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International Journal of Current Research
Vol. 5, Issue, 12, pp.4309-4315, December, 2013

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

SOIL NUTRIENT STATUS UNDER PINE AND OAK FORESTS IN TEMPERATE VALLEY SLOPES OF GARHWAL HIMALAYA, INDIA

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ARTICLE INFO

Article History:
Received 25th September, 2013
Received in revised form
07th September, 2013
Accepted 30th October, 2013
Published online 25th December, 2013

Key words:

Disturbed,
Undisturbed,
Forest soil,
Micronutrients and Forest types.

ABSTRACT

The present study was undertaken in the undisturbed and disturbed pine and oak forests of Pauri area in the Garhwal region of Uttarakhand, India. The aim of the present study was to assess the physic-chemical properties of these soils. Chemical properties of the soil, i.e., total nitrogen (N), available phosphorus (P), available potassium (K), organic carbon (C), soil organic matter (SOM), pH, C:N ratios, exchangeable Calcium (Ca) and Magnesium (Mg) and micronutrients Iron (Fe), copper (Cu), Zinc (Zn) and Manganese (Mn) were analyzed for different depths viz., 0-10, 10-30, 30-60, 60- 90, 90-120, 120-150cm in both the undisturbed and disturbed forest types. The phosphorus was found higher in the lower horizons of the *Quercus leucotrichophora* forest, which may be due to the leaching properties of the soils. The available nitrogen was also higher in the undisturbed forests than in the disturbed forests. The soil pH was found higher at both the disturbed sites. Among the two forest covers, the soils under *Quercus leucotrichophora* showed comparatively higher CEC than the soils under Pine. The higher values of CEC in the soils may be due to availability of higher organic matter and clay content. The content of exchangeable Ca^{2+} was maximum under *Quercus leucotrichophora* and minimum under *Pinus roxburghii* forest types. Among micronutrients, the manganese was found higher under *Pinus roxburghii* forest cover. Pine needles being rich in Mn content might have accounted for high level of Mn. Zn was found higher under oak forest cover. In case of *Pinus roxburghii* forest, a significant positive correlation was found between total nitrogen and organic carbon (0.97), available nitrogen and organic carbon (0.94), CEC and organic carbon (0.98) (Table 5). In case of *Quercus leucotrichophora* forest, a significant positive correlation was found between total nitrogen and available nitrogen (0.93), available phosphorus and total nitrogen (0.98) (Table 6).

INTRODUCTION

Forest soil is the medium that produces nature's most significant association of plants and animals, distinguished by immense practical usefulness and indefinite richness of pattern. Since time immemorial, the daily needs and inborn inquisitiveness of mankind have stimulated interest in the soils of the forest. The composition of forest soil changes constantly by the growth of trees and ground cover vegetation, activity of organisms and effect of climatic agents. Under the influence of these factors, mineral and organic matter undergoes gradual decomposition or disintegration. Some of the related soluble salts and colloids are carried down by percolating water and are deposited to form definite layers of genetic horizons. This translocation of mobile fractions constitutes the most significant process of forest soil development. Because of the intimate relationship between soil, climate and vegetation, soils tend to be distributed on the earth's surface in belts or zones, correlated with the climatic vegetation zones. Within each of such broad zones, local conditions of topography, drainage, parent material and forest cover give rise to a definite association of individual general soil types, characterized by distinctive profiles. The analytical foundations of forest soils comprise the following more or less independent aspects, (i) the genesis of soil i.e., their origin, development and profile characteristics, produced under the influence of climate, topography, parent rock and vegetation: (ii) the properties of soil; viz., their physical, chemical, biological characteristics and: (iii) the effect of soils on the vegetation, namely upon the composition of the forest stand and ground cover, rate of tree growth, quality of wood, vigour of natural reproduction, resistance of stands to diseases and other silviculturally important features (Wilde, 1946). In the virgin forests, however, there are many instances, where the correlation of soil texture and forest growth is masked by the influence of other factors, especially by the ability of tree stands to modify the environment. Through a succession of pioneer species, forest stands tend to adjust the soil to the requirements of trees which compose them. As soon as these species become

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established, they moderate the extremes of temperature with the canopy of their crowns and accumulate humus which increases the water holding capacity and supply of plant nutrients. Thus the present study was conducted to find the site quality of pine and oak forests.

MATERIALS AND METHODS

The study was conducted in the two forest types *Pinus roxburghii* forest and *Quercus leucotrichophora* forest of Pauri Garhwal. Pauri Garhwal a district of Uttrakhand state encompasses an area of 5540 sq.km and situated a 29° 20' to 29° 75' Latitude and 78° 10' to 78 80' E Longitude. Khirsu block located in the Pauri District offers panaromic view of the central Himalaya and attracts a large number of tourists. Located 19 km away from Pauri at an altitude of 1,700 mts.

