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CONTENTS

Status of some extractable macro- and micro-nutrients in soils of Tehri Garhwal district of Uttarakhand

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ABSTRACT: An investigation was carried out to analyze the general soil properties and extractable macro- (N, P, K, Ca, Mg, S) and micro-nutrients (Zn, Cu, Fe, Mn, B, Mo) in the soils of Tehri Garhwal district and the relationships between general soil properties and soil extractable nutrients. Surface (0-15 cm) soil samples (n= 300) were taken from the nine developmental blocks of Tehri Garhwal. The ranges for general properties were: sandy loam to silty clay loam texture, 4.55 to 8.17 soil pH and 0.099-0.931 dSm^{-1} electrical conductivity (EC) (1:2 soil-water suspension) and 3.09-10.68 g kg^{-1} soil organic carbon content. The amount of alkaline $KMnO_4$ extractable N in these soils ranged from 123.2-226.8 mg kg^{-1} soil while Olsen's or Bray's extractable P content ranged from 9.6-92.1 mg kg^{-1} soil. Neutral normal ammonium acetate extractable K, Ca and Mg varied from 44.5-296.7 mg kg^{-1} soil, 50 - 3550 mg kg^{-1} soil and 30 - 1560 mg kg^{-1} soil, respectively. Calcium chloride (0.15 percent) extractable S ranged from 6.8 to 58.1 mg kg^{-1} soil. The contents of DTPA extractable Zn, Cu, Fe, and Mn were 0.20-16.30 mg kg^{-1} soil, 0.25-11.03 mg kg^{-1} soil, 0.39-78.0 mg kg^{-1} soil, and 0.29-61.37 mg kg^{-1} soil, respectively. Hot water-soluble B ranged from 0.30-3.60 mg kg^{-1} soil and ammonium oxalate (pH 3.3) extractable Mo varied from 0.07-0.52 mg kg^{-1} soil. The soil pH had a significant and positive correlation with K, Ca, S, Zn, Cu, and B. Soil extractable P, K, S, Zn, Cu, and B had a significant and positive correlation with soil EC. Organic carbon in the soil had a significant and positive correlation with nitrogen and phosphorus. Overall for the whole district, the extent of macro-nutrient deficiencies was 4.0, 2.3 and 8.0 per cent for K, Ca and S, respectively while these values were 8.3, 12.0, 7.3 and 9.7 per cent for Zn, Fe, Mn and Mo, respectively.

Key words: Macro-nutrients, micro-nutrients, nutrient index, soil properties

Soil fertility is one of the most important factors in determining crop yields in a given region. Though the variation in nutrient supply is a natural occurrence yet some nutrients may be sufficient in supply while others may be deficient. In the absence of judicious use of macronutrient and micronutrient fertilizers to correct existing nutrient deficiencies and imbalances, crop productivity cannot be sustained (Tisdale *et al.,* 1997).

Micronutrients (Zn, Fe, Cu, Mn) and macronutrients (N, P, K) are important soil essentials that regulate soil fertility. The importance of micronutrients i.e. Fe, Cu, Zn, Mn, Cl, Ni, Mo, and B is well documented for soil fertility, plant growth, productivity, human and animal nutrition (Gupta *et al.,* 2008). The cases of micronutrient deficiencies in soil and plants have been increasing owing to intensive cropping. Therefore, it is important to quantify both total and available (active) forms of nutrients in the soil for meaningful soil analysis and recommendations (Welch and Shuman, 1995).

Uttarakhand is a hilly state, and a greater part of the area is covered by the forest (64%). About 14% area is under cultivation of a variety of food and horticultural crops. Major soil zones of the state are Hill soils, *Bhabhar* and *Tarai* soils. Hill soils are greyish brown to brown and dark grey and are moderately acidic to neutral in reaction. Hill soils are highly porous with low moisture retention capacity, moderate to severe erosion-proness, and are often cultivated on the terraces at steep slopes. Rice, wheat, barley, minor millet, sugarcane, potato, and lentil are the main crops of the hills (Shukla *et al*., 2013).

