# Status of some macro- and micro-nutrients in soils of Almora district of Uttarakhand

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**ABSTRACT :** An investigation was carried out to study the soil available macro- and micro-nutrients (N, P, K, Ca, Mg, S, Zn, Cu, Fe, Mn, B and Mo) and some physico-chemical properties in soils (0-15 cm) of Almora district (Uttarakhand). The Global Positioning System (GPS) based 291 soil samples were collected, analyzed for the extractable contents of macro and micro-nutrients and correlated with important soil properties. Soil texture of the district varied from sandy loam to sandy clay loam, soil $pH_{1:2}$ ranged from 4.24 to 8.86, electrical conductivity from 0.02 to 0.41dSm$^{-1}$ and organic carbon from 1.1 to 54.0 g kg$^{-1}$. In the soils of the entire district, the ranges observed for different nutrients were: alkaline $KMnO_4$-N (50.4 to 140.0 mg kg$^{-1}$), extractable P (2.8 to 95.0 mg kg$^{-1}$), K (50.5 to 405.0 mg kg$^{-1}$), S (2.60 to 36.29 mg kg$^{-1}$), Ca (844 to 6244 mg kg$^{-1}$), Mg (120 to 2640 mg kg$^{-1}$), Zn (0.10 to 19.25 mg kg$^{-1}$), Cu (0.18 to 2.99 mg kg$^{-1}$), Fe (1.93 to 127.02 mg kg$^{-1}$), Mn (1.24 to 56.92 mg kg$^{-1}$), B (0.12 to 1.11 mg kg$^{-1}$) and Mo (0.02 to 0.36 mg kg$^{-1}$). The relationship between soil properties and extractable macro- and micro- nutrient contents revealed that soil pH had significant and positive correlation with extractable P, K, S and Zn but had negative correlation with extractable Fe, Mn and B. Electrical conductivity (EC) was significantly and positively correlated with extractable N, K, Ca, S and Zn but negatively correlated with extractable Mn. Organic carbon showed a significant and positive correlation with extractable B but negative correlation with extractable N, K, Ca, S, Zn, Cu and Fe. In general, the soils of Almora district were very acidic to moderately alkaline in reaction, low to medium in salt concentration and generally high in organic carbon status. Based on the calculated nutrient indices (N.I.), the soils of Almora were rated low in N, medium in S and B but high in rest of the other nutrients.

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

Soil fertility is one of the important factors deciding the yields of crops grown in a geographical region. The variation in nutrient supply is a natural phenomenon and some of them may be sufficient in amounts whereas, others may turn out to be deficient. The crop productivity cannot be boosted further without judicious use of macro- and micronutrient fertilizers to overcome existing nutrient deficiencies/imbalances (Tisdale *et al.*, 1997). In Uttarakhand, hill soils are brown to grayish brown and dark grey in color and moderately acidic to neutral in reaction. Hill soils are highly porous with low moisture retention capacity; the soils are moderately to severely erosion prone and terrace cultivation on steep slopes. Wheat, rice, barley, minor millet, sugarcane potato and lentil are the major crops of the hills (Shukla *et al*., 2013). Therefore, periodic evaluation of fertility status of the soils of a region is very important. The present investigation was undertaken to examine the status of soil fertility in all blocks of Almora District and study the relationships between general soil properties and extractable amounts of important macro- and micronutrients.

## MATERIALS AND METHODS

The study area belongs to Almora district of Uttarakhand state, spread over ""29026 to 300 20N latitudes and 7903.5to 800 11E longitudes covering 3083 sq. km geographical area. The altitude ranges from 600 to 3000 meter above the mean sea level and the average elevation of 1,861 meters. It is located on a ridge at the southern edge of the *Kumaon* Hills of the Himalaya range. In the shape of a horse saddle shaped hillock, it is surrounded by thick forests of pine, deodar and oak trees. For the Administrative convenience, the entire district has been divided into 11 developmental blocks viz. Hawalbag, Takula, Dwarahat, Tarikhet, Bhikiyasain, Sult, Chaukutiya, Syaldey, Lamagra, Dhauladevi and Bhaisiyachhana. Global Positioning System (GPS) based soil samples were collected from eleven developmental blocks of Almora district of Uttarakhand at 0-15 cm depth. Soil samples were air-dried, ground and passed through 2 mm sieve and stored in the polythene bags until analysis.

The pH of soil samples was determined in soil-water

suspension (1:2) after half an hour equilibration using a combined glass electrode equipped pH meter (Jackson, 1967). The electrical conductivity of soil samples was determined in the supernatants of soil water suspensions (1:2) with the help of a conductivity meter (Bower and Wilcox,1965) and the values were expressed as $dSm^{-1}$ at 25º C. Soil organic carbon content in the soil samples was determined by modified Walkley and Black method (Jackson, 1967). Alkaline $KMnO_4$ hydrolysable N in soil samples was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956). Phosphorus was extracted from neutral to alkaline soils by 0.5 M $NaHCO_3$ (pH 8.5) as described by Olsen *et al.* (1954). In acidic soils (pH 4.5-5.5), phosphorus was extracted by 0.03 N $NH_4F$ + 0.025 N HCl as described by Bray and Kurtz (1945). Potassium was extracted from soils using 1N ammonium acetate (pH 7.0) following the method of Schollenberger and Simon (1945). Soil samples were also extracted for Ca and Mg in 1 N neutral ammonium acetate extractant and quantified by EDTA titration method as outlined by Cheng and Bray (1951). Sulphur in the soil was extracted with 0.15% $CaCl_2$ and S in the extract was determined by turbidimetry using $BaCl_2$ crystals (Chesnin and Yien, 1951). Zinc, Cu, Fe and Mn were extracted by DTPA (pH 7.3) as described by Lindsay and Norwell (1978). Hot water soluble B in the soil samples was extracted by following the method of Berger and Troug (1939) and determined by Azomethine H method. Molybdenum in the soil samples was extracted in 1M ammonium oxalate (pH 3.3) and determined using a colorimetric method (Grigg, 1953).The soil samples were categorized in low, medium and high categories for different nutrients as per the limit values given in Table 1.

