Print : ISSN 0970 – 7662
Online : ISSN 2455 – 7129

Journal of Tree Sciences
online available at www.ists.in

Volume 39 No. 1 June, 2020

Soil Chemical Properties of *Cedrus deodara* (Roxb) G.Don. Forest Soil in Garhwal Himalaya, India.

Rathod Digvijay*, Ram Gopal[1], Yogesh Kumar[2] and Gaurav C. Ramola[3]

Silviculture and Forest Management Division, FRI, Dehradun; [1]Genetics and Tree Improvement Division, FRI, Dehradun; [2]Ministry of Environment Forest & Climate Change, New Delhi; [3]Forest Protection Division, FRI, Dehradun

**Email*: rddigvijay@gmail.com

DOI: 10.5958/2455-7129.2020.00006.0

ABSTRACT

A study was carried out in moist temperate forest of *Cedrus deodara* in different parts of Garhwal Himalaya, Uttarakhand, to evaluate the physico-chemical properties of soils. The random sampling was carried out in ten different forests sites by laying out three 0.1 ha sample plots in each sites. Soil samples were collected from each sample plot at three different soil depths viz. (i) 'Upper' (0–10 cm), (ii) 'Middle' (11–30 cm), and (iii) 'Lower' (31–60 cm) in all the selected forest types. Values of soil organic carbon, total nitrogen, available phosphorus, available potassium, pH and Electrical conductivity ranged between 1.34 and 1.61 %, 0.40 and 0.49 %, 5.22 and 7.22 kg acre^{-1}, 84.56 and 243.44 kg acre^{-1}, 6.28 and 7, 0.07 and 0.17 dS m^{-1} respectively. The values of soil chemical properties of the present study in most of sites are on the higher end than the previously recorded values for the other similar forests of the region. The possible reason being luxuriant vegetation and undisturbed nature of these forest types, which is evident from higher values of diversity and other parameters.

Key Words:

Electrical conductivity, Organic carbon, pH, Phosphorus, Potassium, Soil depth, Total Nitrogen.

INTRODUCTION

The Indian Himalayan region occupies a unique identity in the mountain ecosystems of the world. These geodynamically young mountains are not only important from the viewpoint of climate and as a provider of life, giving water to a large part of the Indian subcontinent, but they also harbor a rich diversity of flora, fauna, human communities and cultural (Singh, 2006). *Cedrus deodara* (Roxb) G.Don commonly called as "Devdar" belongs to family Pinaceae which occurs throughout western

Himalaya from Afghanistan to Garhwal up to the valley of the Dhauli below the Nitipass at an elevation ranging from 1200 to 3500 m, being most common from 1800 to 2600 m. The endemic species to Himalaya forms the most important commercial timber species. Deodar is typically gregarious and is usually found in pure stands. It total area under deodar forest in India is estimated to about 2,03,263 ha constituting of 69,872, 20,391 and 1,13,000 ha in HP, UK, and J&K respectively (Tiwari 1994). The Deodar is found naturally on all the important geological formation of western Himalaya including granite, gneiss, mica, and other schists, shales, limestone, quartzite, conglomerate and recent boulder bed. The best growth found on deep, fertile, fairly porous soil in cool situation (Troup 1921).

The growth and reproduction of forest cannot be realized without the cognition of soil. The soil and vegetation have a complex interrelatedness because they develop together over a long period of time. The vegetation influences the chemical properties of soil to a great extent. The selective absorption of nutrient elements by different tree species and their capacity to return them to the soil brings about changes in soil properties (Singh et al. 1986). Forests in general have a greater influence on soil conditions than most other plant ecosystem types, due to a well-developed "O" horizon, moderate temperature, humidity at the soil surface, input of litter with high lignin content, high total net primary production, and high water and nutrient demand (Binkley and Giardina 1998).Considering the numerous studies that have been done on the effects of different tree species, it appears that the over storey composition probably does impact soil fertility (Augusto *et al*, 2002). The crucial point is to determine if the nature and the intensity of the modifications caused by a tree species are sufficient to significantly decrease or increase soil fertility (Binkley and Giardina, 1998).

