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Assessment of some extractable essential nutrients in soils of Uttarkashi 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, and S) and micro-nutrients (Zn, Cu, Fe, Mn, B, and Mo) in the soils of Uttarkashi district and the relationships between general soil properties and soil extractable nutrients. Surface (0-15 cm) soil samples (n=300) were taken from the all six development blocks of Uttarkashi district of Uttarakhand. The ranges for general properties were: sandy to sandy clay loam texture, 4.79-8.09 soil pH and 0.10-1.00 dSm^{-1} electrical conductivity (EC) (1:2 soil- water suspension) and 0.17-1.08% soil organic carbon content. The amount of alkaline $KMnO_4$ hydrolysable N in these soils ranged from 104 -365 kg ha^{-1} while Olsen's or Bray's extractable P content ranged from 3.6-35.7 kg ha^{-1}. Neutral 1N ammonium acetate extractable K, Ca and Mg varied from 90 - 470 kg ha^{-1}, 351 -3758 mg kg^{-1} soil and 30 - 941 mg kg^{-1} soil, respectively. Calcium chloride (0.15 percent) extractable S ranged from 5.2-21.8 mg kg^{-1} soil. The contents of DTPA extractable Zn, Cu, Fe, and Mn were 0.10-15.20 mg kg^{-1} soil, 0.10-10.50 mg kg^{-1} soil, 2.86-97.80 mg kg^{-1} soil and 1.84-63.77 mg kg^{-1} soil, respectively. Hot water-soluble B ranged from 0.23-1.22 mg kg^{-1} soil and ammonium oxalate (pH 3.3) extractable Mo varied from 0.47-1.49 mg kg^{-1} soil. The nutrient index (N.I.) computed for different extractable soil nutrients for the entire district of Uttarkashi showed that the overall the district was medium in N, K & S and high in all other nutrients (P, Ca, Mg, Zn, Cu, Fe, Mn, B and Mo).

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

INTRODUCTION

Uttarkashi is known as "Kashi of North" as Bhagirathi and Yamuna rivers originate from this district. Uttarkashi's soils are largely influenced by its high-altitude, mountainous terrain, with types ranging from shallow, rocky soils on ridges to alluvial soils in river valleys, and are generally susceptible to erosion. The soil often found is coarse textured with low to medium organic carbon content. The rajma of *Munsiari* is worldwide famous for its quality. The farmers of this district also have apple orchard. The productivity of the district is low to medium as they do not apply balanced fertilizer and thus nutrient. Research indicated that soil fertility can be improved by appropriate agricultural practices such as tillage (Hussain *et al.,* 1999; Kong *et al.,* 2006), fertilizer application (Guo *et al.,* 2010), incorporation of crop residues into soil (Bi *et al.,* 2009). 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). Shukla *et al.,* (2021) reported a widespread occurrence of multinutrients deficiencies across the different states of India. There were occurrences of two-nutrient (namely S + Zn, Zn + B, S + B, Zn + Fe Zn + Mn, S + Fe, Zn + Cu and Fe + B), three-nutrient (namely S + Zn + B, S + Zn + B and Zn + Fe + B) and four-nutrient (namely Zn + Fe + Cu + Mn and Zn + Fe + Cu + Mn + B) deficiencies in different extents. Over the years intensive agriculture has drastically affected the macro and a micro nutrient status of soil of these regions. As a result, it is critical to assess the fertility status of soils of this region on a regular basis. Therefore, an investigation was conducted in all six blocks of Uttarkashi district of Uttarakhand to examine some important soil properties and to establish the relationship between soil properties and extractable macro-nutrients and micro-nutrients.

MATERIALS AND METHODS

The study area lies from 30º 00' to 30° 89' N latitude and 78º 14 ' to 78º 97' E longitude. The minimum and maximum elevation of the