Based on the number of samples in each category for a given nutrient the nutrient index (NI) value was calculated as: Nutrient index (NI) = $[(N_L \times 1) + (N_M \times 2) + (N_H \times 3)]$/(Total number of soil samples)

Where, $N_L$, $N_M$ and $N_H$ are indicating the number of soil samples in low, medium and high categories, respectively. Accordingly, the areas with nutrient index value > 2.33 were considered high, those with NI between 1.67 to 2.33 were considered medium and those with values < 1.67 were regarded as low in the native supply of that nutrient (Ramamoorthy and Bajaj, 1969). For statistical analysis, simple correlation analysis was done as per the statistical procedure outlined by Snedecor and Cochran (1967). The test of significance was performed both at $p \leqslant 0.05$ and $\leqslant 0.01$. The statistical analysis of the data was done with the help of Standard Computer Programs (STPR) software (GBPUAT, 2004). The test of significance was conducted at 5 and 1% level of significance ($p \leqslant 0.05$ and $p \leqslant 0.01$).

## RESULTS AND DISCUSSION

### General soil properties

The properties of the soil of Almora district are shown in Table 2. In the district of Almora as a whole, soil texture varied from sandy loam to sandy clay loam. The soils of the Almora district were acidic to slightly alkaline in reaction as the pH of the district ranged from 4.24 to 8.86 with the mean value of 6.16. A mean value of pH (7.59) was observed in Bhikiyasain block. Acidic soil pH in many blocks could be related to decomposition of the organic matter in the soil and release of some organic

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

| Nutrients | | Extractable content (mg $kg^{-1}$) | | |
|---|---|---|---|---|
| | | Low | Medium | High |
| Alk. KMnO4 hydr.- 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- 125.0 | >125.0 |
| Ca | | < 200 | 200-300 | > 300 |
| Mg | | < 12 | 12-36 | > 36 |
| S | | < 10 | 10-15 | > 15 |
| Zn | | < 0.6 | 0.6-1.2 | > 1.2 |
| Cu | | < 0.2 | 0.2-0.4 | > 0.4 |
| Fe | | < 4.8 | 4.8-8.7 | > 8.7 |
| Mn | | < 2 | 2-4 | > 4 |
| B | | < 0.25 | 0.25-0.50 | > 0.50 |
| Mo | | < 0.1 | 0.1-0.2 | > 0.2 |
| Organic Carbon (g $kg^{-1}$) | | < 5.0 | 5.0- 7.5 | > 7.5 |

**Table 2: Properties of soils of different blocks of Almora district**

| Blocks | pH (1 : 2) | EC ($dSm^{-1}$) | OC ($g\ kg^{-1}$) | Texture |
|---|---|---|---|---|
| Hawalbag | 4.92 - 8.05 (6.22) | 0.02 - 0.18 (0.07) | 2.7-18.7 (13.1) | Loamy sand to Silty clay loam |
| Takula | 5.05 - 6.72 (5.62) | 0.02 - 0.18 (0.11) | 1.1- 16.1 (9.3) | Sandy loam to Sandy clay loam |
| Dwarahat | 4.24 - 6.92 (5.30) | 0.03- 0.23 (0.09) | 7.9- 15.4 (11.6) | Sandy loam to Sandy clay loam |
| Tarikhet | 6.11 - 7.82 (6.99) | 0.04- 0.19 (0.10) | 3.3 - 13.1 (9.1) | Sandy loam to Silty clay loam |
| Bhikiyasain | 6.51 - 8.86 (7.59) | 0.03- 0.30 (0.14) | 2.8 - 16.7 (11.3) | Sandy loam to Sandy clay loam |
| Sult | 5.12 -7.43 (6.22) | 0.07- 0.25 (0.12) | 11.8 -16.6 (14.3) | Sandy loam to Silty clay loam |
| Chaukhutiya | 5.07 - 8.51 (6.60) | 0.03- 0.19 (0.10) | 2.0 - 16.3 (10.8) | Loamy sand to Silty clay loam |
| Syalde | 4.61 - 7.26 (5.59) | 0.04- 0.18 (0.13) | 4.8 - 15.5 (9.7) | Sandy loam to Silty clay loam |
| Lamgara | 4.72 - 7.35 (5.88) | 0.06- 0.34 (0.17) | 3.0 - 54.0 (9.7) | Loamy sand to Silty clay loam |
| Dhauladevi | 4.35 - 7.80 (5.02) | 0.02- 0.41 (0.09) | 5.5 - 15.0 (11.5) | Loamy sand to Sandy clay loam |
| Bhaisiyachhana | 5.07 - 8.11 (6.42) | 0.002- 0.19 (0.10) | 2.4 - 20.7 (12.3) | Sandy loam to Sandy clay loam |
| Almora district as whole | 4.24 - 8.86 (6.16) | 0.002 - 0.41 (0.11) | 1.1 - 54.0 (11.4) | Sandy loam to Sandy clay loam |

