronutrients are higher in pedon P1 (Table 2) which may be attributed to organic matter content in these soils.

The variation observed in available micronutrient contents among different soils might be the result of variable intensity of different pedogenic processes taking place during soil development. Higher content of micronutrients in surface horizons may be due to the higher amount of organic carbon content, which is ascribed to increase in the solubility of micronutrient cations from soil material. Decomposition of organic material releases micronutrients and reduces pH locally, which assists in mineral solubility (Khanday *et al.*, 2017) [17]. Further availability of metal ions (Zn, Cu, Fe and Mn) increases as the organic matter provides chelating agent for complex formation of these micronutrients. Thus, management of carbon stock will improve their availability to the plants. Similar findings were also reported by Gajbhiye *et al.* (1993) [10] on shallow to deep black soils of Maharashtra.

4. Relationship of available nutrient elements with physicochemical characteristics of the soils

The perusal of data from Table 3 revealed that pH of soil shows non-significant and negative correlation with nitrogen (r = -0.36), non-significant and positive correlation with phosphorus (r = 0.06), potassium (r = 0.11) and sulphur (r = 0.25). The significant and negative correlation between soil pH and available nitrogen indicated that increase in soil pH decreased available nitrogen, which might be due to volatilization loss of nitrogen with rise pH of soil. Khokar *et al.* (2012) [18], Patil *et al.* (2015) [35] and Bhat *et al.* (2017) [4] have also found significant and negative correlations between soil pH and available nitrogen. On the other hand soil pH shows significant and negative correlation with iron (r = -0.96), manganese (r = -0.97), zinc (r = -0.71) and copper (r = -0.89). Reduction in the availability of iron with increasing pH might be attributed to conversion of Fe^{2+} to Fe^{3+} ions (Yadav, 2011) [53]. The ferric (Fe^{3+}) ions compounds have low solubility in solution and so are less bio-available. 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. increases with decreasing pH resulting in greater release of Mn^{2+} in soil solution (Das, 2000) [9]. These results are in agreement with the findings of Rajakumar *et al.* (1996) [36], Chinchmalatpure *et al.* (2000) [8], Sharma *et al.* (2003) [42], Mathur *et al.* (2006) [34], Yadav (2008) [54], Yadav and Meena (2009) [55], Sidhu and Sharma (2010) [44] and Khadka and Lamichhane (2017) [16].

Table 3: Correlation of soil properties with nutrients

	Avail-N	Avail-P	Avail-K	Avail-S	Avail-Fe	Avail-Mn	Avail-Zn	Avail-Cu	pH	EC	OC	$CaCO_3$	CEC
Avail-N	1												
Avail-P	0.20	1.00											
Avail-K	0.38	-0.12	1.00										
Avail-S	0.12	0.02	-0.06	1.00									
Avail-Fe	0.38	-0.02	-0.20	-0.18	1.00								
Avail-Mn	0.40	-0.10	-0.01	-0.27	0.95	1.00							
Avail-Zn	0.64	0.34	0.22	-0.16	0.71	0.76	1.00						
Avail-Cu	0.45	0.02	-0.21	-0.22	0.93	0.88	0.76	1.00					
pH	-0.36	0.06	0.11	0.25	-0.96	-0.97	-0.71	-0.89	1.00				
EC	-0.06	0.06	0.18	0.27	-0.62	-0.57	-0.36	-0.54	0.61	1.00			
OC	0.63	0.20	0.16	0.00	0.34	0.33	0.61	0.51	-0.33	-0.29	1.00		
$CaCO_3$	-0.65	-0.07	-0.16	-0.01	-0.61	-0.61	-0.60	-0.63	0.62	0.34	-0.43	1.00	
CEC	-0.43	0.25	-0.16	0.16	-0.34	-0.37	-0.34	-0.34	0.34	0.20	-0.30	0.16	1.00

Soil organic carbon shows significant and positive correlation with nitrogen (r = 0.63), zinc (r = 0.61) and copper (r = 0.51). On the other hand, it is non-significant and positive with all other nutrients. The significant and positive correlation between organic carbon and available nitrogen could be because of release of mineralize able nitrogen from soil organic matter in proportionate amounts (Vanilarasu and Balkrishnamurthy, 2014) [50] and absorption of ammonical nitrogen (NH_4-N) by humus complex in the soil. Kumar *et al.* (2014) [20] and Bhat *et al.* (2017) [4] studied the similar result. The non-significant and positive correlation between organic carbon and available phosphorus might be due to acidulating effect of organic carbon, formation of easily accessible organophosphate complexes, release of phosphorus from organic complexes and reduction in phosphorus fixation by humus due to formation of coatings on iron and aluminum oxides. The results are in harmony with the findings of Ayele *et al.* (2013) [2], Singh *et al.* (2014) [45] and Bhat *et al.* (2017) [4]. The increase in availability of sulphur by organic carbon may be attributed to release of sulphur from organic complexes as well as acidulating action of soil organic carbon thus enhancing the weathering of minerals containing sulphur. Similar results were reported by Pareek (2007) [33] and Bhat *et al.* (2017) [4]. 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.* (2006) [28] and Bhat *et al.* (2017) [4].

Calcium carbonate content of soil shows significant and negative correlation with nitrogen (r = -0.65), iron (r = -0.61), manganese (r = -0.61), zinc (r = -0.60) and copper (r = -0.63). On the other hand, it is non-significant and negative with all other nutrients. The significant and negative correlation of calcium carbonate with available phosphorus might be due to formation of insoluble calcium phosphates thus reducing its availability. The results are supported by the findings of Min has and Bora (1982) [26]. The significant and negative correlation between available manganese and calcium carbonate content was also reported by Ganai *et al.* (1999) [11].

Conclusion

The fertility status mapping of Kupti micro-watershed showed that the pH is low to medium, electrical conductivity is low, nitrogen is low to medium, phosphorus is low to high, potassium is medium to high, available sulphur is deficient, zinc is below critical level whereas manganese, iron and copper are above critical level. In general, the decreasing trend of these micronutrients content down the profile was observed in all the soils, which might be due to decreasing trend of organic carbon and may be because of manures and fertilizers application at the surface soils. The generated information could be used for managing fertilizer application in crops and reducing the wastages due to inappropriate fertilizer use.

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