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study area was 1112 and 2248 meters, respectively with a geographical area of 8016 km^2. The district has been divided into six developmental blocks *viz.*, Bhatwari, Dunda, Mori, Puraula, Naugaon and Chiniyalisaur. Surface soil samples were collected from soil depth (0-15 cm) based on Global Positioning System (GPS) from six development blocks. The collected soil samples were air-dried and grounded 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 electrical conductivity and pH were determined in 1:2 soil-water suspensions (Jackson, 1967, Bower and Wilcox, 1965). To assess the readily oxidizable organic carbon content of the soil samples, the modified Walkley and Black method was employed (Jackson, 1967). The alkaline potassium permanganate method was used to estimate the amount of hydrolysable nitrogen in 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 extractable contents of Ca and Mg in neutral normal ammonium acetate extract of soils were estimated by titrating the extracts with EDTA solution, as suggested by Cheng and Bray (1951). Sulfur 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). Using DTPA (pH 7.3) extractant, the amounts of extractable Zn, Cu, Fe, and Mn in soil were determined (Lindsay and Norvell, 1978). Hot water-soluble boron content in the soil samples was estimated using the method given by Berger and Troug (1939). Molybdenum in the soil samples was extracted using the 1M ammonium oxalate (pH 3.3) and estimated by colorimetric method (Grigg, 1953). Soil samples were categorized into low, medium, and high categories based on the limits presented by Prajapati *et al.* (2021).

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 less than 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 Uttarkashi district are shown in Table 1. In the district Uttarkashi, soil texture varied from sandy to sandy clay loam. The soils of the Uttarkashi district were acidic to slightly alkaline in reaction as the pH of the district varied from 4.79-8.09. The lowest average pH (5.71) was observed Mori block. Acidic soil pH in many blocks could be described due to decomposition of the organic matter in the soil and subsequent release of organic acids which could lower the pH in soils of lower buffering capacities (Aziz *et al*., 2012). Kumar *et al.* (2015) also reported that the pH ranged from 4.36-8.57 in the soils of sub-tropical regions of Uttar Pradesh. The electrical conductivity of the soil varied from 0.10-1.00 dS m^{-1} with an average of 0.37 dSm^{-1}. Among all the blocks, the highest mean value of electrical conductivity was found in Naugaon block (0.48 dS m^{-1}). Similar results were obtained by Prajapati *et al.*(2021) in the soils of Tehri Garhwal where EC varied from 0.099-0.931 dSm^{-1}. The organic carbon content varied from 0.17-1.08 g kg^{-1} soil with an average of 0.87 g kg^{-1} soil. Among all the blocks, the highest average organic carbon content was found in Mori block (0.91 g kg^{-1} soil).

Table 1: General properties of soils of Uttarkashi district

Blocks	pH(1:2)	EC (dSm^{-1})	OC ($g\ kg^{-1}$)	Texture
Bhatwari	4.88-6.83 (5.60)	0.15-0.64 (0.38)	0.17-1.06 (0.81)	Sandy loam –Sandy clay Loam
Dunda	4.94-7.25 (5.78)	0.11-0.66 (0.27)	0.34-1.07 (0.84)	Sandy-Sandy loam
Mori	4.79-7.47 (5.71)	0.10-0.81 (0.32)	0.30-1.07 (0.91)	Sandy clay Loam-Sandy
Puraula	4.87-7.74 (6.52)	0.10-0.88 (0.37)	0.41-1.08 (0.88)	Sandy loam- Sandy clay Loam
Naugaon	5.50-8.09 (6.70)	0.14-0.98 (0.48)	0.55-1.06 (0.83)	Sandy clay Loam-Sandy
Chiniyalisaur	5.86-8.06 (6.76)	0.16-0.92 (0.42)	0.43-1.05 (0.74)	Sandy loam-Sandy
Entire district	4.79-8.09 (6.18)	0.10-1.00 (0.37)	0.17-1.08 (0.87)	Sandy –Sandy clay Loam

(The mean values are in the parenthesis)