acids which could decrease pH in soils of lower buffering capacities (Aziz *et al.,* 2012).The Electrical conductivity of the Almora district ranged from 0.002 to 0.410 $dSm^{-1}$. Among all the blocks, the lowest and highest average electrical conductivity was found in Hawalbag (0.07 $dSm^{-1}$) and Lamgara (0.114 $dSm^{-1}$) blocks, respectively. In general, the soluble salt content in the soil was within the safe limit for growth of any crop. The organic carbon content in soils of Almora district ranged from 1.1 to 54.0 $g\ kg^{-1}$ with the mean value of 11.4 $g\ kg^{-1}$. Among all the blocks, the lowest and highest average organic carbon content was found in Tarikhet (9.1 $g\ kg^{-1}$) and Sult (14.3 $g\ kg^{-1}$) blocks, respectively.

**Extractable macro-nutrients**

The data on alkaline $KMnO_4N$, extractable soil P as determined by Olsen's-P and Bray's-P method, extractable- K, -Ca and –Mg and -S in the soils of Almora district are presented in Table 3. For the entire district, alkaline $KMnO_4$ hydrolysable N ranged from 50.4 to 140.0 mg N $kg^{-1}$ soil with a mean value of 87.4 mg N $kg^{-1}$ soil, extractable phosphorus content in soils varied from 2.8 to 95.0 mg P $kg^{-1}$ with the mean value of 19.5mg P $kg^{-1}$ of soils. Among all the blocks, the highest average extractable P was recorded in Sult block (31.4 mg $kg^{-1}$). The extractable K content in soils of Almora district varied from 50.5 to 405.0 mg K $kg^{-1}$ with the mean value of 203.0 mg K $kg^{-1}$ of soils. Among all the blocks, the highest average extractable K was found in Bhikiyasain block (274 mg $kg^{-1}$). For the entire district, extractable S content in soils varied from 2.6 to 36.3 mg $kg^{-1}$with the mean value of 14.6 mg $kg^{-1}$of soils. Among all the blocks, the highest average extractable S was found in Bhaisiyachhana block (18.9 mg $kg^{-1}$). The extractable Ca content in soils of Almora district varied from 844 to 6244 mg $kg^{-1}$with the mean value of 2093 mg $kg^{-1}$of soils. Among all the blocks, the highest average extractable Ca was found in Lamgara block (3026 mg $kg^{-1}$). The extractable Mg content in soils of Almora district ranged from 120 to 2640 mg $kg^{-1}$ with the mean value of 946 mg $kg^{-1}$ of soils. Among all the blocks, the highest average extractable Mg was found in Dwarahat block (1197 mg $kg^{-1}$). These results were in the same range as reported earlier by Bungla *et al*. (2018).

**Extractable micro-nutrients**

The data on DTPA extractable micronutrient cations (Zn, Cu, Fe and Mn), hot water soluble B and ammonium oxalate (pH 3.3) extractable Mo are presented in Table 4.The DTPA extractable Zn in soils of Almora district ranged from 0.10 to 20.70 mg $kg^{-1}$ with mean value of 4.09 mg $kg^{-1}$.Among all the blocks, the highest average

**Table 3: Status of extractable macronutrient status in soils of Almora district**

| Blocks | Alk. KMnO4 hydr. N (mg kg$^{-1}$) | Extractable P (mg kg$^{-1}$) | Extractable K (mg kg$^{-1}$) | Extractable S (mg kg$^{-1}$) | Extractable Ca (mg kg$^{-1}$) | Extractable Mg (mg kg$^{-1}$) |
|---|---|---|---|---|---|---|
| Hawalbag | 56.0-134.4 (79.4) | 6.2 - 52.0 (20.7) | 62 - 290 (153) | 2.6 - 10.4 (8.3) | 964 - 2684 (1634) | 120 - 2304 (687) |
| Takula | 56.0-117.6 (85.6) | 6.0 - 52.0 (23.4) | 82 - 355 (208) | 5.2 - 13.0 (8.8) | 1164 - 4764 (2245) | 144 - 1920 (1076) |
| Dwarahat | 56.0-134.4 (87.2) | 5.2- 34.3 (13.0) | 86 - 385 (180) | 5.2 - 18.2 (10.1) | 964 - 2684 (1864) | 432 - 1728 (1197) |
| Tarikhet | 56.0-134.4 (87.3) | 2.8 - 95.0 (23.4) | 140 - 405 (259) | 7.6 - 30.3 (18.3) | 1084 - 2444 (2255) | 256- 2640 (1163) |
| Bhikiyasain | 50.4-134.4 (85.4) | 9.9 - 75.2 (23.2) | 130 - 350 (274) | 7.6 - 30.3 (16.3) | 1164 - 4204 (1863) | 288 - 2016 (941) |
| Sult | 50.4-112.0 (84.0) | 15.9 - 56.9 (31.4) | 89 - 185 (131) | 7.6 - 18.9 (12.9) | 844 - 2444 (1543) | 120 - 1200 (714) |
| Chaukhutiya | 50.4-134.4 (81.4) | 9.3 - 56.9 (26.8) | 57 - 340 (247) | 7.6 - 30.3 (15.3) | 964 - 3644 (1930) | 264 - 1800 (986) |
| Syalde | 50.4-140.0 (87.1) | 3.0 - 48.5 (17.3) | 62.0 - 330.0 (161) | 7.6 - 34.1 (17.1) | 1164 - 2684 (1890) | 288 - 1920 (1016) |
| Lamgara | 56.0-140.0 (97.3) | 2.8 - 20.3 (8.7) | 51 - 270 (185) | 8.01 - 32.3 (16.5) | 1564 - 4444 (3026) | 456 - 1872 (855) |
| Dhauladevi | 56.0-134.4 (92.4) | 2.8 - 15.9 (7.0) | 120- 340 (221) | 8.1 - 36.3 (18.5) | 1164 - 3644 (1899) | 120 - 1368 (629) |
| Bhaisiyachhana | 56.0-140.0 (98.3) | 4.0 - 50.3 (18.5) | 54 - 375 (176) | 8.1 - 32.3 (18.9) | 844 - 4444 (2201) | 336 - 1896 (894) |
| Almora district | 50.4-140.0 (87.4) | 2.8 - 95.0 (19.5) | 50 - 405 (203) | 2.6 - 36.3 (14.6) | 844 - 6244 (2093) | 120 - 2640 (946) |