All the soil samples were collected at three places, randomly selected, in each selected site and thus 12 profiles were excavated (6 profiles each in the disturbed and undisturbed sites). The soil samples were collected from fixed depths of different horizons, i.e., 0-10, 10-30, 30-60, 60- 90, 90-120, 120-150cm. Soil texture was analyzed by Hydrometer method (Black, 1965). Absorbed water content in saturated condition was calculated (Black, 1965; Jackson, 1967). The moisture content of the soil samples was calculated as per standard method given by Mishra (1968). Electrical conductivity of soil was determined in the soil: water suspension (1:2.5) (Jackson, 1967), Available Nitrogen was determined by alkaline permanganate method as described by Subbiah and Ashija (1956). The pH of soil was determined directly with the help of control dynamics digital pH meter (model Ap ? 175E/C). Walkley and Black's rapid titration method as modified by Walkley (1947) was adopted for organic carbon estimation. The factor of 1.724 was used to convert the organic carbon (%) into soil organic matter (%). Available phosphorus was determined in the soil by Olsen *et al.* (1954) method. Potassium was extracted by neutral normal ammonium acetate method (Morwin and Peach 1951) and was determined by the flame photometer (Evans Electro Selenium Ltd; Holsted Essex, England). Total nitrogen was measured by using the standard Kjeldhal procedure (Bremner and Mulvaney 1982). Total carbon (%) was divided by total nitrogen (%) to get values of C:N ratio. Available Copper (Cu), Zinc (Zn), Iron (Fe) and Manganese (Mn) in the Soil were extracted by DPTA (diethalene triamine penta – acetic acid) extractrants, at pH 8.3 (Lindsay and Norvell, 1978) and determined on atomic absorption spectrophotometer.

RESULTS

Pinus roxburghii forest

Physical properties

The soil in undisturbed *Pinus roxburghii* forest was sandy loam in texture and in the disturbed forest it was silty loam. The bulk density was lower at the undisturbed site than at the disturbed site, however it increased with an increase in depth at both undisturbed and disturbed sites and ranged from 0.95±0.23gm/cm^3 to 1.27±0.59 gm/cm^3 (undisturbed forest) and 1.10±0.19 gm/cm^3 to 1.40±0.43gm/cm^3 (disturbed forest). Due to increase of bulk density with depth the porosity thus showed the reverse trend and decreased with depth in both undisturbed and disturbed forest types although it was higher in the undisturbed forest than in the disturbed forest. The water holding capacity and moisture percent were higher in the undisturbed forest than in the disturbed forest. It was maximum in the upper horizons of both the undisturbed and disturbed forest types. The water holding capacity was higher in some lower horizons also, where the percentage of clay was higher. (Table 1a and b).

Chemical properties

The soil pH was near neutral in disturbed forest than in the undisturbed forest. It was almost neutral in the lower horizons than in the upper horizons and ranged from 5.91±0.12 to 6.24±0.14 in the undisturbed forest and 6.06±0.11 to 6.39±0.00 in disturbed forest, which indicated that the soils in these forests were slightly acidic. The soil organic carbon was found higher in the surface horizons of both undisturbed and disturbed forests and decreased with the increase in depth. It was higher in the undisturbed forest than in the disturbed forest and ranged from 0.61±0.04% to 1.91±0.13% and 0.50±0.01% to 1.33±0.21% in undisturbed and disturbed forest types respectively. The amounts of total nitrogen and available nitrogen were directly related to the organic matter content. The total nitrogen and available nitrogen were comparatively higher in the surface horizons in both undisturbed and disturbed forests. The total nitrogen ranged from 0.054±0.01% to 0.13±0.01% and 0.05±0.01 to 0.11±0.20 in undisturbed and disturbed forests respectively and the available nitrogen ranged from 0.01±0.01% to 0.04±0.01% and 0.01±0.00% to 0.03±0.01% in undisturbed and disturbed forests respectively. The available phosphorus was found maximum (7.67±0.58 ppm) at 0-10cm depth and minimum (4.25±0.52 ppm) at 90-120cm depth in the undisturbed forest and in disturbed forest it was found maximum (8.23±0.20 ppm) at 30-60cm depth and minimum (5.23±0.20 ppm) at 90-120cm depth. The available potassium ranged from 15.87±1.14 ppm to 54.08±1.41ppm in the undisturbed forest and 25.21±1.22 ppm to 45.21±1.44 ppm in the disturbed forest. The available potassium was maximum in the surface horizons and decreased with an increase in depth in both undisturbed and disturbed forest types.

