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Status of some extractable macro- and micro-nutrients in the soils of Dehradun district of Uttarakhand

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ABSTRACT

An investigation was carried out to analyze the physico- chemical soil properties and correlation between each other of Dehradun district. Surface (0-15 cm) soil samples (n=300) were taken from the all six development blocks of Dehradun district. The ranges for general properties were: sandy loam to sandy clay loam texture, 5.38-7.88 soil pH and 0.11-0.44 dSm^{-1} electrical conductivity (EC) (1:2 soil- water suspension) and 0.27-1.16% soil organic carbon content. The amount of alkaline $KMnO_4$ extractable N in these soils ranged from 100.4-363.8 kg ha^{-1} while Olsen's or Bray's extractable P content ranged from 3.15-50.96 kg ha^{-1}. Neutral 1 N ammonium acetate extractable K, Ca and Mg varied from 56-414.4 kg ha^{-1}, 736-3562 mg kg^{-1} soil and 112-881 mg kg^{-1} soil, respectively. Calcium chloride (0.15 percent) extractable S ranged from 4.50-42.30 mg kg^{-1} soil. The contents of DTPA extractable Zn, Cu, Fe, and Mn were 0.18-7.58 mg kg^{-1} soil, 0.10-8.57 mg kg^{-1} soil, 2.54-52.13 mg kg^{-1} soil and 0.56-5.48 mg kg^{-1} soil, respectively. Hot water-soluble B ranged from 0.18-0.84 mg kg^{-1} soil and ammonium oxalate (pH 3.3) extractable Mo varied from 0.14-0.97 mg kg^{-1} soil. The nutrient index (N.I.) computed for different extractable soil nutrients for the entire district of Dehradun showed that the overall the district was low in N and P, medium in K, S, B and Mn and high in rest nutrients (Ca, Mg, Zn, Cu, Fe, and Mo).

Keywords: Macro-nutrients, micro-nutrients, nutrient index, soil properties

INTRODUCTION

Dehradun is the capital city of Uttarakhand, located in the Garhwal region of the state. It is situated in the Doon Valley, at the foothills of the Himalayas, and is surrounded by the Shivalik range to the south and the Lesser Himalayas to the north. It is bound by Tehri Garhwal in the east, Haridwar in the south, Himanchal Pradesh in the west and Uttarkashi in the north. The soil's fertility is regulated by macronutrients (N, P and K) and micronutrients (Zn, Fe, Cu, and Mn). One of the key elements influencing crop productivity is soil fertility. An important factor from the standpoint of sustainable agriculture production is the classification of soils with relation to the evaluation of the fertility level of the soils in a region. The response effectiveness of chemical fertilizers has significantly decreased in intensive agriculture in recent years as a result of uneven and inadequate fertilizer use as well as the low efficacy of numerous other inputs. As a result, "fertilizer-induced unsustainability of crop productivity" has been demonstrated by the findings of numerous field studies conducted in various regions of India (Yadav, 2003). Variations in a soil's ability to deliver nutrients are a natural occurrence. However, although some of them might be adequate, others are probably insufficient. Therefore, increasing crop output requires judicious use of macro and micronutrients to correct current shortages.

The availability, rate of depletion, and input of nutrients to the soil system should be regularly monitored due to the chemical and physical characteristics of soil, its mineral composition, and the stock of nutrients for plant growth (Arya *et al.,* 2019). The importance of micronutrients such as Fe, Cu, Zn, Mn, Cl, Ni, Mo, and B in soil fertility, plant growth, productivity, and human and animal nutrition is well documented (Gupta *et al.,* 2008). Zinc, Fe, Mn, and Cu are essential nutrients whose deficiencies can severely reduce the population's physical and mental capacity and negatively impact their health. Almost all of the nutrients consumed by humans are derived from the soil-plant system (Graham *et al.,* 2001). Micronutrient deficiencies in soil and plants have increased as a result of intensive cropping. It is critical to quantify both total and available (active) nutrient forms in soil (Welch and Shuman, 1995). Farmers in Uttarakhand are less aware of the impact of soil conditions on macro- and micronutrient availability and fertilizer

management in different crops. As a result, it is necessary to regularly monitor the fertility level of a region's soils. As a result, an inquiry was carried out in all blocks of Uttarakhand's Dehradun district to examine several important soil characteristics and to determine the relationship between soil properties and extractable macronutrients and micronutrients in these soils.