Extractable macronutrients

The extractable concentrations of macro-nutrients in soils of different blocks of Uttarkashi district are depicted in Table 2. The alkaline $KMnO_4$ hydrolysable N in the soils of Uttarkashi district varied from 104-365 kg ha^{-1} with a mean value of 281 kg ha^{-1}. Highest average hydrolysable N was found in Puraula and Bhatwari blocks (297 kg ha^{-1}). Amritanshu *et al.* (2023) reported similar results of hydrolysable N in the soils of Dehradun district of Uttarakhand, where the range was 100– 363 kg ha^{-1}. The extractable P in the soils of Uttarkashi district varied from 3.6-35.7 kg ha^{-1} with an average of 26.1 kg ha^{-1}. The highest average extractable P was found in Bhatwari block 29.7 kg ha^{-1}). The extractable K in the soils of Uttarkashi district varied from 90-470 kg ha^{-1} with an average of 260 kg ha^{-1}. Similarly, highest average extractable K was in the Bhatwari block (316 kg ha^{-1}).The extractable Ca in the soils of Uttarkashi district varied from 351-3758 mg kg^{-1} with an average of 1576 mg kg^{-1}. In the entire district, the block with the highest average extractable Ca was in Naugaon block (2068 mg kg^{-1}). Bungla et al. (2019) also reported similar trends in various blocks of Pithoragarh district of Uttarakhand, where extractable Ca content was ranging from 478-3782 mg kg^{-1}. The extractable Mg in the soils of Uttarkashi district varied from 30 - 942 mg kg^{-1} with an average of 177 mg kg^{-1}. In the entire district, the block the highest average extractable Mg was in block Dunda (230 mg kg^{-1}).

Table 2: Extractable macro-nutrient status in soils of Uttarkashi district

Blocks	Hydrol.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})
Bhatwari	150-365 (297)	14.5-37.0 (29.7)	101-470 (316)	802-2104 (1405)	30-456 (135)	9.6-15.7 (12.1)
Dunda	104-340 (241)	8.4-37.5 (24.8)	112-135 (230)	601-2054 (1320)	30-486 (230)	8.5-16.6 (11.7)
Mori	110-345 (277)	6.8-35.0 (22.9)	123-426 (270)	351-3056 (1145)	30 -790 (180)	7.0-18.3 (12.0)
Puraula	160-360 (297)	13.7-36.6 (28.3)	90-414 (234)	401-3607 (1739)	30 -942 (143)	8.7-21.0 (13.7)
Naugaon	210-360 (296)	4.4-37.0 (25.0)	123-437 (271)	701-3758 (2068)	30-547 (205)	8.7-21.8 (13.0)
Chiniyalisaur	190-355 (275)	3.6-36.6 (26.0)	90-437 (238)	651-3607 (1779)	30. -729 (168)	5.2-17.5 (10.8)
Entire district	104-365 (281)	3.6-35.7 (26.1)	90-470 (260)	351-3758 (1576)	30-942 (177)	5.2-21.8 (12.2)

(The mean values are in the parenthesis)

The extractable S in the soils of Uttarkashi district varied from 5.2-21.8 mg kg^{-1} with an average of 12.2 mg kg^{-1}. In the entire district, the block with the highest average extractable S was Puraula block (13.7 mg kg^{-1}). Pachauri *et al.* (2023) also reported similar findings from the soil of Haridwar district of Uttarakhand where available S ranged from 5.3 to 29.4 mg kg^{-1} soil.

Extractable micronutrients

The extractable contents of micro-nutrients in soils of different blocks of Uttarkashi district are depicted in Table 3. On the whole, the overall concentration of extractable Zn varied from 0.10-15.20 mg kg^{-1} with an average of 2.00 mg kg^{-1}. In the entire district, the block with the highest average DTPA extractable Zn was in Bhatwari block (3.20 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 Uttarkashi district varied from 0.01-10.50 mg kg^{-1} with an average of 2.03 mg kg^{-1}. In the entire district, the block with the highest average DTPA extractable Cu was in Naugaon (3.39 mg kg^{-1}). Prajapati *et al.* (2021) also found similar results in Tehri Garhwal district of Uttarakhand, where DTPA extractable Cu content varied from 0.25–11.03 mg kg^{-1}. The DTPA extractable Fe content in the soils of Uttarkashi district varied from 2.86-97.80 mg kg^{-1} with an average of 40.55 mg kg^{-1}. In the entire district, the block with the highest average extractable Fe was in Bhatwari block (64.15 mg kg^{-1}).