Exchangeable Ca^{2+} was dominant than exchangeable Mg^{2+} in both undisturbed and disturbed sites. The exchangeable Ca^{2+} was found maximum (7.46±0.45 me%) at 120-150 depth and minimum (1.56±0.40 me%) at 30-60cm depth in the undisturbed forest whereas in disturbed forest it was found maximum (6.43±0.70 me%) at 120-150 depth and minimum (2.00±0.10 me%) at 10-30cm depth. The exchangeable Mg^{2+} was found higher in the undisturbed forest and ranged from 1.48±0.02 me% to 4.22±0.02 me% and 1.30±0.32 me% to 2.50±0.90 me% in the undisturbed and disturbed forest types respectively. The CEC was higher in the surface horizons and ranged from 11.77±0.51 me% to 21.98±0.89 me% and 5.79±0.30 me% to 19.53±0.09 me% in the undisturbed and disturbed forests respectively. Available micronutrients Fe, Mn, Cu, Zn were found maximum in the undisturbed forest than in the disturbed forest. The available Fe ranged from 11.88±0.58 mg kg^{-1} to 49.64±1.34 mg kg^{-1} and 4.28±0.43 mg kg^{-1} to 39.23±2.11 mg kg^{-1} in the undisturbed and disturbed forests respectively. The available Mn ranged from 4.24±0.04 mg kg^{-1} to 14.74±0.50 mg kg^{-1} and 2.23±0.70 mg kg^{-1} to

Table 1a. Physical properties of soil in undisturbed *Pinus roxburghii* forest (Type- 9/Clb)

Soil depth (cm)	Soil colour	Sand (%)	Silt (%)	Clay (%)	Moisture content (%)	Bulk density (gm/cm^3)	Water holding capacity (%)	Soil consistency	Porosity (%)
0-10	Brown 10YR5/3	48.83±2.33	31.11± 3.30	20.06± 2.39	10.57 ±0.12	0.95±0.23	53.17±1.28	Loose	63.46±1.20
10-30	Yellowish brown 10YR5/4	40.43±3.20	47.75 ±1.33	19.65 ±2.10	9.50±0.11	1.07±0.22	51.16± 2.06	Loose	58.84±0.99
30-60	Yellow 10YR8/6	38.19±2.11	49.81 ±1.11	14.06± 3.30	8.40 ±0.23	1.09±0.11	49.23± 2.14	Loose	58.07±0.76
60-90	Yellow 10YR8/6	46.75±3.42	36.73 ±2.33	16.52± 4.28	6.30 ±0.19	1.23±0.54	45.02± 1.81	Loose	52.69±0.66
90-120	Very pale brown 10YR8/4	51.28±2.33	34.10 ±2.11	14.62 ±1.33	4.30 ±0.21	1.25±0.76	44.34± 1.36	Loose	51.92±0.88
120-150	Very pale brown 10YR/8/3	54.10±2.30	34.03± 3.30	12.87 ±1.10	3.30 ±0.11	1.27±0.54	40.22± 1.02	Loose	51.15±0.77

Table 1b. Physical properties of soil in disturbed *Pinus roxburghii* forest (Type- 9/Clb)

Soil depth (cm)	Soil colour	Sand (%)	Silt (%)	Clay (%)	Moisture content (%)	Bulk density (gm/cm^3)	Water holding capacity (%)	Soil consistency	Porosity (%)
0-10	Very pale Brown 10YR7/4	30.83±2.33	50.77± 3.44	18.4± 3.22	7.57 ±0.12	1.10±0.19	49.14± 1.23	Friable	55.53±0.23
10-30	Brownish Yellow 10YR6/6	32.07±4.21	46.35 ±4.11	21.58 ±4.25	6.50 ±0.11	1.19±0.26	44.03± 1.22	Loose	54.23±1.23
30-60	Brownish Yellow 10YR6/6	34.88±2.44	49.06 ±2.41	16.06± 2.33	6.40 ±0.23	1.23±0.27	44.07± 3.44	Loose	50.63±0.77
60-90	Yellow 10YR7/6	30.75±3.33	52.96 ±3.21	16.29± 2.44	6.30 ±0.19	1.33±0.35	41.70± 2.10	Loose	47.30±0.55
90-120	Yellow 10YR8/6	27.15±2.22	54.23 ±2.11	18.62 ±3.22	3.30 ±0.21	1.37±0.01	40.67± 1.33	Loose	48.84±0.33
120-150	Yellow 10YR8/6	31.10±4.22	51.03± 1.25	17.87 ±2.22	3.30±0.11	1.40±0.43	38.88± 0.99	Lose	46.15±0.23

Table 2. Chemical properties of soil in undisturbed and disturbed *Pinus roxburghii* forest