MATERIALS AND METHODS

The study area lies from 30º 00' to 30º 16' N latitude and 78º 00' to 78º 18' E longitude. The minimum and maximum elevation of the study area was 410 and 700 meters, respectively with a geographical area of 3,088 km^2. The district has been divided into six developmental blocks *viz.*, Vikasnagar, Kalsi, Chakrata, Doiwala, Raipur and Sahaspur. Surface (0-15 cm) soil samples (n=300) were collected based on Global Positioning System (GPS) from all six development blocks.

The soil samples were sieved through a 2 mm sieve after being air-dried and crushed with a wooden roller. The processed soil samples were subjected to various chemical analyses. Soil texture, pH, electrical conductivity (EC), organic carbon (OC), and extractable N, P, K, Ca, Mg, S, Zn, Fe, Cu, Mn, B, and Mo were all measured in soil samples. Soil electrical conductivity and pH were determined in 1:2 soil- water suspensions (Jackson, 1967, Bower and Wilcox, 1965).

The organic carbon content of soil samples was determined using a modified Walkley and Black method (Jackson, 1967). The alkaline potassium permanganate method was used to determine the amount of nitrogen extracted from soil samples (Subbiah and Asija, 1956). Phosphorus was extracted from neutral to alkaline soils using 0.5 M $NaHCO_3$ (pH 8.5) as described by Olsen *et al.,* (1954). In acidic soils (pH 4.5-5.5), P was extracted by using 0.03 N NH_4F + 0.025 N HCl, as described by Bray and Kurtz (1945). Estimation of extractable K, Ca and Mg was carried out using 1N ammonium acetate (pH 7.0) by employing method proposed by Schollenberger and Simon (1945). The soil samples were analyzed for Ca and Mg in 1N neutral ammonium acetate extracts by titrating them with EDTA solution, as described by Cheng and Bray (1951). Sulphur content in soil samples was estimated using 0.15% $CaCl_2$ solution and measured using a colorimeter in accordance with the turbidimetric method (Williams and Steinberg, 1969). DTPA extractant (pH 7.3) was used to measure the amounts of Zn, Cu, Fe, and Mn in soil in accordance with procedure proposed by Lindsay and Norvell (1978). Boron in soil samples was determined using hot $CaCl_2$ extractable method developed by Srivastava and Pachauri (2020). Molybdenum in the soil samples was extracted using the 1M ammonium oxalate (pH 3.3) and estimated by colorimetry (Grigg, 1953). Soil samples were categorized into low, medium and high categories based on the limits presented by Pachauri *et al.,* (2023).

The percentile proportion of soil samples falling into the low, medium, and high nutrient categories was used to generate the nutrient index (Ramamoorthy and Bajaj, 1969), which is represented by the expression:

$$NI = (L \times 1 + M \times 2 + H \times 3)/100$$

Where, NI stands for Nutrient Index Value, L stands for percentage of soils low in extractable nutrient, M stands for percentage of soils medium in extractable nutrient, and H stands for percentage of soils high in extractable nutrient. Accordingly, regions with a nutrient index value more than 2.33 were designated as high, those with an NI value between 1.67 and 2.33 as medium, and those with an NI value lessthan 1.67 as low in their native supply of that nutrient (Ramamoorthy and Bajaj, 1969). Simple correlation analysis and Principal component analysis was carried out using R studio software. Significance of correlation coefficient was tested at 1 and 5 % level of significance.