The Garhwal Himalaya region has vast variations in the temperature, precipitation, receiving solar radiation, topography, and soil condition i.e. texture, structure, physico-chemical properties. The knowledge of chemical properties related to species specific study i.e. pure *Cedrus deodara* forest of temperate Garhwal Himalayan regions is meager. Forest soils influence on key factors are composition and growth of the forest stand, ground cover, rate of tree growth, vigor of natural reproduction and other silviculturally important factors (Bhatnagar 1965). The present study was therefore conducted to study the chemical properties of soil under deodar forest at different locations.

MATERIALS AND METHODS

Study site

Ten different forests of Deodar were selected for the assessment of chemical properties of soil (Fig. 1). The study sites are located in Tehri Gahrwal, Dehradun, and Uttarkashi district of Uttarakand.

Climatic and soil condition

The rainfall varies from 400 to 1300mm, 1300 to 2000 mm,1500 to 2300 mm, in Tehri districts (Tehri forest division), Uttarkashi district (Uttarkashi forest division) and Dehradun districts (Chakrata forest division) respectively. Annual temperature varies from 12.04 to 23.0 ˚C in Tehri, -1 to 35˚C in Uttarkashi and -2 to 29 ˚C in Chakrata forest division.

Tehri district soil colour was brown to dark grayish and acidic in nature. The pH value of the soils varies depending upon the type of forests. Soils of Uttarkashi forest area are low in fertility due to large content of boulders and gravels. The soils of the region are brown, black and podzolic soils. The soils of Chakrata are formed as a result of long continued leaching under moist temperate climate and consist of clayey and sandy loam on the hills, and sandy and pebbly loam in the valleys and the entire area has moderately deep, non- calcareous and heavy textured soils.