Forest type Type12Cla	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D
Soil depth	0-10		10-30		30-60		60-90		90-120		120 - 150	
pH	5.91±0.12	6.06±0.11	5.94±0.33	6.08±0.06	5.94±0.19	6.24±0.14	6.08±0.06	5.94±0.33	6.07±0.40	6.08±0.06	6.24±0.14	6.24±0.14
Carbon (%)	1.91±0.13	1.33±0.21	1.42±0.10	0.77±0.09	0.80±0.13	0.61±0.04	0.77±0.09	1.42±0.10	0.70±0.05	0.77±0.09	0.61±0.04	0.61±0.04
OM (%)	3.29±0.23	2.29±0.02	2.44±0.17	1.32±0.16	1.37±0.21	1.04±0.07	1.32±0.16	2.44±0.17	1.13±0.09	1.32±0.16	1.04±0.07	1.04±0.07
T.N (%)	0.13±0.01	0.11±0.02	0.11±0.01	0.09±0.01	0.09±0.02	0.054±0.01	0.09±0.01	0.11±0.01	0.06±0.00	0.09±0.01	0.054±0.01	0.054±0.01
Av.N	0.04±0.06	0.02±0.01	0.03±0.01	0.02±0.01	0.03±0.01	0.01±0.01	0.02±0.01	0.03±0.01	0.02±0.00	0.02±0.01	0.01±0.01	0.01±0.01
Av.P(ppm)	7.67±0.58	6.11±0.09	6.65±0.65	4.75±0.65	5.75±0.65	6.25±0.70	4.75±0.65	6.65±0.65	4.25±0.52	4.75±0.65	6.25±0.70	6.25±0.70
Av.K (ppm)	54.08±1.41	45.21±1.44	36.08±0.59	18.39±1.43	39.34±1.16	15.87±1.14	18.39±1.43	36.08±0.59	18.77±1.48	18.39±1.43	15.87±1.14	15.87±1.14
Ex.Cation Ca^{2+}	6.45±0.43	10.21±0.54	2.65±0.13	5.23±0.76	1.56±0.40	3.31±0.80	4.03±0.25	2.21±0.06	2.37±0.10	2.20±0.67	7.46±0.45	1.96±0.70
(me%) Mg^{2+}	4.22±0.02	3.33±0.22	3.41±1.00	2.30±0.90	1.97±0.02	1.90±0.05	0.23±0.05	0.53±0.11	1.83±0.05	1.23±0.70	4.20±0.34	1.01±0.54
CEC (me%)	21.98±0.89	30.2±0.98	18.79±0.52	29.2±0.80	17.52±0.29	20.3±1.54	17.61±1.05	15.21±0.54	14.92±0.60	14.22±1.43	13.09±0.50	12.21±1.21
Fe (mg kg^{-1})	49.64±1.34	60.23±1.11	44.15±1.55	50.11±0.88	31.89±2.89	45.21±0.11	30.89±2.50	31.21±1.43	13.41±0.51	16.21±0.22	12.22±2.65	9.23±0.32
Mn (mg kg^{-1})	14.74±0.50	7.23±0.21	12.44±0.18	6.21±0.11	12.88±0.58	5.23±0.09	6.00±0.68	5.03±0.21	4.56±0.57	3.33±0.11	4.48±0.54	2.33±0.72
Zn (mg kg^{-1})	1.50±0.01	0.98±0.10	1.23±0.02	0.95±0.43	1.10±0.01	0.75±0.02	0.98±0.01	0.65±0.10	0.45±0.01	0.55±0.04	0.38±0.02	0.25±0.04
Cu (mg kg^{-1})	1.53±0.03	0.76±0.02	0.90±0.01	0.86±0.10	0.93±0.01	0.56±0.03	0.18±0.01	0.46±0.01	0.70±0.04	0.32±0.03	0.24±0.01	0.20±0.03
EC(dSm^{-1})	0.19±0.01	0.30±0.06	0.15±0.01	0.27±0.10	0.11±0.01	0.18±0.30	0.18±0.01	0.12±0.07	0.09±0.01	0.03±0.01	0.24±0.01	0.05±0.01
C:N	12.73	9.40	12.90	10.85	8.88	11.20	8.66	8.50	11	12	6	11

Table 3a. Physical properties of soil in undisturbed *Quercus leucotrichophora* forest

Soil depth (cm)	Soil colour	Sand (%)	Silt (%)	Clay (%)	Moisture content (%)	Bulk density (gm/cm^3)	Water holding capacity (%)	Soil consistency	Porosity (%)
0-10	Dark brown 10YR3/3	36.30±2.03	44.63± 3.33	19.07± 2.39	23..57± 0.12	0.90±0.07	58.14± 2.28	Loose	65.38±1.01
10-30	Light yellowish brown 10YR6/4	33.17±1.76	51.36 ±2.23	15.47 ±2.10	20.50 ±0.11	0.98±0.16	50.86± 2.86	Fairly plastic	62.30±0.98
30-60	Yellowish brown 10YR5/6	52.75±2.11	37.19 ±3.11	10.06± 3.30	16.40 ±0.23	1.01±0.06	41.78± 3.44	Fairly plastic	57.30±0.78
60-90	Brownish yellow 10YR6/6	56.81±3.42	30.17 ±2.33	13.02± 4.28	16.19 ±0.19	1.11±0.03	42.39± 2.10	Loose	52.69±0.76
90-120	Light yellowish brown 10YR6/4	25.85±2.33	45.30 ±2.11	28.85 ±1.33	15.30 ±0.21	1.29±0.12	44.71± 2.35	Fairly plastic	50.38±1.42
120-150	Light yellowish brown 10YR6/4	56.10±3.30	32.16± 3.30	11.14 ±1.10	15.10 ±0.11	1.33±0.21	37.61± 3.05	Fairly plastic	48.84±1.11