RESULTS AND DISCUSSION

General properties of soils

General properties *viz.,* pH, EC, organic carbon content and texture of the soils of Dehradun district are shown in Table 1. In the district Dehradun, soil texture varied from sandy loam to sandy clay loam. The soils of the Dehradun district were acidic to slightly alkaline in reaction as the pH of the district varied from 5.38-7.88. The highest average pH (7.03) was observed in Doiwala block. Acidic soil pH in many blocks could be related to decomposition of the organic matter in the soil and release of some organic acids which could decrease pH in

soils of lower buffering capacities (Aziz *et al.,* 2012). Kumar *et al.* (2015) also reported that the pH varied from 4.36-8.57 in the soils of sub-tropical regions of Uttar Pradesh. The electrical conductivity of the Dehradun district varied from 0.11-0.44 dSm^{-1}. Among all the blocks, the highest mean value of electrical conductivity was found in Kalsi block (0.25 dSm^{-1}). Similar results were obtained by Sharma *et al.* (2008) in the soils of Amritsar where the EC varied from 0.10-1.00 dSm^{-1}. The organic carbon content in the soils of Dehradun district varied from 0.27-1.16 % with a mean value of 0.82 %. Among all the blocks the highest average organic carbon content was found in Chakrata block (0.89 %). Meena *et al.* (2006) observed that the organic carbon content ranged from 0.19 to 0.90% with a mean value of 0.45% in the soils in Tonk, Rajasthan.

Table 1: General properties of soils of Dehradun district (The mean values are in the parenthesis)

Blocks	pH (1:2)	EC (dSm^{-1})	OC (%)	Texture
Vikasnagar	6.08-7.88(6.91)	0.11-0.29(0.20)	0.35-1.04(0.79)	Sandy loam – Sandy clay loam
Kalsi	6.52-7.61(6.94)	0.11-0.44(0.25)	0.45-1.16(0.86)	Sandy loam – Sandy clay loam
Chakrata	5.70-7.64(6.80)	0.11-0.37(0.21)	0.27-1.05(0.89)	Sandy loam – Sandy clay loam
Doiwala	5.72-7.83(7.03)	0.12-0.37(0.23)	0.38-1.05(0.86)	Sandy loam – Sandy clay loam
Raipur	5.38-6.96(6.52)	0.11-0.32(0.17)	0.52-1.04(0.81)	Sandy loam – Sandy clay loam
Sahaspur	5.80-7.69(6.80)	0.11-0.30(0.16)	0.40-1.03(0.71)	Sandy loam – Sandy clay loam

Extractable macronutrients

The extractable concentrations of macro-nutrients in soils of different blocks of Dehradun district are depicted in Table 2. The extractable N in the soils of Dehradun district varied from 100.4-363.8 kg ha^{-1} with a mean value of 243.6 kg ha^{-1}. The block with the highest average extractable N was Chakrata block (273 kg ha^{-1}). Vijaykumar *et al*. (2011) observed that the extractable nitrogen content ranged from 124.49 to 397.67 kg ha^{-1} with an average of 185.7 kg ha^{-1} in South-East Coast plain-riverine soils of India. The extractable P in the soils of Dehradun district varied from 3.15-50.96 kg ha^{-1} with an average of 13.60 kg ha^{-1}. In the entire district, the block with the highest average extractable P was Vikasnagar block (16.95 kg ha^{-1}). Meena *et al.* (2006) observed that the soils in Rajasthan's Tonk district had an extractable phosphorus level that ranged from 9.2 to 65.2 kg ha^{-1}, with an average of 25.2 kg ha^{-1}. The extractable K in the soils of Dehradun district varied from 56.0- 414.4 kg ha^{-1} with an average of 244.2 kg ha^{-1}. In the entire district, the block with the highest average extractable K was Sahaspur block (261.4 kg ha^{-1}). Athokpam *et al.* (2013) observed that the extractable potassium ranged from 55.60 to 359.11 kg ha^{-1}, with an average of 208.06 kg ha^{-1} in the soils of Manipur's Senapati district. The extractable Ca in the soils of Dehradun district varied from 736- 3562 mg kg^{-1} with an average of 1774 mg kg^{-1}. In the entire district, the block with the highest average extractable Ca was Chakrata block (2196 mg kg^{-1}). Bungla *et al.* (2019) observed that the extractable calcium ranged from 478.3 to 3782.6 mg kg^{-1} in the soils of Uttarakhand's Pithoragarh district. The extractable Mg in the soils of Dehradun district varied from 112 - 881 mg kg^{-1} with an average of 342 mg kg^{-1}. In the entire district, the block with the highest average extractable Mg was Vikasnagar block (464 mg kg^{-1}). Prajapati *et al*. (2021) observed that the extractable Mg in the soils of Tehri Garhwal district, Uttarakhand varied from 30 to1560 mg kg^{-1} with an average of 397 mg kg^{-1}. The extractable S in the soils of Dehradun district varied from 4.50-42.30 mg kg^{-1} with an average of 14.13 mg kg^{-1}. In the entire district, the block with the highest average extractable S was Doiwala block (20.4 mg kg^{-1}). Bungla *et al.* (2019) also obtained similar results in the soils of Pithoragarh district of Uttarakhand where available S ranged from 4.2 to 84.5 mg kg^{-1} soil.