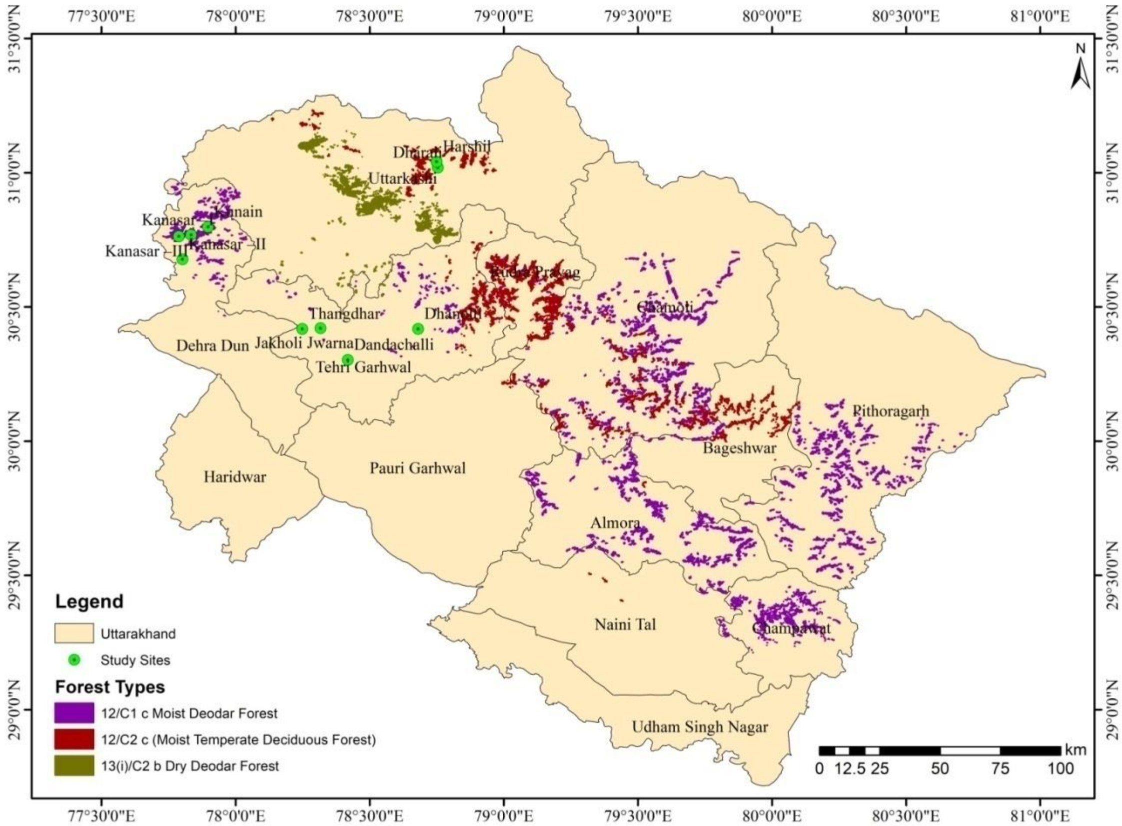

Fig. 1. Study sites

Soil analysis

The soil samples were randomly collected from each sample plot at three different depths *viz.*, 0-15 cm, 16-30 cm and 31-45 cm for assessing the chemical properties of the soil in all the selected forest sites. The collected soil samples were pooled, air dried, grounded, sieved by 2 mm sieve and stored in polythene bag for analysis. The soil analysis were conducted at soil science laboratory of GSFC, Vadodara, Gujarat. The factor of 1.724 was used to convert the organic carbon (%) into soil organic matter (%) (Gairola et al. 2012). Total carbon (%) was divided by total nitrogen (%) to get the values of C:N ratio. The standard methods were used to analyzed the soil for different parameters *i.e.* Soil reaction (pH) by soil water suspension 1:2 ratio (Jackson 1973), Electrical Conductivity (EC) by soil water suspension 1:2 ratio (Jackson 1973), organic Carbon by volumetric method (Walkley and Black 1934), Total nitrogen by alkaline permagnate method (Subbaiah and Asija, 1956), Available phosphorus by Olsen's method, Colorimetry (Olsen et al. 1954), Available potassium by Neutral normal NH_4OAc, Flame photometry (Stanford and English 1949).

Statistical analysis

Different sets of data were statistically analaysed using the Web Agri Stat Package and Microsoft office Excel 2007.

RESULTS AND DISCUSSIONS

pH

Among different sites the maximum (7.00) pH was recorded under Kanasar-II sites as compared to all other sites (Table 1).The minimum (6.28) pH was recorded in Jakholi jwarna site. In different soil depth (0-15 to 31-45 cm) similar value of pH was recorded i.e. 6.5. Whereas, interaction between sites and soil depths, the maximum (7.10) pH was recorded in 0-15 cm soil depth in the Kanasar-II site than all the other combination of sites and soil depths. In 16-30 cm soil depth, higher pH was recorded under Kanasar-II. The minimum (6.28) soil pH was exhibited in 31-45 cm soil layer under Jakholi jwarna sites than all other combination of sites and soil depth. The values of pH among different sites ranged between 6.28 to 7.10, 6.27 to 7.01 and 6.28 to 6.90 at 0-15, 16-30 and 31-45 cm different soil depth, respectively. A fertile soil generally has a pH range between 5.5 and 7.2, which makes the essential elements and nutrients available to plants. The soils were slightly acidic to buffer in nature on all the ten sites and the pH values of these soils ranged from 6.28 to 7.00. Data presented in the Table 1, showed nearly acidic pH value for different sites with few values as alkaline. Gairola et al. (2012) have also reported low pH for Conifer mixed broadleaf forest and *Abies pindrow* forest in Mandal – chopta, Chamoli Garhwal region. Khera et al. (2001) also reported acidic pH values range of 5.47 and 5.20 for *Quercus leucotrichophora* and *Q. floribunda* forest in Uttarkashi Garhwal region. This may be due to higher organic matter content and protected nature of forest. Bhatt et al. (2002) have reported acidic soil in different studied sites under different *C. deodara* forest of Garhwal Himalaya with the pH values of 6.12 to 6.45.

Electrical conductivity (EC)

Electrical conductivity of soil was significantly influenced by varying sites, soil depth and interaction between them (Table 1). The maximum (0.17 dSm^{-1}) electrical conductivity was recorded at Dhanolti sites as compared to all other sites. Which was followed by Kanasar -I and Dandachalli, Thangdhar sites *etc.* The minimum (0.07 dSm^{-1}) electrical conductivity was recorded in Harshil. Whereas electrical conductivity decreased significantly with increase in soil depth *i.e.* from 0-15 to 31 - 45 cm and the maximum (0.15 dSm^{-1}) electrical conductivity was observed in 0-15 cm soil depth than other soil depths. Among the interaction between sites and soil depth, the maximum (0.23 dSm^{-1}) electrical conductivity was recorded in 0-15 cm under the Dhanolti site than all other combination of sites and soil depths. In 16-30 cm soil depth, higher electrical conductivity was recorded at Kanasar-II. The minimum (0.07 dSm^{-1}) and significantly lower electrical conductivity was exhibited in 31-45 cm soil layer at Harshil sites than all other combination of sites and soil depth.