Table 3: Extractable micro-nutrient status in soils of Uttarkashi district

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})
Bhatwari	0.23-15.20 (3.20)	0.74-6.94 (2.32)	33.65-97.80 (64.15)	5.15-63.41 (30.72)	0.27-0.90 (0.58)	0.47-1.20 (0.82)
Dunda	0.36-3.76 (1.16)	0.42-.375 (1.90)	6.61-84.96 (50.16)	5.20-63.77 (30.27)	0.23-0.86 (0.41)	0.55-1.20 (0.87)
Mori	0.10-8.00 (1.51)	0.01-5.11 (1.09)	3.35-67.26 (40.07)	1.84-58.28 (21.25)	0.23-0.77 (0.50)	0.55-1.24 (0.86)
Puraula	0.47-10.84 (1.75)	0.27-3.14 (1.35)	6.07-92.02 (40.87)	3.17-54.62 (18.20)	0.45-0.86 (0.62)	0.58-1.20 (0.87)
Naugaon	0.30-8.54 (2.13)	0.52-10.50 (3.39)	6.52-66.98 (28.71)	7.97-50.85 (24.63)	0.27-1.22 (0.56)	0.51-1.42 (0.86)
Chiniyalisaur	0.34-10.94 (2.22)	0.65-5.61 (2.11)	2.86-55.10 (19.36)	6.18-54.56 (23.79)	0.23-0.95 (0.53)	0.51-1.49 (0.84)
Entire district	0.10-15.20 (2.00)	0.01-10.50 (2.03)	2.86-97.80 (40.55)	1.84-63.77 (24.81)	0.23-1.22 (0.53)	0.47-1.49 (0.85)

(The mean values are in the parenthesis)

Singh *et al.* (2006) also reported similar results in soils of Uttaranchal hills under different vegetation, where extractable Fe content varied from 14.0-284.0 mg kg^{-1}. The DTPA extractable Mn content in the soils of Uttarkashi district varied from 1.84-63.77 mg kg^{-1} with an average of 24.81 mg kg^{-1}. In the entire district, the block with the highest average extractable Mn was in Bhatwari block (30.72 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 Uttarkashi district varied from 0.23-1.22 mg kg^{-1} with an average of 0.53 mg kg^{-1}. In the entire district, the block with the highest average content of hot water soluble B was in Puraula block (0.62 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 Uttarkashi district varied from 0.47-1.49 mg kg^{-1} with an average of 0.85 mg kg^{-1}. In the entire district, the block with the highest average extractable Mo was in Dunda and Puraula block (0.87 mg kg^{-1}).

Percent distribution of soil samples in different categories of available macronutrients in different blocks

Percent samples in low, medium and high categories and the computed nutrient index (N.I.) for different soil extractable macronutrients in different blocks of Uttarkashi district are shown in Table 4. The soil samples deficient in hydrolysable N were 16, 44,34,22,24 and 46 per cent in Bhatwari, Dunda, Mori, Puraula, Naugaon and Chiniyalisaur, respectively. In the entire Uttarkashi district only 31 per cent soil samples were found deficient in soil hydrolysable N due to sufficient mineralization of soil organic matter. The majority of soil samples from all the blocks of Uttarkashi district were found high in soil extractable P. The soil samples deficient in extractable soil K were 12 and 20 percent in Puraula and Chiniyalisaur, respectively. In the entire Uttarkashi district, 6 percent soil samples were found deficient in extractable soil K. All Blocks of Uttarkashi were found high in extractable Calcium and magnesium. The soil sample deficient in extractable soil S were 6,10,16,8,24 and 40 percent in Bhatwari, Dunda, Mori, Puraula, Naugaon and Chiniyalisaur, respectively. In the entire Uttarkashi district only 17.3 per cent soil samples were found deficient in extractable soil S.

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

Name of Blocks	Categories	N	P	K	Ca	Mg	S
Bhatwari	Low	16	0	2	0	0	6
(50)	Medium	84	20	18	0	12	90
	High	0	82	80	100	88	4
	NI	1.84	2.80	2.78	3.00	2.88	1.98
Dunda	Low	44	4	2	0	0	10
(50)	Medium	56	40	74	0	8	88
	High	0	56	24	100	92	2
	NI	1.56	2.52	2.22	3.00	2.92	1.92
Mori	Low	34	10	0	0	0	16
(50)	Medium	66	42	54	0	10	74
	High	0	48	46	100	90	10
	NI	1.96	2.38	2.46	3.00	2.90	1.94
Puraula	Low	22	0	12	0	0	8
(50)	Medium	78	26	60	0	16	68
	High	0	74	28	100	84	24
	NI	1.78	2.74	2.16	3.00	2.84	2.16
Naugaon	Low	24	14	0	0	0	24
(50)	Medium	76	28	50	0	6	50
	High	0	58	50	100	94	26
	NI	1.76	2.44	2.50	3.00	2.94	2.02
Chiniyalisaur	Low	46	2	20	0	0	40
(50)	Medium	54	32	24	0	14	54
	High	0	64	56	100	86	6
	NI	1.54	2.64	2.36	3.00	2.86	1.66
Entire District	Low	31	5	6	0	0	17.3
(300)	Medium	69	31.5	55.3	0	11	70.7
	High	0	63.7	38.7	100	89	12
	NI	1.69	2.59	2.33	3.00	2.89	1.95