Table 2: Extractable macro-nutrient concentration in soils of Dehradun district (The mean valuesare in the parenthesis)

Blocks	Extractable N(kg ha^{-1})	Extractable P (kg ha^{-1})	Extractable K (kg ha^{-1})	Extractable Ca (mg kg^{-1})	Extractable Mg (mg kg^{-1})	Extractable S (mg kg^{-1})
Vikasnagar	100.4-338.7 (215)	7.06-50.96 (16.95)	56.0-246.4 (129.9)	1017-2645 (1512)	182-759 (464)	5.4-17.1 (11.97)
Kalsi	163.1-363.8 (247.6)	3.15-32.20 (15.50)	190.4-313.6 (260.7)	1077-3562 (2086)	140-486 (309)	6.3-23.4 (12.1)
Chakrata	163.1-363.8 (273)	5.49-23.52 (12.23)	134.4-414.4 (249.1)	977-3557 (2196)	149-881 (413)	4.5-23.4 (12)
Doiwala	163.1-363.8 (262.9)	7.06-24.3 (13.61)	179.2-347.2 (253.3)	772-3081 (1883)	146-851 (404)	8.1-40.5 (20.4)
Raipur	175.6-351.2 (243.6)	7.06-18.03 (10.05)	168.0-324.8 (260.7)	736-2966 (1433)	118-525 (220)	7.2-42.3 (13.88)
Sahaspur	163.1-351.2 (219.8)	7.58-22.74 (13.28)	179.2-313.6 (261.4)	1082-3066 (1533)	112-513 (242)	7.2-35.1 (14.36)
Entire district	100.4-363.8 (243.6)	3.15-50.96 (13.60)	56.0-414.4 (244.2)	736-3562 (1774)	112-881 (342)	4.5-42.3 (14.13)

Extractable micronutrients

The extractable contents of micro-nutrients in soils of different blocks of Dehradun district are depicted in Table 3. The DTPA extractable Zn content in the soils of Dehradun district varied from 0.18-7.58 mg kg^{-1} with an average of 2.14 mg kg^{-1}. In the entire district, the block with the highest average DTPA extractable Zn was Kalsi block (3.12 mg kg^{-1}). Kumar *et al.* (2015) also found similar results in the soils of sub-tropical regions of Uttar Pradesh, where the extractable Zn content varied from 0.12-13.06 mg kg^{-1}. The DTPA extractable Cu content in the soils of Dehradun district varied from 0.10-8.57 mg kg^{-1} with an average of 0.99 mg kg^{-1}. In the entire district, the block with the highest average DTPA extractable Cu was Kalsi block (1.47 mg kg^{-1}). Patel *et al.* (2015) observed that the extractable Cu concentration ranged from

Table 3: Extractable micro-nutrient concentration in soils of Dehradun district (The mean values are in the parenthesis)