Table 3b. Physical properties of soil in disturbed *Quercus leucotrichophora* forest

Soil depth (cm)	Soil colour	Sand (%)	Silt (%)	Clay (%)	Moisture content (%)	Bulk density (gm/cm^3)	Water holding capacity (%)	Soil consistency	Porosity (%)
0-10	Light Yellowish Brown 10YR6/4	30.30±2.11	39.63± 1.12	30.07± 3.23	12.57± 0.12	1.25±0.86	55.14± 2.28	Friable	51.92±0.76
10-30	Yellowish brown 10YR5/4	30.31±2.55	34.22 ±2.31	35.47±2.33	11.50 ±0.11	1.27±1.11	54.86± 2.86	Friable	51.15±0.55
30-60	Yellowish Brown 10YR5/4	47.02±4.22	37.19 ±3.34	15.79±1.45	11.40 ±0.23	1.29±0.87	50.00± 3.44	Loose	50.38±0.34
60-90	Yellowish Brown 10YR5/4	47.81±1.24	40.17 ±3.22	12.02± 2.14	10.19 ±0.19	1.30±0.93	42.21± 2.10	Loose	50.09±0.33
90-120	Yellowish Brown 10Yr5/4	43.90±2.54	44.35 ±2.45	9.85 ±2.31	9.30 ±0.21	1.31±1.21	38.23± 2.35	Loose	44.61±0.44
120-150	Yellowish Brown 10YR5/4	43.18±3.22	49.16± 2.21	7.66 ±1.45	4.30 ±0.11	1.40±1.01	33.33± 3.05	loose	46.15±0.21

Table 4. Chemical properties of soil in undisturbed and disturbed *Quercus leucotricophora* forest

Forest type	UD	D	UD	D	UD	D	UD	D	UD	D	UD	D
Soil depth	0-10		10-30		30-60		60-90		90-120		120 - 150	
pH	5.84±0.04	6.66±0.20	5.81±0.22	6.67±0.11	5.94±0.02	6.55±0.03	6.28±0.17	6.75±0.50	6.35±0.02	6.39±0.34	6.37±0.13	6.50±0.04
Carbon (%)	2.31±0.11	1.41±0.10	1.16±0.18	0.76±0.09	0.82±0.05	0.56±0.05	0.78±0.08	0.51±0.30	0.64±0.12	0.42±0.30	0.42±0.02	0.32±0.10
OM (%)	3.99±0.20	2.43±0.01	1.99±0.32	1.31±0.20	1.41±0.07	1.65±0.30	1.34±0.06	0.87±0.10	1.10±0.10	0.72±0.05	0.72±0.02	0.55±0.40
T.N (%)	0.25±0.03	0.15±0.01	0.15±0.03	0.07±0.09	0.10±0.01	0.11±0.20	0.09±0.01	0.10±0.01	0.08±0.01	0.03±0.01	0.07±0.01	0.03±0.01
Av.N	0.06±0.02	0.03±0.02	0.05±0.10	0.03±0.01	0.05±0.02	0.05±0.01	0.02±0.01	0.06±0.01	0.01±0.00	0.01±0.01	0.01±0.01	0.01±0.01
Av.P(ppm)	4.25±0.30	6.52±0.02	5.25±0.43	9.26±0.60	6.53±0.45	8.25±0.80	4.25±0.45	4.75±0.10	5.23±0.05	4.22±0.20	4.11±0.37	4.25±0.03
Av.K (ppm)	139.59±1.38	87.23±0.30	126.24±0.92	78.21±0.04	114.62±1.32	60.56±1.44	66.89±0.57	48.53±2.11	114.23±1.00	70.63±1.67	70.92±0.92	72.44±0.33
Ex.Catio Ca^{2+}	12.53±0.05	10.21±0.54	4.25±0.04	5.23±0.76	4.08±0.14	3.31±0.80	4.03±0.25	2.21±0.06	3.46±0.05	2.20±0.67	3.33±0.20	1.96±0.70
n(me%) Mg^{2+}	4.73±0.20	3.33±0.22	3.60±0.96	2.30±0.90	2.50±0.20	1.90±0.05	0.23±0.05	0.53±0.11	0.20±0.00	1.23±0.70	0.20±0.00	1.01±0.54
CEC (me%)	36.20±1.00	30.2±0.98	31.05±1.28	29.2±0.80	36.23±1.05	20.3±1.54	17.61±1.05	15.21±0.54	19.33±0.90	14.22±1.43	13.09±0.50	12.21±1.21
Fe (mg kg^{-1})	98.67±1.49	60.23±1.11	80.90±1.52	50.11±0.88	60.81±0.64	45.21±0.11	30.89±2.50	31.21±1.43	20.21±1.99	16.21±0.22	12.22±2.65	9.23±0.32
Mn (mg kg^{-1})	10.22±0.99	7.23±0.21	7.59±0.38	6.21±0.11	7.89±0.35	5.23±0.09	6.00±0.68	5.03±0.21	4.33±1.01	3.33±0.11	4.48±0.54	2.33±0.72
Zn (mg kg^{-1})	1.99±0.06	0.98±0.10	1.48±0.01	0.95±0.43	1.28±0.01	0.75±0.02	0.98±0.01	0.65±0.10	0.79±0.01	0.55±0.04	0.38±0.02	0.25±0.04
Cu (mg kg^{-1})	0.32±0.01	0.76±0.02	0.33±0.00	0.86±0.10	0.24±0.01	0.56±0.03	0.18±0.01	0.46±0.01	0.16±0.04	0.32±0.03	0.24±0.01	0.20±0.03
EC(dSm^{-1})	0.32±0.01	0.30±0.06	0.33±0.00	0.27±0.10	0.24±0.01	0.18±0.30	0.18±0.01	0.12±0.07	0.16±0.04	0.03±0.01	0.24±0.01	0.05±0.01
C:N	9.24	9.40	7.72	10.85	8.2	11.20	8.66	8.50	8	12	6	11