(The numbers of samples are in the parenthesis)

Percent 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 along with nutrient index (NI) are presented in Table 5. The soil samples deficient in soil extractable Zn were 12, 26, 32, 6, 20 and 6 per cent in Bhatwari, Dunda, Mori, Puraula, Naugaon and Chiniyalisaur, respectively. In the entire Uttarkashi district, 17 percent soil samples were found to be deficient in

soil extractable Zn. The soil samples deficient in soil extractable Cu were 4 percent in Mori block. The soil samples deficient in in soil extractable Fe were 2 and 4 percent in Mori and Chiniyalisaur, respectively. In the entire Uttarkashi district, only one percent soil samples were found to be deficient in soil extractable Fe. The soil samples deficient in soil extractable Mn were 2 percent in Mori. In general, 0.3 percent soil samples were found deficient in soil extractable Mn. No soil samples were found deficient in hot water-soluble B and Mo in all the blocks of Uttarkashi but 47 percent samples were found in medium category in hot water-soluble B.

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

Name of Blocks	Categories	Zn	Cu	Fe	Mn	B	Mo
Bhatwari	Low	12	0	0	0	0	0
(50)	Medium	22	0	0	0	22	0
	High	66	100	100	100	78	100
	NI	2.54	3.00	3.00	3.00	2.78	3.00
Dunda	Low	26	0	0	0	0	0
(50)	Medium	34	0	2	0	76	0
	High	40	100	98	100	24	100
	NI	2.14	3.00	2.98	3.00	2.24	3.00
Mori	Low	32	4	2	2	0	0
(50)	Medium	22	14	4	6	42	0
	High	46	82	94	92	58	100
	NI	2.14	2.78	2.92	2.90	2.58	3.00
Puraula	Low	6	0	0	0	0	0
(50)	Medium	38	10	4	2	6	0
	High	56	90	96	98	94	100
	NI	2.50	2.90	2.96	2.98	2.94	3.00
Naugaon	Low	20	0	0	0	0	0
(50)	Medium	18	0	2	0	38	0
	High	62	100	98	100	62	100
	NI	2.42	3.00	2.98	3.00	2.62	3.00
Chiniyalisaur	Low	6	0	4	0	0	0
(50)	Medium	26	0	22	0	42	0
	High	68	100	74	100	58	100
	NI	2.62	3.00	2.70	3.00	2.58	3.00
Entire District	Low	17	0.7	1	0.3	0	0
(300)	Medium	26.7	4	5.7	1.3	47.3	0
	High	56.3	95.3	95.3	98.4	52.7	100
	NI	2.39	2.95	2.92	2.98	2.50	3.00

(The numbers of samples are in the parenthesis)

Nutrient Indices

The nutrient index (N.I.) was worked out for different blocks of Uttarkashi district for different soil extractable nutrients and shown in Table 4 and 5. Bhatwari and Naugaon block was medium in N and S, but high in rest of the nutrients. Dunda block was medium in N, K, S, Zn and B but high in rest of the nutrients. Mori block was medium in N, S and Zn, but high in rest of the nutrients. Bhatwari block was medium in N and S, but high in rest of the nutrients. Puraula block was medium in N, K and S, but high in rest of the nutrients. Chiniyalisaur block was low in N and S, but high in rest of the nutrients. The nutrient index (N.I.) computed for different extractable soil nutrients for the entire district of Uttarkashi showed that the overall the district was medium in N, K & S and high in all other nutrients (P, Ca, Mg, Zn, Cu, Fe, Mn, B and Mo).