In Uttarakhand, the farmers are less aware, about the effect of soil properties on the availability of macro- and micro-nutrients and fertilizer management in various crops. As a result, it is critical to assess the fertility status of soils of a region on a

regular basis. Therefore, an investigation was conducted in all blocks of Tehri Garhwal district of Uttarakhand to examine some important soil properties and to establish the relationship between soil properties and extractable macronutrients and micronutrients in these soils.

MATERIALS AND METHODS

The study area is located at latitudes 30º 03' and 30º 53' N and longitudes 77º 56' and 79º 04' E. It has an average elevation of 1550 meters (5085 feet) with a geographical area of 3796 km^2. The district has been divided into 9 developmental blocks *viz.*, Chamba, Jakhanidhar, Deoprayag, Kirtinagar, Bhilangana, Thauldhar, Pratapnagar, Jaunpur, and Narendranagar. Surface (0-15 cm) soil samples were collected based on Global Positioning System (GPS) from nine development blocks. The soil samples were air-dried and ground by a wooden roller and then passed through a 2 mm sieve. Various chemical analyses were conducted on the processed soil samples. Soil samples were analyzed for soil texture, pH, electrical conductivity, organic carbon, and extractable N, P, K, Ca, Mg, S, Zn, Fe, Cu, Mn, B, and Mo.

Soil pH and electrical conductivity were estimated in 1:2 soil-water suspensions (Jackson, 1967, Bower and Wilcox, 1965). Modified Walkley and Black method was used to determine the readily oxidizable organic carbon content of the soil samples (Jackson, 1967). Extractable nitrogen in soil samples was determined by the alkaline potassium permanganate method (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). Potassium, Ca and Mg extraction from was carried out using 1N ammonium acetate (pH 7.0) following the method of Schollenberger and Simon (1945).

Table 1: Rating limits for extractable soil macro- and micro-nutrients (Tandon, 1993)

Nutrients		Extractable content (mg kg^{-1})		
		Low	Medium	High
N		<125	125-250	>250
P	Olsen's P	<4.46	4.46-11.16	>11.16
	Bray's P	<15.17	15.17-30.35	>30.35
K		<53.57	53.57-125	>125
Ca		<200	200-300	>300
Mg		<12	12-36	>36
S		<10	10-15	>15
Zn		<0.60	0.60-1.20	>1.20
Cu		<0.20	0.20-0.40	>0.40
Fe		<4.8	4.8-8.7	>8.7
Mn		<2.0	2.0-4.0	>4.0
B		<0.25	0.25-0.50	>0.50
Mo		<0.10	0.10-0.20	>0.20

The extractable contents of Ca and Mg in neutral normal ammonium acetate extract of soils were estimated by titrating the extracts with EDTA solution, according to Cheng and Bray (1951). Sulphur content in soil samples was extracted using 0.15% $CaCl_2$ solution and estimated by the turbidimetric method using a colorimeter (Williams and Steinberg, 1969).

The contents of extractable Zn, Cu, Fe, and Mn were determined in soil using DTPA (pH 7.3) extractant (Lindsay and Norvell, 1978). Hot water soluble boron content in the soil samples was estimated using the method of Berger and Troug (1939). Molybdenum in the soil samples was extracted using the 1M ammonium oxalate (pH 3.3) (Grigg, 1953) and estimated by colorimetry. Soil samples were categorized into low, medium, and high categories based on the limits presented in Table 1.

Nutrient index (Ramamoorthy and Bajaj, 1969) was calculated using the percentile proportion of soil samples falling into the low, medium, and high nutrient categories, as represented by the expression:

$$NI = \frac{Lx1 + Mx2 + Hx3}{100}$$

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. In this way, areas with a nutrient index value greater than 2.33 were

classified as high, those with an NI value between 1.67 and 2.33 as medium, and those with an NI value less than 1.67 as low in their native supply of that nutrient (Ramamoorthy and Bajaj, 1969). Simple correlation analysis was carried out following the procedure outlined by Snedecor and Cochran (1967) and the significance was examined both at 0.05 and 0.01 probability levels.. The STPR (Standard Computer Programs) software was used to analyze the data (GBPUAT, 2004).