Electrical conductivity values ranged from 0.07 to 0. 17 dSm^{-1}. The lower electrical conductivity values exhibited by different sites may be attributed to the lesser release of ions from mineral weathering under different temperature and moisture regimes (Kaushal et al. 1997). Within the soil depths, the electrical conductivity decreases with increases in depth which may be related to leaching of nutrients from surface soils, consequently increasing their concentration in lower soil layer. Accumulation of soluble salts in mountainous region is unlikely because of the climatic conditions of the region e.g. heavy rainfall. Electrical conductivity values of 0.218 dS m^{-1} were reported for soils of temperate coniferous forests in southern region of Kashmir Himalaya (Wani et al. 2013), which is in line with present study. Another study conducted in coniferous forests of Tangmarg J & K reported electrical conductivity value of 0.139 dS m^{-1} for dense forest site and 0.196 dSm^{-1} for deforested site (Jehangir et al. 2012).

Organic Carbon

Maximum mean organic carbon percentage (2.68 %) was recorded in Thangdhar and minimum (1.86 %) was in Harshil and all the sites are statistically at par with each other except Dharali and Harshil (Table 2). Among different soil depth soil organic carbon was found to decrease with increasing soil depth from (0-15 to 31-45 cm). Maximum mean organic carbon percentage (2.92 %) was recorded in (0-15 cm) soil depth and minimum (1.41 %) in (31-45 cm). Significantly higher soil organic carbon percent was in 0-15 cm soil depth as compared to other. Results further showed that the interaction effect between different sites and soil depth maximum soil organic carbon percentage (2.92 %) was recorded in Kanasar-I in 0-15cm soil depth, which was followed by Dhanolti and Thangdhar (2.82). However, minimum percentage of organic carbon (2.12 %) was recorded in Dharali site. All the values pertaining to interaction between sites and different soil depth are statistically at par with each other except Harshil (31-45 cm and Kanasar- II (31-45 cm). Organic carbon percentage ranged from 2.12 to 2.83 %, 1.75 to 2.81 % and 1.41 to 2.60 % for 0-15 cm, 16-30 cm and 31- 45 cm soil depth respectively. Higher soil organic content was obtained under Thangdhar as compared to Harshil (29 times more than Harshil). The soil enrichment with soil organic carbon content in Thangdhar could be due to addition of litter, thick humus layer (up to 5 cm) and minimum soil organic carbon percentage was recorded in Harshil due to heavy rainfalls recorded in Uttarkashi region as compared to Tehri district. This might have a key factor contributing to decrease soil organic carbon content, which may erode the soil surface and removed organic matter- rich fine sediments from the soil surface. The soil organic carbon content decreased with the soil depth in all sites, which might be due to the fact that humus formation and decomposition of organic matter takes place in upper layer.

Table 1. pH and Electrical conductivity (1:2) at various depths in the soil of different *Cedrus deodara* forest sites

Site name	pH (1:2)				Electrical conductivity (1:2)			
	0-15 cm	16-30 cm	31-45 cm	Mean ± SD	0-15 cm	16-30 cm	31-45 cm	Mean ± SD
Dandachalli	6.31	6.27	6.29	6.29 ± 0.01	0.18	0.12	0.09	0.13 ± 0.03
Dhanolti	6.56	6.59	6.60	6.58 ± 0.01	0.23	0.15	0.13	0.17 ± 0.03
Dharali	6.70	6.73	6.78	6.74 ± 0.02	0.09	0.08	0.08	0.08 ± 0.00
Harshil	6.39	6.37	6.30	6.35 ± 0.03	0.08	0.06	0.07	0.07 ± 0.00
Jakholi Jwarna	6.28	6.27	6.28	6.28± 0.00	0.13	0.09	0.08	0.10 ± 0.02
kanasar-I	6.76	6.76	6.80	6.77 ± 0.01	0.16	0.11	0.12	0.13 ± 0.01
kanasar-II	7.10	7.01	6.90	7.00± 0.06	0.16	0.11	0.1	0.12 ± 0.02
Kanasar-III	6.33	6.37	6.45	6.38 ± 0.04	0.17	0.16	0.11	0.15 ± 0.02
Kunain	6.39	6.36	6.31	6.35 ± 0.02	0.10	0.1	0.13	0.11 ±.01
Thangdhar	6.30	6.39	6.38	6.36 ± 0.03	0.20	0.11	0.08	0.13 ± 0.04