extractable Zn was found in Tarikhet block (6.32 mg kg$^{-1}$). The high content of Zn in soil might be associated with high organic matter content and less weathered soil conditions. The DTPA extractable Cu in soils of Almora district ranged from 0.11to 2.99 mg kg$^{-1}$ with mean value of 0.83 mg kg$^{-1}$ and among all the blocks, the highest average extractable Cu was found in Takula block (1.46 mg kg$^{-1}$). Similar range of DTPA extractable Cu was reported in the study of Chattopadhyay *et al*., (1996) and Yurembam *et al.*, (2015). The DTPA extractable Fe in soils of Almora district ranged from 1.93 to 127.02 mg kg$^{-1}$ with mean value of 18.06 mg kg$^{-1}$ and among all the blocks, the highest average extractable Fe was found in Takula block (48.66 mg kg$^{-1}$). These findings are in conformity with those of Jalali *et al.* (1989). The DTPA extractable Mn in soils of Almora district ranged from 1.24 to 56.92 mg kg$^{-1}$ with mean value of 18.84 mg kg$^{-1}$ and among all the blocks, the highest average extractable Mn was found in Syalde block (28.35 mg kg$^{-1}$). Hot water soluble B in soils of Almora district ranged from 0.12 to 1.11 mg kg$^{-1}$ with mean value of 0.40 mg kg$^{-1}$ and among all the blocks, the highest average extractable B was found in Syalde block (0.44 mg kg$^{-1}$). Ammonium oxalate (pH 3.3) extractable Mo in soils of Almora district ranged from 0.02 to 0.36 mg kg$^{-1}$ with mean value of 0.11 mg kg$^{-1}$ and among all the blocks, the highest average extractable Mo was found in Dhauladevi block (0.16 mg kg$^{-1}$) (Table 4).These results were similar to those reported by Shukla *et al*. (2013).

High micronutrient availability of micronutrients in soils of high organic matter content could be ascribed to chelating action of humic substances produced during the decomposition of organic matter which prevents their fixation, precipitation, oxidation and leaching in soils (Babu *et al*., 2007)

**Nutrient indices**

Percent samples in low, medium and high categories and the computed nutrient index (N.I.) for different soil extractable nutrients in different blocks of Almora district and shown in Table 5 and 6. In all 91.4% soil samples were deficient in N due to less use of fertilizers and poor mineralization of soil organic matter on account of low temperature regimes. The percent samples deficient in P were 3.4, 3.2, 16.7, 27.3 and 8.0% for Tarikhet, Syalde, Lamgara, Dhauladevi and Bhaisiyachhana blocks, respectively, with an overall percent deficiency of 4.8% in Almora district. The percent samples deficient in K were 0.7% in Almora district. The percent samples deficient in S were 46.4, 46.4, 42.3, 17.2, 18.5, 29.4, 23.5, 19.4, 29.2, 18.2 and 20.0% for Hawalbag, Takula, Dwarahat, Tarikhet, Bhikiyasain, Sult, Chaukhutiya, Syalde, Lamgara,

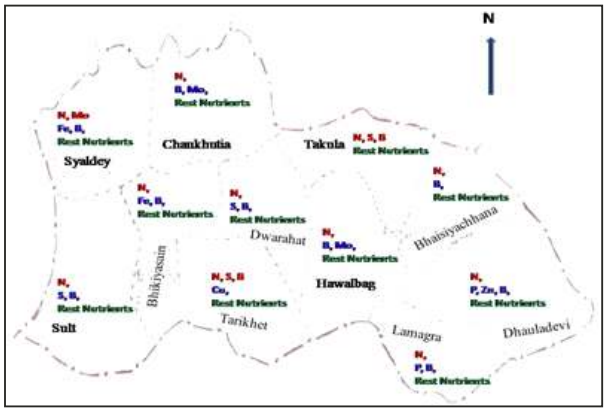
**Table 4: Status of extractable micronutrient status in soils of Almora district**