RESULTS AND DISCUSSION

General properties of soils

General properties *viz.,* pH, EC, organic carbon content and texture of the soils of Tehri Garhwal district are shown in Table 2. In the district Tehri, soil texture varied from sandy loam to silty clay loam. The soils of the Tehri Garhwal district were acidic to slightly alkaline in reaction as the pH of the district varied from 4.55-8.17. The highest average pH (7.34) was observed in Kirtinagar 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 soil varied from 0.099-0.931 dS m^{-1} with an average of 0.392 dS m^{-1}. Among all the blocks, the highest mean value of electrical conductivity was found in Thauldhar block (0.543 dS m^{-1}). Similar results were obtained by Arya *et al.* (2019) in the soils of Almora where the EC varied from 0.002 - 0.410 dSm^{-1}. The organic carbon content varied from 3.09-10.68 g kg^{-1} soil with an average of 7.45 g kg^{-1} soil. The organic carbon content in the soils of Tehri Garhwal district varied from 3.09-10.68 g kg^{-1} soil with a mean value of 7.45 g kg^{-1} soil. Among all the blocks, the highest average organic carbon content was found in Bhilangana block (8.82 g kg^{-1} soil).

Extractable macro-nutrients

The extractable concentrations of macro-nutrients in soils of different blocks of Tehri Garhwal district are depicted in Table 3.

The extractable N in the soils of Tehri Garhwal district varied from 123.2-226.8 mg kg^{-1} with a mean value of 181.98 mg kg^{-1}. The block with the highest average extractable N was Bhilangana block (191.47 mg kg^{-1}). Arya *et al.* (2019) reported similar results of extractable N in the soils of Almora district of Uttarakhand, where the range was 50.4 – 140.0 mg kg^{-1} soil. The extractable P in the soils of Tehri Garhwal district varied from 9.6-92.1 mg kg^{-1} with an average of 57.3 mg kg^{-1}. In the entire district, the block with the highest average extractable P was Bhilangana block (66.8 mg kg^{-1}). The extractable K in the soils of Tehri Garhwal district varied from 44.5-296.7 mg kg^{-1} with an average of 133.0 mg kg^{-1}. In the entire district, the block with the highest average extractable K was Chamba block (158.5 mg kg^{-1}).

The extractable Ca in the soils of Tehri Garhwal district varied from 50 - 3550 mg kg^{-1} with an average of 1527 mg kg^{-1}. In the entire district, the block with

Table 2: General properties of soils of Tehri Garhwal district (The mean values are in the parenthesis)

Blocks	pH(1:2)	EC (dSm^{-1})	OC (g kg^{-1})	Texture
Chamba	4.55-8.06 (6.67)	0.099-0.574 (0.276)	4.64-9.47 (7.46)	sandy loam- clay loam
Jakhanidhar	5.21-7.74 (6.54)	0.114-0.750 (0.339)	3.09-9.66 (7.42)	sandy loam- clay loam
Deoprayag	5.58-7.91 (6.71)	0.108-0.722 (0.339)	4.64-9.85 (8.06)	sandy loam -silty clay loam
Kirtinagar	6.38-7.99 (7.34)	0.160-0.675 (0.392)	5.22-9.47 (7.57)	sandy loam - silty clay loam
Bhilangana	5.89-8.05(6.73)	0.124-0.526 (0.322)	5.02-10.68 (8.82)	sandy loam-silty clay loam
Thauldhar	5.38-7.78 (6.92)	0.231-0.859 (0.543)	3.86-9.27 (6.64)	sandy loam - clay loam
Pratapnagar	5.62-8.17 (7.16)	0.223-0.870 (0.490)	4.48-9.85 (7.31)	loam- clay loam
Jaunpur	5.16-7.76 (6.39)	0.125-0.931 (0.420)	5.02-8.89(7.18)	sandy loam- sandy clay loam
Narendranagar	6.23-7.89 (7.32)	0.173-0.626 (0.409)	4.06-8.89 (6.54)	sandy loam –clay loam
Tehri Garhwal district	4.55-8.17 (6.86)	0.099-0.931 (0.392)	3.09-10.68 (7.45)	sandy loam- silty clay loam