Blocks	Extractable Zn (mg kg^{-1})	Extractable Cu(mg kg^{-1})	Extractable Fe (mg kg^{-1})	Extractable Mn (mg kg^{-1})	Extractable B (mg kg^{-1})	Extractable Mo (mg kg^{-1})
Vikasnagar	0.18-3.82 (1.12)	0.18-1.63 (0.59)	2.54-49.45 (13.75)	0.86-5.37 (3.03)	0.24-0.84 (0.50)	0.14-0.80 (0.40)
Kalsi	0.41-7.37 (3.12)	0.12-8.57 (1.47)	4.21-50.29 (21.13)	2.12-5.27 (3.55)	0.18-0.84 (0.42)	0.24-0.84 (0.55)
Chakrata	0.27-7.58 (2.62)	0.18-3.73 (1.07)	9.65-52.13 (22.42)	2.16-5.25 (3.71)	0.27-0.78 (0.43)	0.17-0.87 (0.53)
Doiwala	0.53-6.73 (2.01)	0.22-3.22 (0.99)	5.11-51.49 (20.22)	2.01-5.48 (3.46)	0.27-0.72 (0.46)	0.21-0.94 (0.61)
Raipur	0.30-5.68 (1.90)	0.31-2.52 (0.96)	19.64-51.55 (31.55)	2.0-5.42 (3.79)	0.27-0.81 (0.42)	0.17-0.87 (0.51)
Sahaspur	0.30-6.36 (2.05)	0.10-5.53 (0.83)	8.89-49.59 (26.91)	0.56-5.42 (3.57)	0.27-0.48 (0.33)	0.17-0.97 (0.57)
Entire district	0.18-7.58 (2.14)	0.10-8.57 (0.99)	2.54-52.13 (22.67)	0.56-5.48 (3.52)	0.18-0.84 (0.43)	0.14-0.97 (0.53)

2.0 to 8.0 mg kg^{-1} in soils of Central India. The DTPA extractable Fe content in the soils of Dehradun district varied from 2.54 -52.13 mg kg^{-1} with an average of 22.67 mg kg^{-1}. In the entire district, the block with the highest average extractable Fe was Raipur block (31.55 mg kg^{-1}). Shukla *et al.* (2020) observed that the amount of available Fe in the surface soils of various management zones in the Indian Indo-Gangetic Plain ranged from 0.19 to 55.7 mg kg^{-1}.

The DTPA extractable Mn content in the soils of Dehradun district varied from 0.56-5.48 mg kg^{-1} with an average of 3.52 mg kg^{-1}. In the entire district, the block with the highest average extractable Mn was Raipur block (3.79 mg kg^{-1}). Yurembam *et al.* (2015) observed that the amount of available Mn varied from 0.11-4.7 mg kg^{-1} with an average of 1.51 mg kg^{-1} in the subsurface soils to 1.2 to 5.9 mg kg^{-1} in surface soils in the soils of Someshwar Agricultural Watershed, Almora. The hot water-soluble B content in the soils of Dehradun district varied from 0.18- 0.84 mg kg^{-1} with an average of 0.43 mg kg^{-1}. In the entire district, the block with the highest average content of hot water-soluble B was Vikasnagar block (0.50 mg kg^{-1}). Athokpam *et al.* (2013) also recorded similar results in the soils of Senapati district of Manipur, where the hot water-soluble B was ranging from 0.05-1.00 mg kg^{-1}. The extractable Mo content in the soils of Dehradun district varied from 0.14-0.97 mg kg^{-1} with an average of 0.53 mg kg^{-1}. In the entire district, the block with the highest average extractable Mo was Doiwala block. (0.61mg kg^{-1}). Singh *et al.* (2014) also obtained similar results in alluvial soils of Chambal region, Madhya Pradesh, where the extractable Mo varied between 0.09 to 0.72 mg kg^{-1} soil.

Table 4: Per cent distribution of soil samples in different categories of available macronutrients in different blocks

Name of Blocks	Soil Sample		Percent distribution of extractable macro- nutrients					
	No.	Categories	N	P	K	Ca	Mg	S
Vikasnagar	50	Low	80	26	24	0	0	22
		Medium	20	64	60	0	0	62
		High	0	10	16	100	100	16
		NI	1.20	1.84	1.92	3.00	3.00	1.94
Kalsi	50	Low	60	36	0	0	0	52
		Medium	40	38	82	0	0	24
		High	0	26	18	100	100	24
		NI	1.40	1.90	2.18	3.00	3.00	1.72
Chakrata	50	Low	44	48	0	0	0	46
		Medium	56	52	88	0	0	28
		High	0	0	12	100	100	26
		NI	1.56	1.52	2.12	3.00	3.00	1.80
Doiwala	50	Low	50	54	0	0	0	26
		Medium	50	46	92	0	0	10
		High	0	0	8	100	100	64
		NI	1.50	1.46	2.08	3.00	3.00	2.38
Raipur	50	Low	68	64	0	0	0	32
		Medium	32	36	72	0	0	44
		High	0	0	28	100	100	24
		NI	1.32	1.36	2.28	3.00	3.00	1.92
Sahaspur	50	Low	80	42	0	0	0	30
		Medium	20	58	74	0	0	38
		High	0	0	26	100	100	32
		NI	1.20	1.58	2.26	3.00	3.00	2.02
Entire District	300	Low	64	45	4	0	0	35
		Medium	36	49	78	0	0	34
		High	0	6	18	100	100	31
		NI	1.36	1.61	2.14	3.00	3.00	1.96