* SD= Standard deviation

Soil organic matter

Maximum mean soil organic matter (4.64 %) was recorded in Thangdhar and minimum (3.22 %) was in Harshil and all the sites are statistically at par with each other except Dharali and Harshil (Table 2). Among different soil depth soil organic matter was found to decreases with increasing soil depth from (0-15 to 31-45 cm). Maximum mean soil organic matter percent (5.03 %) was recorded in (0-15 cm) soil depth and minimum (2.46 %) in (31-45 cm). Significantly higher soil organic matter percent in 0-15 cm soil depth compared to other. Results further showed that the interaction effect between different sites and soil depth maximum soil organic matter percent (5.03 %) was recorded in Kanasar-I in 0-15cm soil depth, which was followed by Dhanolti and Thangdhar (4.88 %). However, minimum percent of organic matter (3.66 %) was recorded in Dharali site. Soil organic matter percent range from 3.66 to 5.06 %, 3.02 to 4.84 % and 2.46 to

4.53 % for 0-15 cm, 16-30 cm and 31- 45 cm soil depth respectively. Therefore, all the sites and varying soil depth showed higher percentage of Soil organic matter. Similar results was also observed by Gairola et al. 2012, the values of soil organic matter varied between 3.95 and 7.43 % in mixed *Abies pindrow* and mainly *Aesculus indica* forest types of Uttarakhand regions respectively.

Table 2. Organic carbon, soil organic matter, and C: N ratios at various depth in the soil of different sites of *Cedrus deodara* forest.

	Soil Organic Carbon (OC %)				Organic matter (%)				C: N ratio			
Site name	0-15 cm	16-30 cm	31-45 cm	Mean ± SD	0 -15 cm	16-30 cm	31 -45 cm	Mean ± SD	0 - 15 cm	16 – 30 cm	31 -45 cm	Mean ± SD
Dandachalli	2.48	2.19	2.19	2.29 ± 0.10	4.28	3.78	3.81	3.96 ± 0.16	11.80	11.52	11.52	11.61 ± 0.09
Dhanolti	2.82	2.38	2.13	2.44 ± 0.20	4.88	4.10	3.71	4.23 ± 0.34	11.75	11.90	11.83	11.83 ± 0.04
Dharali	2.12	1.81	1.98	1.97 ± 0.09	3.66	3.12	3.45	3.41 ± 0.16	11.77	11.31	11.64	11.57 ± 0.14
Harshil	2.18	1.75	1.65	1.86± 0.16	3.76	3.02	2.87	3.22 ± 0.27	11.47	11.66	11.78	11.64 ± 0.09
Jakholijwarna	2.49	2.24	2.22	2.32 ± 0.09	4.29	3.86	3.87	4.01 ± 0.14	11.85	11.78	11.68	11.77 ± 0.05
kanasar-I	2.92	1.76	2.07	2.25 ± 0.35	5.03	3.03	3.61	3.89 ± 0.59	11.68	11.73	11.50	11.64 ± 0.07
kanasar-II	2.32	2.20	1.41	1.98 ± 0.29	4.00	3.79	2.46	3.42 ± 0.48	11.60	11.57	11.75	11.64 ± 0.06
Kanasar-III	2.59	2.81	2.60	2.67 ± 0.07	4.47	4.84	4.53	4.61 ± 0.12	11.78	11.70	11.81	11.76 ± 0.03
Kunain	2.80	1.92	2.15	2.29 ± 0.26	4.83	3.31	3.75	3.96 ± 0.45	11.66	11.29	11.94	11.63 ± 0.19
Thangdhar	2.82	2.72	2.49	2.68± 0.10	4.88	4.69	4.34	4.64 ±0.16	11.79	11.82	11.85	11.82± 0.02

* SD= Standard deviation

Carbon: Nitrogen ratio (C:N ratio)