| 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$^{-1}$) |
|---|---|---|---|---|---|---|
| Hawalbag | 0.39-20.70 (3.82) | 0.11-1.71 (0.49) | 2.83-54.46 (18.37) | 2.80-39.74 (14.74) | 0.12-0.70 (0.29) | 0.04-0.30 (0.14) |
| Takula | 0.73-7.46 (2.74) | 0.43-6.21 (1.46) | 5.61-112.62 (48.66) | 1.57-47.87 (14.20) | 0.12-0.70 (0.25) | 0.04-0.28 (0.12) |
| Dwarahat | 0.35-14.98 (2.87) | 0.28-2.09 (0.89) | 6.54-127.02 (28.79) | 5.23-52.65 (20.41) | 0.12-0.97 (0.41) | 0.02-0.28 (0.12) |
| Tarikhet | 1.54-14.31 (6.32) | 0.30-2.03 (0.96) | 2.94-41.52 (21.21) | 3.56-56.92 (27.54) | 0.16-0.97 (0.33) | 0.02-0.28 (0.12) |
| Bhikiyasain | 1.27-9.57 (3.29) | 0.44-1.58 (0.61) | 1.93-16.22 (6.68) | 2.03-26.06 (10.05) | 0.16-0.99 (0.39) | 0.04-0.34 (0.12) |
| Sult | 0.75-2.83 (1.62) | 0.18-1.26 (0.71) | 4.01-20.56 (11.05) | 6.93-26.03 (16.25) | 0.16-0.99 (0.36) | 0.04-0.34 (0.09) |
| Chaukhutiya | 0.77-9.42 (2.22) | 0.34-1.87 (0.95) | 5.71-89.75 (38.29) | 1.24-43.56 (13.67) | 0.16-0.99 (0.36) | 0.02-0.28 (0.09) |
| Syalde | 1.17-19.25 (5.94) | 033-2.73 (0.74) | 2.54-18.72 (7.41) | 1.74-53.98 (28.35) | 0.18-1.11 (0.44) | 0.02-0.11 (0.05) |
| Lamgara | 0.10-9.54 (4.43) | 0.23-1.66 (0.68) | 7.32-36.00 (19.75) | 5.05-35.61 (16.58) | 0.16-1.11 (0.38) | 0.02-0.36 (0.12) |
| Dhauladevi | 0.43-4.75 (1.08) | 0.29-1.65 (0.57) | 5.30-27.50 (12.03) | 5.46-39.39 (24.33) | 0.16-0.95 (0.39) | 0.03-0.36 (0.16) |
| Bhaisiyachhana | 0.70-17.35 (5.49) | 0.22-2.99 (0.89) | 4.65-29.38 (16.35) | 2.70-27.46 (9.85) | 0.16-0.95 (0.34) | 0.02-0.36 (0.14) |
| Almora district | 0.10-20.70 (4.09) | 0.11-2.99 (0.83) | 1.93-127.02 (18.06) | 1.24-56.92 (18.84) | 0.12-1.11 (0.40) | 0.02-0.36 (0.11) |

Dhauladevi and Bhaisiyachhana, respectively, with an overall percent deficiency of 27.8% in Almora district.

A close perusal of the data contained in table 6 revealed that the percent samples deficient in available Zn were 10.7, 3.8, 12.5 and 13.6% for Hawalbag, Dwarahat, Lamgara and Dhauladevi blocks, respectively with an overall percent deficiency of 3.4% in Almora district. The percent samples deficient in available Cu were 25.0, and 5.9%for Hawalbag and Sult blocks, respectively with an overall percent deficiency of 2.7% in Almora district.

The percent samples deficient in available Fe were 14.3, 3.4, 29.6, 5.9, 22.6 and 4.0% for Hawalbag, Tarikhet, Bhikiyasain, Sult, Syalde and Bhaisiyachhana blocks, respectively with an overall percent deficiency of 7.6% in Almora district. The percent samples deficient in available Mn were 3.6, 2.9 and 3.2% for Hawalbag, Takula and Syalde blocks, respectively with an overall percent deficiency of 1.0% in Almora district. The percent samples deficient in available B were 67.9, 82.1, 30.8, 31.0, 25.9, 29.4, 26.5, 29.0, 25.0, 27.3 and 32.0% for Hawalbag, Takula, Dwarahat, Tarikhet, Bhikiyasain, Sult, Chaukhutiya, Syalde, Lamgara, Dhauladevi and Bhaisiyachhana blocks, respectively with an overall percent deficiency of 37.5% in Almora district. The percent samples deficient in available Mo were 7.1, 21.4, 11.5, 20.7, 18.5, 29.4, 44.1, 67.7, 20.8, 9.1 and 20.0% for Hawalbag, Takula, Dwarahat, Tarikhet, Bhikiyasain, Sult, Chaukhutiya, Syalde, Lamgara, Dhauladevi and Bhaisiyachhana blocks, respectively with an overall percent deficiency of 25.8% in Almora district.