Per cent distribution of soil samples in different categories of extractable macro-nutrients

The data on percent distribution in different categories of extractable macro-nutrients are arranged in Table 4. In the entire Dehradun district 64 percent soil samples were found deficient in soil extractable N. The soil samples of all the 6 blocks of Dehradun district were found low to medium in soil extractable P. The soil sample deficient in soil extractable K was 24 percent in Vikasnagar. In the entire Dehradun district, 4 percent soil samples were

found deficient in soil extractable K. All the blocks of Dehradun were found high in calcium and magnesium. The soil samples deficient in soil extractable S were 22, 26, 32 percent in Vikasnagar, Doiwala and Raipur, respectively. In the entire Dehradun district, 35 percent soil samples were found deficient in soil extractable S.

Per cent distribution of soil samples in different categories of available micronutrients in different blocks

The data related to the percent distribution of extractable micro-nutrients in different categories are specified in Table 5. The soil samples deficient in soil extractable Zn were 12, 2, 6, 2, 14 and 14 percent in Vikasnagar, Kalsi, Chakrata, Doiwala, Raipur and Sahaspur, respectively. In the entire Dehradun district, 8 percent soil samples were found to be deficient in soil extractable Zn. The soil samples deficient in soil extractable Cu were 2, 10 and 10 percent in Vikasnagar, Kalsi and Sahaspur, respectively. In the entire Dehradun district, 5 percent soil samples were found to be deficient in soil extractable Cu. The soil samples deficient in soil extractable Fe were 18 and 2 percent in Vikasnagar and Kalsi blocks, respectively. In the entire Dehradun district, only 3 percent soil samples were found to be deficient in soil extractable Fe. The soil samples deficient in soil extractable Mn were 6 and 2 percent in Vikasnagar and Sahaspur blocks, respectively. In general, only 1 percent soil samples were found deficient in soil extractable Mn in entire Dehradun district. The soil samples deficient in hot water-soluble B were 2 and 10 percent in Vikasnagar and Kalsi blocks, respectively. In general, only 2 percent soil samples were found deficient in hot water-soluble B in entire district. All blocks of Dehradun district were not found low in extractable Mo.

Table 5: Per cent distribution of soil samples in different categories of available micronutrients in different blocks

Name of Blocks	Soil Sample		Percent distribution of extractable micro-nutrients					
	No.	Categories	Zn	Cu	Fe	Mn	B	Mo
Vikasnagar	50	Low	12	2	18	6	2	0
		Medium	58	34	20	88	56	4
		High	30	64	62	6	42	96
		NI	2.18	2.62	2.44	2.00	2.40	2.96
Kalsi	50	Low	2	10	2	0	10	0
		Medium	24	46	2	70	62	0
		High	74	44	96	30	28	100
		NI	2.72	2.34	2.94	2.30	2.18	3.00
Chakrata	50	Low	6	0	0	0	0	0
		Medium	24	0	0	60	78	2
		High	70	100	100	40	22	98
		NI	2.64	3.00	3.00	2.40	2.22	2.98
Doiwala	50	Low	2	0	0	0	0	0
		Medium	34	16	12	82	68	0
		High	64	84	88	18	32	100
		NI	2.62	2.84	2.88	2.18	2.32	3.00
Raipur	50	Low	14	0	0	0	0	0
		Medium	30	12	0	58	80	2
		High	56	88	100	42	20	98
		NI	2.42	2.88	3.00	2.42	2.20	2.98
Sahaspur	50	Low	14	10	0	2	0	0
		Medium	30	36	0	66	100	2
		High	56	54	100	32	0	98
		NI	2.42	2.44	3.00	2.30	2.00	2.98
Entire District	300	Low	8	5	3	1	2	0
		Medium	32	29	6	71	74	2
		High	60	66	91	28	24	98
		NI	2.53	2.61	2.88	2.27	2.22	2.98