the highest average extractable Ca was Chamba block (1930 mg kg^{-1}). Kavitha and Sujatha (2015) also observed similar trends in various agro-ecosystems of Thrissur district of Kerala, where extractable Ca content varied from 20.6-3515 mg kg^{-1}.The extractable Mg in the soils of Tehri Garhwal district varied from 30 -1560 mg kg^{-1} with an average of 397 mg kg^{-1}. In the entire district, the block with the highest average extractable Mg was Thauldhar block (727 mg kg^{-1}). The extractable S in the soils of Tehri Garhwal district varied from 6.8-58.1 mg kg^{-1} with an average of 23.9 mg kg^{-1}. In the entire district, the block with the highest average extractable S was Thauldhar block (36.0 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.

Extractable micro-nutrients

The extractable contents of micro-nutrients in soils of different blocks of Tehri Garhwal district are depicted in Table 4. On the whole, the overall concentration of extractable Zn varied from 0.20-16.3 mg kg^{-1} with an average of 3.51 mg kg^{-1}. In the entire district, the block with the highest average DTPA extractable Zn was Chamba block (5.00 mg kg^{-1}). Arya *et al.* (2019) also found similar results in the soils of Almora district of Uttarakhand, where the extractable Zn content varied from 0.10 – 20.70 mg kg^{-1}. The DTPA extractable Cu content in the soils of Tehri Garhwal district varied from 0.25-11.03 mg kg^{-1} with an average of 1.32 mg kg^{-1}. In the entire district, the block with the highest average DTPA extractable Cu was Narendranagar block (2.35 mg kg^{-1}). Arya *et al.* (2019) also found similar results in Almora district of Uttarakhand, where DTPA extractable Cu content varied from 0.11– 2.99 mg kg^{-1}. The DTPA extractable Fe content in the soils of Tehri Garhwal district varied from 0.39-78.0 mg kg^{-1} with an average of 16.18 mg kg^{-1}. In the entire district, the block with the highest average

Table 3:Extractable macro-nutrient concentration in soils of Tehri Garhwal district (The mean values are in the parenthesis)

Blocks	Extractable N (mg kg^{-1})	Extractable P (mg kg^{-1})	Extractable K (mg kg^{-1})	Extractable Ca (mg kg^{-1})	Extractable Mg (mg kg^{-1})	Extractable S (mg kg^{-1})
Chamba	123.2-213.6 (178.2)	13.6-74.4 (47.3)	49.5-296.7 (158.5)	800-3400 (1930)	60-1560 (545)	8.1-45.2 (17.4)
Jakhanidhar	123.2-215.2 (180.0)	12.0-86.4 (52.17)	54.4-227.5 (129.1)	200-3550 (1571)	60-960 (524)	6.8-26.3 (12.9)
Deoprayag	145.6-226.8 (189.4)	9.6-86.4 (57.8)	49.5-232.4 (131.9)	150-3550 (1566)	60-510 (285)	16.2-37.8 (26.0)
Kirtinagar	164.8-218.4 (184.7)	28.8-76.8 (56.3)	49.5-227.5 (126.8)	50-3550 (1845)	30-420 (254)	12.8-33.8 (25.0)
Bhilangana	162.4-218.4 (191.4)	48.0-92.1 (66.8)	49.5-224.5 (124.2)	100-3550 (1571)	60-1140 (361)	9.5-39.8 (21.3)
Thauldhar	135.2-215.6 (175.0)	30.4-75.0 (61.2)	49.5-243.5 (131.6)	50-2500 (1343)	180-1470 (727)	18.9-58.1 (36.0)
Pratapnagar	156.8-220.4 (182.0)	26.4-84.5 (59.1)	49.5-250.5 (155.9)	100-2550 (1230)	30-930 (288)	13.5-52.0 (28.6)
Jaunpur	160.4-201.4 (182.3)	40.0-90.2 (66.3)	49.5-236.3 (143.8)	200-3150 (1345)	30-1410 (299)	12.2-47.9 (27.1)
Narendranagar	145.6-190.8 (174.4)	12.0-75.2 (48.7)	44.5-246.2 (95.2)	600-2400 (1341)	30-810 (298)	12.8-29.0 (20.8)
Tehri Garhwal district	123.2-226.8 (181.9)	9.6-92.1 (57.3)	44.5-296.7 (133.0)	50-3550 (1527)	30-1560 (397)	6.8-58.1 (23.9)