The nutrient index (N.I.) calculated for different nutrients in different blocks of Almora district (Plate 1) showed that Hawalbag block was low in N, S and B, medium in Cu, high in rest other nutrients. Takula block showed that the block was low in N, S and B, and high in rest other nutrients. Dwarahat block showed that the block was low in N, medium in S and B and high in rest other nutrients, Tarikhet block showed that the block was low in N , medium in B and high in rest other nutrients, Bhikiyasain

**Table 5: Distribution of soil extractable macro- nutrients in the different categories of availability (%)in the blocks of Almora district**

| Name of Blocks | Soil Sample | | Percent distribution of extractable macro- nutrients | | | | | |
|---|---|---|---|---|---|---|---|---|
| | No. | Categories | N | P | K | Ca | Mg | S |
| Hawalbag | 28 | Low | 96.4 | 0.0 | 0.0 | 0.0 | 0.0 | 46.4 |
| | | Medium | 3.6 | 14.3 | 35.7 | 0.0 | 0.0 | 53.6 |
| | | High | 0.0 | 85.7 | 64.3 | 100.0 | 100.0 | 0.0 |
| | | NI | 1.04 | 2.86 | 2.64 | 3.00 | 3.00 | 1.54 |
| Takula | 28 | Low | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 46.4 |
| | | Medium | 0.0 | 39.3 | 7.1 | 0.0 | 0.0 | 53.6 |
| | | High | 0.0 | 60.7 | 92.9 | 100.0 | 100.0 | 0.0 |
| | | NI | 1.00 | 2.61 | 2.93 | 3.00 | 3.00 | 1.54 |
| Dwarahat | 26 | Low | 88.5 | 0.0 | 0.0 | 0.0 | 0.0 | 42.3 |
| | | Medium | 11.5 | 42.3 | 23.1 | 0.0 | 0.0 | 46.2 |
| | | High | 0.0 | 57.7 | 76.9 | 100.0 | 100.0 | 11.5 |
| | | NI | 1.12 | 2.58 | 2.77 | 3.00 | 3.00 | 1.69 |
| Tarikhet | 29 | Low | 89.7 | 3.4 | 0.0 | 0.0 | 0.0 | 17.2 |
| | | Medium | 10.3 | 10.3 | 0.0 | 0.0 | 0.0 | 3.4 |
| | | High | 0.0 | 86.2 | 100.0 | 100.0 | 100.0 | 79.3 |
| | | NI | 1.10 | 2.83 | 3.00 | 3.00 | 3.00 | 2.62 |
| Bhikiyasain | 27 | Low | 88.9 | 0.0 | 0.0 | 0.0 | 0.0 | 18.5 |
| | | Medium | 7.4 | 7.4 | 0.0 | 0.0 | 0.0 | 18.5 |
| | | High | 3.7 | 92.6 | 100.0 | 100.0 | 100.0 | 63.0 |
| | | NI | 1.15 | 2.93 | 3.00 | 3.00 | 3.00 | 2.44 |
| Sult | 17 | Low | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 29.4 |
| | | Medium | 0.0 | 0.0 | 47.1 | 0.0 | 0.0 | 11.8 |
| | | High | 0.0 | 100.0 | 52.9 | 100.0 | 100.0 | 58.8 |
| | | NI | 1.00 | 3.00 | 2.53 | 3.00 | 3.00 | 2.29 |
| Chaukhutiya | 34 | Low | 91.2 | 0.0 | 0.0 | 0.0 | 0.0 | 23.5 |
| | | Medium | 8.8 | 14.7 | 5.9 | 0.0 | 0.0 | 11.8 |
| | | High | 0.0 | 85.3 | 94.1 | 100.0 | 100.0 | 64.7 |
| | | NI | 1.09 | 2.85 | 2.94 | 3.00 | 3.00 | 2.41 |
| Syalde | 31 | Low | 96.8 | 3.2 | 0.0 | 0.0 | 0.0 | 19.4 |
| | | Medium | 3.2 | 29.0 | 41.9 | 0.0 | 0.0 | 9.7 |
| | | High | 0.0 | 67.7 | 58.1 | 100.0 | 100.0 | 71.0 |
| | | NI | 1.03 | 2.65 | 2.58 | 3.00 | 3.00 | 2.52 |
| Lamgara | 24 | Low | 87.5 | 16.7 | 4.2 | 0.0 | 0.0 | 29.2 |
| | | Medium | 12.5 | 54.2 | 25.0 | 0.0 | 0.0 | 8.3 |
| | | High | 0.0 | 29.2 | 70.8 | 100.0 | 100.0 | 62.5 |
| | | NI | 1.13 | 2.13 | 2.67 | 3.00 | 3.00 | 2.33 |
| Dhauladevi | 22 | Low | 90.9 | 27.3 | 0.0 | 0.0 | 0.0 | 18.2 |
| | | Medium | 9.10 | 54.5 | 4.5 | 0.0 | 0.0 | 4.5 |
| | | High | 0.0 | 18.2 | 95.5 | 100.0 | 100.0 | 77.3 |
| | | NI | 1.09 | 1.91 | 2.95 | 3.00 | 3.00 | 2.59 |
| Bhaisiyachhana | 25 | Low | 76.0 | 8.0 | 4.0 | 0.0 | 0.0 | 20.0 |
| | | Medium | 24.0 | 24.0 | 20.0 | 0.0 | 0.0 | 8.0 |
| | | High | 0.0 | 68.0 | 76.0 | 100.0 | 100.0 | 72.0 |
| | | NI | 1.24 | 2.60 | 2.72 | 3.00 | 3.00 | 2.52 |
| ENTIRE ALMORA DISTRICT | 291 | Low | 91.4 | 4.8 | 0.7 | 0.0 | 0.0 | 27.8 |
| | | Medium | 8.2 | 26.1 | 18.2 | 0.0 | 0.0 | 21.3 |
| | | High | 0.3 | 69.1 | 81.1 | 100.0 | 100.0 | 50.9 |
| | | NI | 1.09 | 2.64 | 2.80 | 3.00 | 3.00 | 2.23 |

block showed that the block was low in N, medium in Fe and B, high in rest other nutrients. Sult block showed that the block was low in N, medium in S and B but high in rest other nutrients. Chaukhutiya block showed that the block was low in N, medium in B and Mo and high in rest other nutrients. Syalde block showed that the block was low in N and Mo, medium in Fe and B but high in rest other nutrients, Lamgara block showed that the block was low