Correlation coefficient between soil extractable nutrients and general soil properties

As shown in Table 6, soil pH showed a significant and positive correlation with Ca^{++} (r = 0.581**) S (r = 0.254**), B (r = 0.178**), Zn (r = 0.154*), N (r = 0.152**), Cu (r = 0.145**), Mg^{++} (r

= 0.116*) and K (r= 0.069*) but showed negative correlation with Fe (r = -0.572), Mn (r = -194) P (r = -0.028) and Mo (r = -0.026). A positive correlation between soil pH and soil extractable Ca, S, B, Zn, N, Cu and Mg possibly indicated higher soil retention of these nutrients at neutral soil pH and lower leaching losses, especially K. A significant negative correlation between soil pH and soil extractable Fe indicated a decrease in solubility of Fe with increase in soil pH. Soil EC showed a significant and positive correlation with P (r = 0.941**), Ca (r = 0521**), K (r = 0.322**), S (r = 0.281**), N (r = 0.201**), Cu (r =0.183**), B (r=0176**), Zn (r= 0.170**) and Mg (r= 0.083*). 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, Ca, K, S, N, Cu, B, Zn, and Mg could be attributed to this reason (Smaling et al., 1993). Soil organic carbon overall showed a significant and positive correlation with N (r = 0.638**), Fe (r =0.106*), S (r =0.050*) and Cu (r =0.011*). A significant positive correlation between soil organic C content and these elements implied that presence of soil organic matter played significant role in retention of these nutrients.

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

Nutrients	pH(1:2)	EC (dSm^{-1})	Organic carbon (%)
N	0.152**	0.201**	0.638**
P	-0.028	0.941**	-0.047
K	0.069*	0.322**	-0.166
S	0.254**	0.281**	0.050*
Zn	0.154*	0.170**	-0.096
Fe	-0.572	-0.206	0.106*
Cu	0.145**	0.183**	0.011*
Mn	-0.194	-0.081	-0.015
B	0.178**	0.176**	-0.064
Ca^{++}	0.581**	0.521**	-0.023
Mg^{++}	0.116*	0.083*	-0.016
Mo	-0.026	-0.070	-0.010

***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 Uttarkashi 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 Uttarkashi showed that the overall the district was medium in N, K and S and high in rest nutrients (P, Ca, Mg, Zn, Cu, Fe, Mn, B and Mo). 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, 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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REFERENCES

Amritanshu, Pachauri, S.P.; Tyagi, A.K.;Srivastava, Ajaya and Pathak, Anand (2023). Status of some macro- and micro- nutrients in soils of Dehradun district of Uttarakhand. *Annals of Plant and Soil Research*, 25(2): 221-229.

Arya, R.P., Pachauri, S.P. and Srivastava, P.C. (2019). Status of some macro- and micro- nutrients in soils of Almora district of Uttarakhand. *Pantnagar Journal of Research*, 17(2):138-146.

Athokpam, H., Wani, S.H., Kamei, D., Athokpam,

H.S., Nongmaithem, J., Kumar, D., Singh, Y.K., Naorem, B.J., Devi, T.R. and Devi, L. (2013). Soil macro- and micro-nutrient status of Senapati district, Manipur (India). *African Journal of Agricultural Research*, 8(39):4932-4936.

Aziz, M.A., Amees, T., Aezum,S., Sheeraz, M. and Tahir, A. (2012). Effect of integrated nutrients management on soil physical properties using soybean as indicator crop under temperate conditions. *International Journal of Current Research*, 4:203-207.

Berger, K.C. and Troug, E. (1939). Boron determination in soils and plants. *Industrial & Engineering Chemistry Analytical Edition*, 11: 540-545.

Bi, L., Zhang, B., Liu, G., Li, Z., Liu, Y., Ye, C., Yu, X., Lai, T., Zhang, J., Yin, J. and Liang, Y. (2009). Long-term effects of organic amendments on the rice yields for double rice cropping systems in subtropical China. *Agriculture, Ecosystems & Environment,* 129:534–541.

Bower, C.A. and Wilcox, L.A. (1965). Soluble Salts. pp. 433-451. In: Black C.A. et al. (ed.). Method of soil analysis, part 2, ASA, Inc. Madison, Wis, USA.

Bray, R.H. and Kurtz, L.T. (1945). Determination of total, organic and available forms of phosphorus in soils. *Soil Science*, 59: 39-45.

Bungla, P., Pachauri, S.P., Srivastava, P.C., Pathak, A and Singh, R.K. (2019). Macro- and Micro- nutrients status in some soils of Pithoragarh district of Uttarakhand. *Annals of Plant and Soil Research*, 21(2): 108-115.