Table 4: Extractable micro-nutrient concentration in Soils of Tehri Garhwal 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})
Chamba	0.20-16.30 (5.00)	0.26-2.99 (0.92)	3.93-29.32 (14.00)	4.79-57.26 (21.10)	0.30-3.00 (1.10)	0.07-0.23 (0.13)
Jakhanidhar	0.30-5.80 (1.70)	0.33-1.52 (0.73)	4.03-37.48 (11.82)	3.24-61.37 (11.83)	0.30-2.20 (0.80)	0.07-0.33 (0.15)
Deoprayag	0.20-7.80 (2.10)	0.25-2.75 (0.65)	2.92-19.30 (8.82)	3.22-25.18 (11.00)	1.20-3.20 (1.90)	0.09-0.49 (0.24)
Kirtinagar	0.30-9.70 (1.40)	0.29-2.51 (1.33)	1.69-27.32 (12.28)	0.29-16.93 (3.21)	0.60-2.30 (1.20)	0.08-0.46 (0.20)
Bhilangana	1.85-9.95 (4.24)	0.90-3.03 (1.70)	5.56-57.64 (22.61)	1.58-30.06 (10.62)	0.30-3.60 (1.10)	0.07-0.45 (0.16)
Thauldhar	0.93-13.0 (4.90)	0.40-1.38 (0.90)	2.46-59.48 (14.23)	1.25-18.98 (6.03)	0.30-3.40 (1.00)	0.14-0.52 (0.31)
Pratapnagar	0.96-10.54 (3.50)	0.76-2.75 (1.69)	1.91-78.00 (20.53)	3.80-17.30 (10.54)	0.30-1.90 (0.80)	0.17-0.51 (0.30)
Jaunpur	0.44-11.45 (4.02)	0.33-11.03 (1.60)	0.39-46.12 (20.90)	5.52-40.59 (17.18)	0.30-1.40 (0.80)	0.08-0.36 (0.20)
Narendranagar	1.25-13.00 (4.73)	0.31-5.39 (2.35)	3.01-58.03 (20.45)	2.39-60.03 (20.76)	0.40-2.00 (1.00)	0.08-0.36 (0.18)
Tehri Garhwal district	0.20-16.30 (3.51)	0.25-11.03 (1.32)	0.39-78.00 (16.18)	0.29-61.37 (12.47)	0.30-3.60 (1.08)	0.07-0.52 (0.21)

extractable Fe was Bhilangana block (22.61 mg kg^{-1}). Singh *et al.* (2006) also reported similar results in soils of Uttaranchal hills under different vegetations, where extractable Fe content varied from 14.0-284.0 mg kg^{-1}.The DTPA extractable Mn content in the soils of Tehri Garhwal district varied from 0.29-61.37 mg kg^{-1} with an average of 12.47 mg kg^{-1}. In the entire district, the block with the highest average extractable Mn was Chamba block (21.10 mg kg^{-1}). Chander *et al.* (2014) also found similar results in the soils of sub-humid and wet-temperate zones of H.P., where DTPA extractable Mn varied from 2.1-34.9 mg kg^{-1}. The hot water soluble B content in the soils of Tehri Garhwal district varied from 0.30-3.60 mg kg^{-1} with an average of 1.08 mg kg^{-1}. In the entire district, the block with the highest average content of hot water soluble B was Deoprayag block (1.90 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 Tehri Garhwal district varied from 0.07-0.52 mg kg^{-1} with an average of 0.21 mg kg^{-1}. In the entire district, the block with the highest average extractable Mo was Thauldhar block. (0.31 mg kg^{-1}).

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

Per cent samples in low, medium and high categories and the computed nutrient index (N.I.) for different soil extractable macronutrients in different blocks of Tehri Garhwal district are shown in Table 5.