**Table 6: Distribution of soil extractable micro- nutrients in the different categories of availability (%)in the blocks of Almora district**

| Name of Blocks | Soil Sample | | Percent distribution of extractable macro- nutrients | | | | | |
|---|---|---|---|---|---|---|---|---|
| | No. | Categories | Zu | Cu | Fe | Mn | B | Mo |
| Hawalbag | 28 | Low | 10.7 | 25.0 | 14.3 | 0.0 | 67.9 | 7.1 |
| | | Medium | 17.9 | 17.9 | 17.9 | 7.1 | 17.9 | 0.0 |
| | | High | 71.4 | 57.1 | 67.9 | 92.9 | 14.3 | 92.9 |
| | | NI | 2.61 | 2.32 | 2.54 | 2.93 | 1.46 | 2.86 |
| Takula | 28 | Low | 0.0 | 0.0 | 0.0 | 3.6 | 82.1 | 21.4 |
| | | Medium | 21.4 | 0.0 | 3.6 | 14.3 | 10.7 | 0.0 |
| | | High | 78.6 | 100.0 | 96.4 | 82.1 | 7.1 | 78.6 |
| | | NI | 2.79 | 3.00 | 2.96 | 2.79 | 1.25 | 2.57 |
| Dwarahat | 26 | Low | 3.8 | 0.0 | 0.0 | 0.0 | 30.8 | 11.5 |
| | | Medium | 19.2 | 23.1 | 3.8 | 0.0 | 50.0 | 0.0 |
| | | High | 76.9 | 76.9 | 96.2 | 100.0 | 19.2 | 88.5 |
| | | NI | 2.73 | 2.77 | 2.96 | 3.00 | 1.88 | 2.77 |
| Tarikhet | 29 | Low | 0.0 | 0.0 | 3.4 | 0.0 | 31.0 | 20.7 |
| | | Medium | 0.0 | 3.4 | 3.4 | 6.9 | 58.6 | 0.0 |
| | | High | 100.0 | 96.6 | 93.1 | 93.1 | 10.3 | 79.3 |
| | | NI | 3.00 | 2.97 | 2.90 | 2.93 | 1.79 | 2.59 |
| Bhikiyasain | 27 | Low | 0.0 | 0.0 | 29.6 | 0.0 | 25.9 | 18.5 |
| | | Medium | 0.0 | 0.0 | 37.0 | 18.5 | 59.3 | 0.0 |
| | | High | 100.0 | 100.0 | 33.3 | 81.5 | 14.8 | 81.5 |
| | | NI | 3.00 | 3.00 | 2.04 | 2.81 | 1.89 | 2.63 |
| Sult | 17 | Low | 0.0 | 5.9 | 5.9 | 0.0 | 29.4 | 29.4 |
| | | Medium | 29.4 | 0.0 | 5.9 | 0.0 | 58.8 | 0.0 |
| | | High | 70.6 | 94.1 | 88.2 | 100.0 | 11.8 | 70.6 |
| | | NI | 2.71 | 2.88 | 2.82 | 3.00 | 1.82 | 2.41 |
| Chaukhutiya | 34 | Low | 0.0 | 0.0 | 0.0 | 2.9 | 26.5 | 44.1 |
| | | Medium | 17.6 | 2.9 | 8.8 | 5.9 | 61.8 | 0.0 |
| | | High | 82.4 | 97.1 | 91.2 | 91.2 | 11.8 | 55.9 |
| | | NI | 2.82 | 2.97 | 2.91 | 2.88 | 1.85 | 2.12 |
| Syalde | 31 | Low | 0.0 | 0.0 | 22.6 | 3.2 | 29.0 | 67.7 |
| | | Medium | 3.2 | 12.9 | 38.7 | 3.2 | 41.9 | 0.0 |
| | | High | 96.8 | 87.1 | 38.7 | 93.5 | 29.0 | 32.3 |
| | | NI | 2.97 | 2.87 | 2.16 | 2.90 | 2.00 | 1.65 |
| Lamgara | 24 | Low | 12,5 | 0.0 | 0.0 | 0.0 | 26.1 | 21.7 |
| | | Medium | 4.2 | 21.7 | 8.7 | 0.0 | 56.5 | 0.0 |
| | | High | 83.3 | 78.3 | 91.3 | 100.0 | 17.4 | 78.3 |
| | | NI | 2.71 | 2.78 | 2.91 | 3.00 | 1.91 | 2.57 |
| Dhauladevi | 22 | Low | 13.0 | 0.0 | 0.0 | 0.0 | 26.1 | 8.7 |
| | | Medium | 60.9 | 30.4 | 21.7 | 0.0 | 56.5 | 0.0 |
| | | High | 26.1 | 69.6 | 78.3 | 100.0 | 17.4 | 91.3 |
| | | NI | 2.13 | 2.70 | 2.78 | 3.00 | 1.91 | 2.83 |
| Bhaisiyachhana | 25 | Low | 0.0 | 0.0 | 4.0 | 0.0 | 32.0 | 20.0 |
| | | Medium | 16.0 | 4.0 | 8.0 | 4.0 | 56.0 | 0.0 |
| | | High | 84.0 | 96.0 | 88.0 | 96.0 | 12.0 | 80.0 |
| | | NI | 2.84 | 2.96 | 2.84 | 2.96 | 1.80 | 2.60 |
| ENTIRE ALMORA | 291 | Low | 3.4 | 2.7 | 7.6 | 1.0 | 37.5 | 25.8 |
| DISTRICT | | Medium | 16.2 | 10.3 | 14.8 | 5.8 | 47.4 | 0.0 |
| | | High | 80.4 | 86.9 | 77.7 | 93.1 | 15.1 | 74.2 |
| | | NI | 2.77 | 2.84 | 2.70 | 2.92 | 1.78 | 2.48 |