Table 5. Correlation between various soil parameters in *Pinus roxburghii* forest

Variables	pH	OC (%)	Total N (%)	Av. N (%)	Av.P (ppm)	Av. K (ppm)	Exg.Ca (me%)	Exg.Mg (me%)	CEC (me%)	Av.Fe $Mgkg^{-1}$	Av.Mn $mgkg^{-1}$	Av. Zn $mgkg^{-1}$	Av. Cu $mgkg^{-1}$	EC dSm^{-1}	C:N
pH	1.000														
OC (%)	-0.841	1.000													
Total N (%)	-0.823	**0.975	1.000												
Av.N (%)	-0.829	*0.947	0.977	1.000											
Av.P. (ppm)	-0.397	0.089	0.143	0.048	1.000										
Av. K (ppm)	-0.835	*0.679	0.770	0.744	*0.672	1.000									
Exg. Ca (me%)	0.341	*0.191	0.169	0.170	-0.662	-0.376	1.000								
Exg. Mg (me%)	-0.128	0.492	0.433	*0.512	-0.591	-0.091	**0.807	1.000							
CEC (me%)	-0.849	0.982	0.989	**0.991	0.076	0.732	0.174	*0.506	1.000						
Av.Fe $mgkg^{-1}$	-0.849	0.982	0.989	**0.991	0.076	0.732	0.174	0.506	1.000	1.000					
Av.Mn $mgkg^{-1}$	-0.893	0.821	*0.878	0.846	0.573	0.973	-0.226	**0.089	0.851	0.851	1.000				
Av.Zn $mgkg^{-1}$	-0.952	0.905	0.932	**0.946	0.319	0.884	-0.134	0.281	0.944	0.944	**0.947	1.000			
Av.Cu $mgkg^{-1}$	-0.836	0.927	0.976	0.938	0.246	0.834	0.013	0.238	0.946	0.946	0.905	0.928	1.000		
Ec dSm^{-1}	-0.913	0.982	0.964	0.951	0.135	0.734	0.029	0.383	0.977	0.977	0.852	0.947	**0.943	1.000	
C:N	0.821	-0.768	-0.858	-0.827	-0.573	-0.982	0.197	-0.058	-0.817	-0.817	-0.986	-0.912	-0.898	-0.795	1.000

*significant at 1% level and **significant at 5% level

Table 6. Correlation between various soil parameters in *Quercus leucotrichophora* forest

Variables	pH	OC (%)	Total N (%)	Av. N (%)	Av.P (ppm)	Av. K (ppm)	Exg.Ca (me%)	Exg.Mg (me%)	CEC (me%)	Av.Fe $mgkg^{-1}$	Av.Mn $mgkg^{-1}$	Av. Zn $mgkg^{-1}$	Av.Cu $mgkg^{-1}$	EC dSm^{-1}	C:N
pH	1.000														
OC (%)	-0.761	1.000													
Total N (%)	-0.961	*0.856	1.000												
Av.N (%)	-0.968	*0.654	0.937	1.000											
Av.P. (ppm)	-0.952	**0.891	0.989	0.893	1.000										
Av. K (ppm)	-0.860	0.817	0.906	0.808	0.917	1.000									
Exg. Ca (me%)	-0.607	0.972	0.752	0.512	0.783	0.705	1.000								
Exg. Mg (me%)	-0.967	**0.867	0.968	0.932	**0.957	0.841	0.760	1.000							
CEC (me%)	-0.898	0.703	0.929	**0.950	0.873	0.873	0.605	0.900	1.000						
Av.Fe $mgkg^{-1}$	-0.943	**0.917	0.970	0.863	**0.991	0.933	*0.806	**0.956	*0.852	1.000					
Av.Mn $mgkg^{-1}$	-0.868	*0.835	0.945	0.838	*0.943	**0.983	0.743	0.863	0.906	0.938	1.000				
Av.Zn $mgkg^{-1}$	-0.905	0.930	0.957	0.830	0.976	0.963	*0.835	**0.928	0.862	**0.989	0.966	1.000			
Av.Cu $mgkg^{-1}$	-0.799	0.590	0.760	0.766	**0.759	0.450	0.486	0.792	0.582	0.708	*0.524	0.613	1.000		
Ec dSm^{-1}	-0.799	0.590	0.760	0.766	0.759	0.450	0.486	0.792	0.582	0.708	0.524	*0.613	1.000	1.000	
C:N	-0.194	0.471	0.261	0.085	0.317	0.620	0.450	0.218	0.276	0.409	0.513	0.507	-0.340	-0.340	1.000