Nutrient Indices

The nutrient index (N.I.) was worked out for different blocks of Dehradun district for different soil extractable nutrients and arranged in Table 4 and Table 5. Vikasnagar block was low in N; medium in P, K, S, Zn and Mn and high in rest of the nutrients. Kalsi block was low in N, medium in P, K, S, Mn and B and high in rest of the nutrients. Chakrata block was low in N and P; medium in K, S and B and high in rest of the nutrients. Doiwala block was low in N and P; medium in K, Mn, B and high in rest of the nutrients. Raipur block was low in N and P; medium in K, S and B and high in rest of the nutrients. Sahaspur block was low in N and P; medium in K, S, Mn and B and high in rest of the nutrients. The nutrient index (N.I.) computed for different soil extractable nutrients in Dehradun district showed that the entire district was low in N and P; medium in K, S, Mn and B and high in all other nutrients (Ca, Mg, Zn, Cu, Fe, Mo).

Correlation coefficient between soil extractable nutrients and general soil properties

As shown in Table 6, in the soils of Dehradun district, soil pH showed a significant and positive correlation with Ca ($r = 0.428^{**}$), Mg ($r = 0.238^{**}$), S ($r = 0.176^{**}$), Zn ($r = 0.177^{**}$) and Mo ($r = 0.170^{**}$) but was negatively correlated with Fe ($r = -0.286^{**}$) at 1% level of significance. Soil EC showed a significant and positive correlation with N ($r = 0.127^{*}$), P ($r = 0.130^{*}$) and Cu ($r = 0.125^{*}$) at 5% level of significance and had a significant and positive correlation with Ca ($r = 0.530^{**}$), Mg ($r = 0.191^{**}$), S ($r = 0.202^{**}$), Zn ($r = 0.251^{**}$), B ($r = 0.164^{**}$) and Mo ($r = 0.165^{**}$) but was negatively correlated with Fe ($r = -0.285^{**}$) at 1% level of significance. Soil organic carbon had a significant and positive correlation with N ($r = 0.770^{**}$), Ca ($r = 0.165^{**}$) and Mg ($r = 0.176^{**}$) at 1% level of significance and had a significant and positive correlation with Zn ($r = 0.114^{*}$) and B ($r = 0.115^{*}$) at 5% level of significance.

Table 6: Simple correlation (r) between general soil properties and extractable macro- and micro-nutrients in soils of Dehradun district

Nutrients	pH (1:2)	EC (dSm^{-1})	Organic carbon (%)
N	0.061	0.127*	0.770**
P	0.084	0.130*	0.064
K	-0.096	0.060	0.001
Ca	0.428**	0.530**	0.165**
Mg	0.238**	0.191**	0.176**
S	0.176**	0.202**	0.071
Fe	-0.286**	-0.285**	-0.078
Mn	-0.046	0.072	-0.086
Zn	0.177**	0.251**	0.114*
Cu	0.110	0.125*	0.085
B	0.057	0.164**	0.115*
Mo	0.170**	0.165**	0.046

***Significant at p ≤ 0.01, *Significant at p ≤ 0.05*

CONCLUSION

From the results of this study, it may be concluded that the soils of Dehradun district had a widely variable pH from acidic to slightly alkaline. The nutrient index (N.I.) computed for different extractable soil nutrients for the entire district of Dehradun showed that overall, the district was low in extractable N and P; medium in K, S, B and Mn and high in rest nutrients (Ca, Mg, Zn, Cu, Fe, and Mo). The deficiencies of micronutrients and sulphur were site specific; therefore, the relevantchemical fertilizers should be recommended based on their site-specific deficiencies. In order to augment crop production, preserve soil health and quality in the district, site specific nutrient recommendations and adequate availability of specific nutrient fertilizers need to be ensured.

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