Maximum mean C:N ratio (11.83 %) was recorded in Dhanolti and minimum (11.57%) was in Dharali and all the sites are statistically at par with each other (Table 2). Among different soil depth C:N ratio was found to increase with increase soil depth (0-15 cm to 31-45 cm). Maximum mean C:N ratio percent (11.94 %) was recorded in (31- 45 cm) soil depth and minimum (11.29%) in (16-30 cm).Results further showed that the interaction effect between different sites and soil depth maximum C:N ratio percent (11.85 %) was recorded in Jakholi jwarna in 0-15cm soil depth, which was followed by Dhandachalli and Thangdhar (11.80 & 11.79 %). However, minimum percent of C:N ratio (11.29 %) was recorded in Kunain site in 16-30 cm soil depth. C : N ratio percent ranged from 11.47 to 11.85 %, 11.29 to 11.90 % and 11.50 to 11.94 % for 0-15 cm, 16-30 cm and 31- 45 cm soil depth respectively. Therefore, all the sites and varying soil depths were reach in C:N ratio.

Total Nitrogen percent (N %)

Variation among different sites and the maximum total nitrogen percent (0.23 %) was recorded in Kanasar-III and Thangdhar (Table 3). Whereas, minimum N (0.16%) was recorded in Harshil. All the sites are statistically at par with each other except Dharali, Harshil and Kanasar -II. Among different soil depths total nitrogen decreases with increase in soil depth from (0-15 to 31-45 cm). Maximum mean total nitrogen percent (0.25 %) was recorded in (0-15 cm) and minimum (0.14 %) in (31-45 cm).Interaction effect between different sites and soil depths revealed that maximum total nitrogen percent (0.25 %) was recorded in Kanasar-I at 0-15cm soil depth, which was followed by Dhanolti, and Thangdhar (0.24 %). However minimum percent of total nitrogen (0.12 %) was recorded in Kanasar-II sites in 31-45 cm soil depth. Interaction between sites and soil depths are statistically at par. Total nitrogen percent ranged from 0.19 to 0.25 %, 0.15 to 0.24 % and 0.14 to 0.22 % for 0-15 cm, 16-30 cm and 31- 45 cm soil depth respectively among all the sites.

Table 3. Total Nitrogen, available Phosphorus and available Potassium at various depth in the soil of different *Cedrus deodara*

	Total Nitrogen %				Available Phosphorus (kg/ha.)				Available Potassium (kg/ha.)			
Site name	0-15 cm	16-30 cm	31-45 cm	Mean ± SD	0-15 cm	16-30 cm	31-45 cm	Mean ± SD	0-15 cm	16-30 cm	31-45 cm	Mean ± SD
Dandachalli	0.21	0.19	0.19	0.20 ± 0.01	14.01	13.17	14.83	14.00 ± 0.83	572.47	492.55	430.78	498.60 ± 71.04
Dhanolti	0.24	0.20	0.18	0.21 ± 0.02	14.83	14.01	14.83	14.55 ± 0.47	268.53	241.35	235.57	248.48 ± 19.60
Dharali	0.18	0.16	0.17	0.17 ± 0.01	18.95	18.11	16.48	17.85 ± 1.26	276.76	281.70	315.48	291.31 ± 21.07
Harshil	0.19	0.15	0.14	0.16 ± 0.01	14.83	14.83	16.48	15.38 ± 0.96	253.70	219.11	187.80	220.20 ± 32.97
Jakholijwarna	0.21	0.19	0.19	0.20 ± 0.01	17.30	14.83	11.54	14.55 ± 2.89	485.98	319.58	220.74	342.10 ± 34.05
Kanasar – I	0.25	0.15	0.18	0.19 ± 0.03	11.54	14.01	13.17	12.91 ± 1.26	293.24	156.49	177.10	208.94 ± 73.73
Kanasar – II	0.20	0.19	0.12	0.17 ± 0.02	14.83	14.83	12.36	14.00 ± 1.43	304.75	255.33	253.70	271.26 ± 29.02
Kanasar – III	0.22	0.24	0.22	0.23 ± 0.01	16.48	14.83	18.11	16.47 ± 1.64	253.70	325.36	267.69	282.25 ± 37.98
Kunain	0.24	0.17	0.18	0.20 ± 0.02	13.17	13.17	14.83	13.72 ± 0.96	245.45	247.92	214.98	236.12 ± 18.35
Thangdhar	0.24	0.23	0.21	0.23 ± 0.01	14.01	13.17	14.01	13.73 ± 0.49	761.90	683.67	359.12	601.56 ± 13.57