The soil samples deficient in soil extractable N were 2.2 and 6.7 per cent in Chamba and Jakhanidhar, respectively. In the entire Tehri Garhwal district only 1.3 per cent soil samples were found deficient in soil extractable N due to sufficient mineralization of soil organic matter. The soil samples of all the 9 blocks of Tehri Garhwal district were found high in soil extractable P. The soil samples deficient in extractable soil K were 2.2, 6.7, 6.7, 3.3, 3.3, 3.3, 3.3 and 10.0 per cent in Chamba, Deoprayag, Kirtinagar, Bhilangana, Thauldhar, Pratapnagar, Jaunpur and Narendranagar, respectively. In the entire Tehri Garhwal district, 4.0 per cent soil samples were found deficient in extractable soil K. The soil samples deficient in Ca were 3.3, 3.3, 3.3, 6.7 and 6.7 per cent in Deoprayag, Kirtinagar, Bhilangana, Thauldhar and Pratapnagar, respectively. In the entire Tehri Garhwal district, only 2.3 per cent soil samples were found deficient in soil extractable Ca. All Blocks of Tehri Garhwal were found high in etractable magnesium. The soil samples deficient in extractable soil S were 17.8, 33.3 and 3.3 per cent in Chamba, Jakhanidhar and Bhilangana, respectively. In the entire Tehri Garhwal district, only 8.0 per cent soil samples were found deficient in extractable soil S.

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

The data related to the percent distribution of extractable micro-nutrients in different categories are presented in Table 6. The soil samples deficient in soil extractable Zn were 4.4, 20, 20, 10 and 10 per cent in Chamba, Jakhanidhar, Deoprayag, Kirtinagar and Jaunpur, respectively. In the entire Tehri Garhwal district, 8.3 percent soil samples were found to be deficient in soil extractable Zn. No soil sample in all the 9 blocks of Tehri Garhwal district was low in soil extractable Cu. The soil samples deficient in soil extractable Fe were 4.4, 6.7, 16.7, 13.3, 43.3, 20, 6.7 and 3.3 per cent in Chamba, Jakhanidhar, Deoprayag, Kirtinagar, Thauldhar, Pratapnagar, Jaunpur and Narendranagar blocks, respectively. In the entire Tehri Garhwal district, 12.0 per cent soil samples were found to be deficient in soil extractable Fe. The soil samples deficient in soil extractable Mn were 60.0, 3.3 and 10.0 percent in Kirtinagar, Bhilangana and Thauldhar blocks, respectively. In general, 7.3 percent soil samples were found deficient in soil extractable Mn. No soil sample in all the blocks of Tehri Garhwal was low in hot water soluble B. The soil samples deficient in Mo were 22.2, 13.3, 3.3, 3.3, 23.3,6.7 and 6.7 per cent in Chamba, Jakhanidhar, Deoprayag, Kirtinagar, Bhilangana, Jaunpur and Narendranagar blocks, respectively. In general, 9.7 percent soil samples

were found deficient in Mo in the entire district.

Nutrient Indices

The nutrient index (N.I.) was worked out for different blocks of Tehri Garhwal district for different soil extractable nutrients and shown in Table 5 and 6. Chamba block was medium in N, Mo but high in rest of the nutrients. Jakhanidhar block was medium in N, S, Mo and high in rest of the nutrients. Deoprayag block was medium in N, Zn, Fe and high in rest nutrients. Kirtinagar block was medium in N, Zn, Mn, Mo and high in rest other nutrients. Bhilangana block was medium in N, Mo and high in rest of the nutrients. Thauldhar block was medium in N, Fe, Mn and high in rest of the nutrients. Pratapnagar block was medium in N, Fe and high in rest nutrients. Jaunpur block was medium in N and high in rest of the nutrients. Narendranagar block was medium in N, K and high in rest of the nutrients. The