*significant at 1% level and **significant at 5% level

10.23± 0.98 mg kg^{-1} in the undisturbed and disturbed forests respectively. The available Zn ranged from 0.23±0.01 mg kg^{-1} to 1.50±0.01 mg kg^{-1} and 0.19±0.04 mg kg^{-1} to 0.95±0.20 mg kg^{-1} in the undisturbed and disturbed forests respectively. The available Cu ranged from 0.66±0.02 mg kg^{-1} to 1.53±0.03 mg kg^{-1} and 0.19±0.03 mg kg^{-1} to 0.99±0.01 mg kg^{-1} in the undisturbed and disturbed forests respectively. On the other hand the EC ranged from 0.06±0.01 dSm^{-1} to 0.19±0.01 dSm^{-1} and 0.07±0.01 dSm^{-1} to 0.15±0.03 dSm^{-1} in the undisturbed and disturbed forests respectively (Table 2).

Quercus leuchotrichophora forest

Physical properties

In undisturbed *Quercus leucotrichophora* forest type, the soil texture was sandy loam and in disturbed forest it was silty loam. The bulk density was lower in the undisturbed site than in the disturbed site, however it increased with an increase in depth and ranged from 0.90±0.07 gm/cm^3 to 1.33±0.21 gm/cm^3 in undisturbed forest and 1.25±0.86 gm/cm^3 to 1.40±1.01 gm/cm^3 in disturbed forest cover. Due to increase of bulk density with depth the porosity decreased in both undisturbed and disturbed sites. The water holding capacity and moisture content were higher in the undisturbed forest type than in the disturbed forest type (Table 3a and b).

Chemical properties

The soils in these forests were generally moderately to slightly acidic. The soil pH in *Quercus leucotrichophora* forest was almost neutral in disturbed forest than in the undisturbed forest where it was slightly acidic. It was higher in the lower horizons than in the upper horizons and ranged from 5.81±0.22 to 6.35±0.13 in the undisturbed forest and 6.39±0.34 to 6.75±0.50 in disturbed forest. The soil organic carbon, total nitrogen and available nitrogen were found higher in the upper horizons of both undisturbed and disturbed forests and decreased subsequently with an increase in depth. The organic carbon ranged from 0.42±0.02% to 2.31±0.11% and 0.32±0.10% to 1.41±0.10% in undisturbed and disturbed forest types respectively. The total nitrogen ranged from 0.07±0.01% to 0.25±0.03% and 0.03±0.01 to 0.15±0.01 in the undisturbed forest and disturbed forest respectively and the available nitrogen ranged from 0.01±0.01% to 0.06±0.02% and 0.01±0.00% to 0.06±0.01% in undisturbed and disturbed forest types respectively. The available phosphorus content was found maximum (6.53±0.45 ppm) at 30-60cm depth and minimum (4.11±0.37 ppm) at 120-150cm depth in the undisturbed forest and in disturbed forest it was maximum (9.26±0.60 ppm) at 10-30cm depth and minimum (4.22±0.20 ppm) at 90-120cm depth. The availability of phosphorus in the lower horizons may be due to the leaching properties of soils. The available potassium ranged from 66.89±0.57 ppm to 139.59±1.38 ppm in the undisturbed forest cover and 48.53±2.11 ppm to 87.23±0.3 ppm in the disturbed forest cover. The exchangeable calcium ranged from 3.33±0.20 me% to 12.53±0.05 me% and 1.96±0.7 me% to 10.21±0.54 me% in the undisturbed and disturbed forest types respectively. The exchangeable Mg^{2+} was found higher in the undisturbed forest and it ranged from 0.20±0.00 me% to 4.73±0.20 me% and 0.53±0.11 me% to 3.33±0.22 me% in the undisturbed and disturbed forest types respectively. The CEC ranged from 13.09±0.50 me% to 36.20±1.00 me% and 12.21±1.21 me% to 30.20±0.98 me% respectively which was prominently higher in the upper horizons of both the undisturbed and disturbed forest types. The available Fe was comparatively more in the undisturbed forest than in the disturbed forest and ranged from 12.22±2.65 mg/kg^{-1} to 98.67±1.49 mg/kg^{-1} and 9.23±0.32 mg kg^{-1} to 60.23±1.11 mg kg^{-1} in the undisturbed and disturbed forest types respectively. The available Mn ranged from 4.33±1.01 mg kg^{-1} to 10.22±0.99 mg kg^{-1} and 2.33±0.72 mg kg^{-1} to 7.23±0.21 mg kg^{-1} in the undisturbed and disturbed forest types respectively. The available Zn ranged from 0.38±0.02 mg kg^{-1} to 1.99± 0.06 mg kg^{-1} and 0.25±0.04 mg kg^{-1} to 0.98±0.10 mg kg^{-1} in the undisturbed and disturbed forest types respectively. The available Cu ranged from 0.16± 0.04 mg kg^{-1} to 0.33±0.00 mg kg^{-1} and 0.20±0.03 mg kg^{-1} to 0.86±0.10 mg kg^{-1} in the undisturbed and disturbed forests respectively. The EC ranged from 0.16±0.01 dSm^{-1} to 0.32±0.01 dSm^{-1} and 0.03±0.01 dSm^{-1} to 0.30±0.06 dSm^{-1} in the undisturbed and disturbed forest types respectively (Table 4).