* SD= Standard deviation

The values of total nitrogen in the study area varied between 0.16 % and 0.23 %. A value of total nitrogen in study sites was higher in upper soil layer as compared to lower layers. This could be attributed to higher soil organic carbon. Gairola et al. (2012) reported the higher total nitrogen (0.17 to 0.45 %) in Mandal – Chopta forest of Garhwal Himalaya. Pande et al. (2001) also reported the higher total nitrogen percent (0.46 – 0.50 %) in conifer mixed broadleaf forest at Pangarbasa, Chamoli Garhwal. Similarly, Sharma *et al.* (2010) reported the total nitrogen percent between 0.16 and 0.21 % in *Quercus leucotrichophora* at Buvakhal, Pauri Garhwal.

Available Phosphorus

Data showed in Table 3, available phosphorus (kg ha^{-1}) in soil was significantly influenced by the varying sites, soil depth and interaction between them. Among different sites maximum mean available phosphorus (17.85 kg ha^{-1}) was recorded in Dharali sites and minimum (12.91 kg ha^{-1}) recorded in Kanasar-I sites. However values for available phosphorus in Harshil and Kanasar-III sites were statistically at par with each other. Among interaction effect between sites and different soil depths, maximum available phosphorus (18.95 Kg ha^{-1}) was recorded in Dharali sites in 0-15 cm soil depth, which was followed by Kanasar-III (18.11 Kg ha^{-1}) in 31-45 cm soil depth. However minimum available phosphorus (11.54kg ha^{-1}) was recorded in Jakholi jwarna in 31-45 soil depth. The values for available phosphorus under Dharali, Dhanolti, Harshil, Jakholi jwarna, Kanasar-II, Kanasar-III in 0-15 cm soil depth, Dharali, Harshil, Jakholi jwarna, Kanasar-II, Kanasar-III and Kunain in 16-30 cm soil depth and Dandachalli, Dhanolti, Dharali, Harshil, Kanasar-III and Kunain in 31-45 cm soil depth are all statistically at par with each other. Therefore among interaction effects Dharali sites with 0-15 cm soil depth proved to be best for available phosphorus.

The value of available phosphorus in study area ranged from 12.90 to 17.84kg ha^{-1}. Similarly, Mehta et al. (2014) had reported higher value of phosphorus (6.52 to 13.42 kg ha^{-1}) in forest of Central Himalaya. The available phosphorus was higher in lower soil depth in Dandachalli, Kanasar-III and Kunain, which may be due to the leaching effect.

Available Potassium

Among different sites, maximum mean available potassium (601.56 kg ha^{-1}) was recorded in Thangdhar site as compared to all other sites and minimum available potassium (208.94 kg ha^{-1}) in Kanasar-I site, however values for available potassium at Dandachalli sites were statistically at par. Maximum mean available potassium (371.64 kg ha^{-1}) was recorded in 0-15 cm soil depth and minimum (266.30 kg ha^{-1}) was recorded in 31-45. However, the values observed under 16-30 cm are at par with each other. Within the different soil depth noticed that available potassium was decreases with increasing in soil depth from 0-15 to 31-45 cm (Table 3).The interaction effect between sites, different soil depths and maximum available potassium (761.90 kg ha^{-1}) was recorded in Thangdhar sites in 0-15 cm soil depth. However, minimum available potassium (156.49 kg ha^{1}) was recorded in Kanasar-I in 16-30 cm soil depth. The values for available potassium under Dandachalli, Jakholi jwarna in 0-15 cm soil depth; Dandachalli, Thangdhar in 16-30 cm soil depth, and Dandachalli, Thangdhar in 31-45 cm soil depth are statistically at par with each other. Thangdhar sites with 0-15 cm soil depth proved to be best for available potassium and Kanasar-I sites with 16-30 cm soil depth was poor to provide available potassium to tree growth.