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

Name of Blocks	Soil Sample		Per cent distribution of extractable macro- nutrients					
	No.	Categories	N	P	K	Ca	Mg	S
Chamba	45	Low	2.2	0	2.2	0	0	17.8
		Medium	97.8	4.4	31.1	0	0	35.5
		High	0	95.6	66.7	100	100	46.7
		NI	1.98	2.96	2.6	3.00	3.00	2.29
Jakhanidhar	45	Low	6.7	0	0	0	0	33.3
		Medium	93.3	0	51.1	8.9	0	44.5
		High	0	100	48.9	91.1	100	22.2
		NI	1.93	3.00	2.49	2.91	3.00	1.89
Deoprayag	30	Low	0	0	6.7	3.3	0	0
		Medium	100	3.3	46.6	3.3	0	0
		High	0	96.7	46.6	93.4	100	100
		NI	2.00	2.97	2.39	2.90	3.00	3.00
Kirtinagar	30	Low	0	0	6.7	3.3	0	0
		Medium	100	0	40	3.3	3.3	6.7
		High	0	100	53.3	93.4	96.7	93.3
		NI	2.00	3.00	2.47	2.90	2.97	2.93
Bhilangana	30	Low	0	0	3.3	3.3	0	3.3
		Medium	100	0	53.4	0	0	26.7
		High	0	100	43.3	96.7	100	70
		NI	2.00	3.00	2.4	2.93	3.00	2.67
Thauldhar	30	Low	0	0	3.3	6.67	0	0
		Medium	100	0	50	0	0	0
		High	0	100	46.7	93.3	100	100
		NI	2.00	3.00	2.43	2.86	3.00	3.00
Pratapnagar	30	Low	0	0	3.3	6.7	0	0
		Medium	100	0	30	3.3	6.7	3.3
		High	0	100	66.7	90	93.3	96.7
		NI	2.00	3.00	2.63	2.83	2.93	2.97
Jaunpur	30	Low	0	0	3.3	0	0	0
		Medium	100	0	46.7	10	6.7	10
		High	0	100	50	90	93.3	90
		NI	2.00	3.00	2.47	2.90	2.93	2.90
Narendranagar	30	Low	0	0	10	0	0	0
		Medium	100	0	86.7	0	3.3	13.3
		High	0	100	3.3	100	96.7	86.7
		NI	2.00	3.00	1.93	3.00	2.97	2.87
Entire Tehri Garhwal District	300	Low	1.3	0	4.0	2.3	0	8
		Medium	98.7	0.01	47.7	3.3	2	18
		High	0	99.99	48.3	94.4	98	74
		NI	1.99	2.99	2.44	2.92	2.98	2.66

nutrient index (N.I.) computed for different extractable soil nutrients for the entire district of Tehri Garhwal showed that the overall the district was medium in N and high in all other nutrients (P, K, Ca, Mg, S, Zn, Cu, Fe, Mn, B and Mo).

Correlation coefficient between soil extractable nutrients and general soil properties

As shown in Table 7, soil pH showed a significant and positive correlation with Ca (r = 0.171), S (r = 0.251), Zn (r = 0.357), Cu (r = 0.246) and B (r = 0.240) at 1% level of significance, K (r = 0.305) at 5% level of significance but showed a significant and negative correlation with Fe (r = -0.359) and Mn (r = -0.237) at 1% level of significance. A positive correlation between soil pH and soil extractable K, S, Ca, Cu, B and Zn possibly indicated higher soil retention of these nutrients at neutral soil pH and lower leaching losses of especially, K and

Table 6: Per cent distribution of soil samples in different categories of availability in different blocks