DISCUSSION

Soil texture may influence productivity in a variety of manners i.e., by affecting moisture availability, soil temperature, nutrient supply and the accessibility of soil organic matter to microbial decomposition (Schimel *et al*., 1996). Texture denotes the relative proportions of sand, silt and clay in the soil. Although the texture is a basic property of soil that can not be changed easily yet the downward movement of soil particles along with water takes place in such a way that there is a preferential migration of finer soil particles to the lower layers due to the changes brought by organic matter and root activities of plants under the plantation (Gupta, 1987; Gupta and Sharma, 2008). The bulk density of soil is expected to decrease with increasing elevation (Hanawalt and Whittaker, 1976). Low bulk density in soil indicates higher organic matter content, good granulation, high infiltration and good aeration conversely, higher bulk density value inhibited root penetration and low infiltration and penetrability (NRC, 1981). In both the forest types of the present study the bulk density increased with the increasing soil depths under disturbed and undisturbed forest types because the lower layers were more compact under the weight of upper portion of soil and also due to the lower amount of organic matter in deeper layers (as was also suggested by Haans, 1977). Moreover, the bulk density was found high in the disturbed forest types, where as, the low bulk density was found in undisturbed sites (Singh and Singh, 1991; Gupta and Sharma, 2008 have reported similar results, while working on the disturbed and undisturbed sites in the soils of Uttrakhand).

The water holding capacity increased with the increase in the clay content at all the sites and was low on the sites, where percent sand was higher. Sandy soils generally have less favourable moisture holding capacity and nutrient retention characteristics than non-sandy soils (Pastor and Post, 1986; Perry, 1994). The soil pH was found higher at both the disturbed sites. This indicates that the disturbance may promote the alkalinity of the soils. Robertson and Vitousek (1981) and Adams and Sidle (1987) have reported an increase in soil pH in disturbed ecosystems. The soil pH was found low under oak forest. Singh and Bhatnagar (1997) have also reported that high organic carbon and low pH under oak vegetation may probably be attributed to high decomposition rate of oak leaf in soil than the soil receiving coniferous needles (Pine and Deodar). The C: N ratio was generally higher in highly disturbed sites. Singh and Singh (1991) have also reported high C:N ratio under disturbed forests. The available nitrogen was also higher in the undisturbed forests than in the disturbed forests. It is mostly present in the form of nitrates in the soil which is very mobile and because of this property the ions get moved freely with moisture (Gupta and Singh, 2008). The maximum potassium was reported under *Quercus leucotrichophora* forest. The oak individuals are believed to be related with higher potassium release (Tomlinson and Tomlinson, 1990; and Sharpe *et al*., 1992; Srivastava *et al*., 2005). Among the two forest covers, the soils under *Quercus leucotrichophora* showed comparatively higher CEC than the soils under Pine. The higher values of CEC in the soils may be due to availability of higher organic matter and clay content. Like CEC, the content of exchangeable calcium is usually greater in the surface horizons and decreased with the depth. The exchangeable cations Ca^{2+} was dominant, followed by Mg^{2+} in the forest types. The content of exchangeable Ca^{2+} was maximum under *Quercus leucotrichophora* and minimum under *Pinus roxburghii* forest types of the present study are similar to the results of Raina *et al*. (2001) who have found out that the higher values of CEC of the soils may be due to higher organic matter and clay content. Among micronutrients, the manganese was found higher under *Pinus roxburghii* forest cover. Pine needles being rich in Mn content might have accounted for high level of Mn. Zn was found higher under oak forest cover. These results are in accordance with the results of Singh *et al*. (2006).

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