in N, and medium in P and B and high in rest other nutrients, Dhauladevi block showed that the block was low in N, medium in P, Zn and B but high in rest other nutrients. Bhaisiyachhana block showed that the block was low in N, medium in B and high in rest other nutrients. The nutrient index (N.I.) calculated for different nutrients in Almora district showed that the entire district was low in N, medium in S and B and high in rest other nutrients.

**Table 7: Correlation between soil properties and available nutrients in the soils of Almora district**

| Extractable Soil Nutrients | pH (1:2) | EC ($dSm^{-1}$) | OC ($g\ kg^{-1}$) |
|---|---|---|---|
| N | -0.006 | 0.120* | -0.163** |
| P | 0.281** | 0.058 | 0.026 |
| K | 0.271** | 0.127* | -0.214** |
| S | 0.115* | 0.140* | -0.145** |
| Ca | 0.039 | 0.357** | -0.162** |
| Mg | 0.087 | 0.024 | -0.027 |
| Zn | 0.187** | 0.111* | -0.117* |
| Cu | -0.030 | 0.053 | -0.202** |
| Fe | -0.258** | -0.063 | -0.228** |
| Mn | -0.298** | -0.235** | 0.054 |
| B | -0.146** | -0.018 | -0.130* |
| Mo | -0.005 | -0.013 | -0.003 |

**Significant at p≤0.01 and * Significant at p≤0.05.

**Correlation between general soil properties and extractable macro- and micro-nutrients**

It is evident from Table 7 that soil pH showed a significant and positive correlation with extractable-P (r = 0.281, significant at p⩽ 0.01), -K (r = 0.271, significant at p⩽ 0.01), -S (r = 0.115, significant at p⩽ 0.05) and -Zn (r = 0.187, significant at p⩽ 0.01) but showed a significant and negative correlation with extractable-Fe (r = -0.258, significant at p⩽ 0.01), -Mn (r = -0.298, significant at p⩽ 0.01) and -B (r = -0.146, significant at p⩽ 0.05). A positive correlation between soil pH and soil extractable P, K, S and Zn possibly indicated higher soil retention of these nutrients at neutral soil pH and lower leaching losses of especially, K. A significant negative correlation between soil pH and soil extractable Fe, Mn and B indicated decrease in solubility of Fe and Mn with increase in soil pH but higher leaching losses of B. The electrical conductivity (EC) showed a significant and positive correlation with soil hydrolysable N (r = 0.120, significant at p⩽ 0.05), extractable-K (r = 0.120, significant at p⩽ 0.05), extractable-S (r = 0.140, significant at p⩽ 0.05), -Ca (r = 0.357, significant at p⩽ 0.01) but showed a significant and negative correlation with extractable- Mn (r = -0.235, significant at p⩽ 0.01). 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 N, K, S and Ca could be attributed to this reason (Smaling *et al.*, 1993). The organic carbon (OC) showed a significant and positive correlation with extractable-B (r = 0.130, significant at p⩽ 0.05) but negative correlation with hydrolysable N (r = -0.163, significant at p⩽ 0.01), extractable- K (r =- 0.214, significant at p⩽ 0.01), -Ca (r = -0.162, significant at p⩽ 0.01), -S (r = -0.145, significant at p⩽ 0.01), -Zn (r = -0.117, significant at p⩽ 0.05), -Cu (r = -0.202, significant at p⩽ 0.01), and -Fe (r = -0.228, significant at p⩽ 0.01). A significant positive correlation between soil organic C content and soil extractable B indicated that organic matter could help in retaining B against leaching by forming complexes with OH-groups of organic compounds while a negative correlation observed between soil organic C and hydrolysable soil N and extractable soil K and S could be related to poor mineralization of organo- N and -S compounds in hill soils owing to low temperature in soils and leaching losses of K and mineralized S from hill soils. The negative correlation between soil organic C content and extractable- micronutrient cations and -Ca could be due to the formation of stable organic complex between organic matter and micronutrient cations and Ca (Chinchmaltpure *et al.* ,2000).

## CONCLUSION

From this study, it may be concluded that soils of Almora district are mainly coarse textured soils rich in organic C with widely varying soil pH which ranged from very acidic to moderately alkaline in reaction. Based on the calculated nutrient indices (N.I.), the soils of Almora district were low in N, medium in S and B and high in rest other nutrients. In view of varying soil fertility status of macro- and micronutrients in different blocks of Almora district, site specific nutrient management has to be adopted for improving crop yields.

## ACKNOWLEDGEMENTS

Authors are thankful to Project Coordinator, AICRP-Micronutrients, IISS, Bhopal for providing necessary facility to conduct this study.

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*Received: July 18, 2019*
*Accepted: July 31, 2019*