Name of Blocks	Soil Sample		Percent distribution of extractable micro-nutrients					
	No.	Categories	Zn	Cu	Fe	Mn	B	Mo
Chamba	45	Low	4.4	0	4.4	0	0	22.2
		Medium	11.2	15.6	24.5	0	8.9	73.4
		High	84.4	84.4	71.1	100	91.1	4.4
		NI	2.80	2.84	2.67	3.00	2.91	1.82
Jakhanidhar	45	Low	20.0	0	6.7	0	0	13.3
		Medium	26.7	8.9	26.6	6.7	11.1	71.2
		High	53.3	91.1	66.7	93.3	88.9	15.5
		NI	2.33	2.91	2.60	2.93	2.89	2.02
Deoprayag	30	Low	20	0	16.7	0	0	3.3
		Medium	30	16.7	40	10	0	43.4
		High	50	83.3	43.3	90	100	53.3
		NI	2.30	2.83	2.27	2.90	3.00	2.50
Kirtinagar	30	Low	10	0	13.3	60	0	3.3
		Medium	56.7	3.3	23.4	16.7	0	60
		High	33.3	96.7	63.3	23.3	100	36.7
		NI	2.23	2.97	2.50	1.63	3.00	2.33
Bhilangana	30	Low	0	0	0	3.3	0	23.3
		Medium	0	0	13.3	3.3	16.7	20
		High	100	100	86.7	93.4	83.3	56.7
		NI	3.00	3.00	2.87	2.90	2.83	2.33
Thauldhar	30	Low	0	0	43.3	10	0	0
		Medium	10	0	20	50	23.3	10
		High	90	100	36.7	40	76.7	90
		NI	2.90	3.00	1.93	2.30	2.77	2.90
Pratapnagar	30	Low	0	0	20	0	0	0
		Medium	10	0	33.3	3.3	23.3	6.7
		High	90	100	46.7	96.7	76.7	93.3
		NI	2.90	3.00	2.27	2.97	2.77	2.93
Jaunpur	30	Low	10	0	6.7	0	0	6.7
		Medium	3.3	6.7	13.3	0	13.3	50
		High	86.7	93.3	80	100	86.7	43.3
		NI	2.77	2.93	2.73	3.00	2.87	2.37
Narendranagar	30	Low	0	0	3.3	0	0	6.7
		Medium	0	3.3	13.4	13.3	6.7	36.7
		High	100	96.7	83.3	86.7	93.3	56.6
		NI	3.00	2.97	2.80	2.87	2.93	2.50
Entire Tehri Garhwal District	300	Low	8.3	0.0	12.0	7.3	0.0	9.7
		Medium	14.3	6.7	20.7	10.7	11.3	44.3
		High	77.3	93.3	67.3	82.0	88.7	46
		NI	2.69	2.93	2.55	2.75	2.89	2.36

Table 7: Simple correlation between general soil properties and extractable macro- and micro-nutrients

Nutrients	pH (1:2)	EC (dSm ^{1})	Organic carbon (gkg^{-1})
N	-0.147	-0.195	0.918**
P	0.049	0.149**	0.141*
K	0.305*	0.158*	-0.027
Ca	0.171**	0.027	-0.040
Mg	-0.051	0.001	-0.051
S	0.251**	0.486**	-0.072
Fe	-0.359**	0.019	0.046
Mn	-0.237**	-0.281**	-0.028
Zn	0.357**	0.237**	-0.106
Cu	0.246**	0.147*	-0.049
B	0.240**	0.139*	0.001
Mo	0.098	0.153	-0.011

** Significant at $p \leq 0.01$, *Significant at $p < 0.05$

B. A significant negative correlation between soil pH and soil extractable Fe and Mn indicated a decrease in solubility of Fe and Mn with increase in soil pH. Soil EC showed a significant and positive correlation with P (r = 0.149), S (r = 0.486) and Zn (r = 0.237) at 1% level of significance, K (r = 0.158),Cu (r = 0.147) and B (r = 0.139) at 5% level of significance but showed a negative and significant correlation with Mn (r = -0.281) at 1% level of significance. Relatively higher EC values are indicator of lower leaching losses due to physiographic position of soils, therefore, a positive correlation between soil EC and soil extractable P, K, Zn, B and Cu could be attributed to this reason (Smaling *et al.*, 1993).

Soil organic carbon overall showed a significant and positive correlation with N (r = 0.918) at 1% level of significance and P (r = 0.141) at 5% level of significance. A significant positive correlation between soil organic C content and soil extractable N and P implied that the soil extractable N and P were mainly resulted by the mineralization of soil organic- nitrogen and -P.

CONCLUSION

From the results of this study, it may be concluded that the soils of Tehri Garhwal district had a widely variable pH from acidic to slightly alkaline. According to the calculated nutrient index (N.I.) Tehri Garhwal district was overall medium in extractable N but high in rest nutrients (P, K, Ca, Mg, S, Zn, Cu, Fe, Mn, B and Mo), though deficiencies of K, Ca, S, Zn, Fe, Mn and Mo were recorded in different blocks. The deficiencies of micronutrients and sulphur were site specific; therefore, the relevant chemical fertilizers should be recommended based on their site-specific deficiencies. In order to augment crop production and 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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