Chander, G., Sharma, S., Sharma, V., Verma, S., Sharma, S. and Verma, T.S. (2014). Micronutrient cations status in vegetable growing soils of sub-humid and wet-temperate zones of Himachal Pradesh. *Himachal Journal of Agricultural Research*, 40(1): 79-83.

Cheng, K.L. and Bray, R.H. (1951). Determination of calcium and magnesium in soil and plant material. *Soil Science*, 72: 449-458.

Grigg, J.L. (1953). Determination of available molybdenum of soils. *New Zealand Journal of Science and Technology*, 34: 405-414.

Guo, J.H., Liu, X.J., Zhang, Y., Shen, J.L., Han, W.X., Zhang, W.F., Christie, P., Goulding, K.W.T., Vitousek, P.M. and Zhang, F.S. (2010). Significant acidification in major Chinese croplands. *Science,* 327:1008–1010.

Hussain, I., Olson, K.R., Wander, M.M., Karlen, D.L. (1999). Adaptation of soil quality indices and application to three tillage systems in southern Illinois. *Soil and Tillage Research,* 50: 237–249.

Jackson, M.L. (1967). Soil Chemical Analysis. Prentice Hall of India (P) Ltd., New Delhi, Pp. 183-192.

Kong, X.B., Zhang, F.R., Wei, Q., Xu, Y., Hui, J.G. (2006). Influence of land use change on soil nutrients in an intensive agricultural region of North China. *Soil and Tillage Research,* 88:85–94.

Kumar, K., Adak, T. and Singh, V.K. (2015). Status and distribution of Micronutrient in Mango orchards under sub-tropical region of Uttar Pradesh. *Journal of Agricultural Physics*, 15(2): 127-139.

Lindsay, W.L. and Norvell, W.A. (1978). Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of America Journal*, 42: 421-428.

Olsen, S.R., Col, C.V., Watanabe, F.S. and Dean, L.A. (1954). Estimation of available phosphorus in soils by extraction with bicarbonate, Circular of the United States Department of Agriculture 939, US Government Printing Office, Washington DC.

Pachauri, S. P.; Pathak, Anand; Tyagi, A.K.; Pant, Chayan; Tiwari, Sadanand and Pal, Yogendra (2023). Assessment of some macro- and micro- nutrients along with multivariate analysis of their special distribution in soils of Haridwar district of Uttarakhand. *Annals of Plant and Soil Research*, 25(1): 70-78.

Prajapati, A., Pachauri, S.P., Srivastava, P.C., Pathak, A. and Rawat, D. (2021).Status of some extractable macro-and micro-nutrients in soils of Tehri Garhwal district of Uttarakhand. *Pantnagar Journal of Research*, 19(2):171-179.

Ramamoorthy and Bajaj (1969). Available N, P and K status of Indian soils. *Fertiliser News*, 14 (8): 24-28.

Schollenberger, C.J. and Simon, R.H. (1945). Determination of exchange capacity of exchangeable bases in soil- ammonium acetate method. *Soil Science*, 59: 13-24.

Shukla, A. K., Behera, S. K., Prakash, C., Patra, A. K., Rao, C. S., Chaudhari, S. K. and Green, A. (2021). Assessing multi-micronutrients deficiency in agricultural soils of India. *Sustainability*, 13(16): 9136.

Singh, R.D., Kumar, S. and Pande, H. (2006). Micronutrient status of soils under different vegetations in Uttaranchal hills. *Journal of the Indian Society of Soil Science*, 54 (1):115-116.

Smaling, E.M.A., Stoorvogel, J.J. and Windmeijer, P.N. (1993) Calculating soil nutrient balances in Africa at different scales. *Fertilizer Research* 35, 237–250

Subbiah, B.V. and Asija, G.L. (1956). A rapid procedure for assessment of available nitrogen in rice plots. *Current Science*, 31: 196-200.

Tisdale, S.L., Nelson, W.L., Beaton, J.D. and Havlin, J.L. (1997). Soil Fertility and Fertilizers, 5th Edition, Macmillan Publishing Co., New Delhi. Pp. 144, 180, 198,201.

Williams, C.H. and Steinbergs, A. (1969). Soil sulphur fractions as chemical indices of available sulphur in some Australian soils. *Australian Journal Agricultural Research*, 10: 340-352.