Available potassium in the present study varied between 208.95 kg ha^{-1} to 601.55 kg ha^{-1}. Bhatt et al (2002) have reported higher values for potassium. Exchangeable potassium in soil depends on composition of parent rock material. Therefore higher values and variation in exchangeable potassium at different sites and soil depths may be the varying composition of parent rock material, which form the basis for availability of potassium at particular sites.

Relationship between different parameters of chemical properties

A kinship among different parameter of soil is presented in table 4. A perusal of data indicated that a correlation study of soil organic carbon with soil organic matter, total nitrogen, potassium, electrical conductivity Strong positive relationship with r = 0.919, perfect positive (r =1.000), weak positive (r = 0.481), Moderate positive (r = 0.716) respectively and phosphorus and pH showed negative relationships (r= -0.198, r = -0.434). Soil organic matter and total nitrogen percentage expressed strong positive correlation (r = 0.920) followed by C:N ratio (r =0.827) , electric conductivity (r = 0.745) while Phosphorus (r = -0.149) and pH (r = -0.288) was indicated weak negative relationship. C: N ratio is highly correlated with total nitrogen percentage (r = 0.766) where as it is negative with phosphorus and pH. Phosphorus and potassium showed less positive kinship with pH and electric conductivity respectively. pH is also indicated to a lesser extent positive relationship with electric conductivity (r = 0.095).

Table 4. Correlation between different chemical soil properties

	SOC	SOM	C : N ratio	Total N	Available P	Available K	pH	EC
Soil organic carbon	1							
Soil Organic matter	0.919	1						
C: N ratio	0.766	0.827	1					
Total Nitrogen	1.000	0.920	0.766	1				
Available P	-0.198	-0.149	-0.152	-0.195	1			
Available K	0.481	0.512	0.314	0.480	-0.175	1		
pH	-0.434	-0.288	-0.327	-0.435	0.011	-0.409	1	
Electrical conductivity	0.716	0.745	0.596	0.717	-0.332	0.155	0.095	1

CONCLUSIONS

The analytical findings conclude that the soil chemical properties indicating that soils were well enriched by soil nutrients i.e. organic carbon, total nitrogen, phosphorus and potassium. The nutrients were decreasing with increasing soil depths under all sites except soil pH. Soil reaction was observed slightly acidic to neutral in nature. It will help to improve soil structure and pH value indicated that soil are rich in nutrients such as N, P, K, Ca, Mg, S, B, Cu. This quantification study is helpful in understanding the soil health of the *Cedrus deodara* forest. Soil organic carbon is seen as one way to mitigate climate change by reducing atmospheric carbon dioxide because soil organic carbon is one component of the global carbon cycle that involves the cycling of carbon through the soil, vegetation, ocean, and the atmosphere. The argument is that small increases of SOC over very large areas in the forest and pastoral lands will significantly reduce atmospheric carbon dioxide. The total nitrogen, phosphorus, and potassium results will be helping to understand the site's productivity and soil health.

ACKNOWLEDGEMENTS

We express our sincere thanks to all the staff members of the Department of Forestry, College of Forestry, Ranichauri, VCSG UUHF, Bharsar for providing facility and guidance for work. We extent our heartiest thanks to all staff members of the concerned Forest Division of Uttarakhand Forest Department for helping in fieldwork and provided accommodation during the fieldwork.

REFERENCES

Adams PW. and Sidle RC. 1987. Soil conditions in three recent landslides in southeast Alaska. Forest Ecology and Management, 18(2):93–102

Anon. 1945. Storage of coniferous sleepers. Forest Research Indian Burma, 1(194): 45

Augustoa L., Rangera J., Binkleyb D., and Rothe A. 2002**.** Impact of several common tree species of European temperate forests on soil fertility. Annals of Forest Science, 59: 233–253

Bhatt A., Sharma CM. and Khanduri V.P. 2000.Growing stock variation in different *Cedrus deodara* forests of Garhwal, Himalaya**.** *Indian forester***.** 218 (8): 903 – 916

Bhatnagar HP. 1965. Soils from different quality sal (S. robusta) forests of Uttar Pradesh. Tropical Ecology, 6: 56- 62

Binkley D. and Giardina, C. 1998. Why do tree species affect soils? The warp and woof of tree- soil interactions, Biogeochemistry 42: 89–106

Binkley D. and Giardina C. 1998.Why do tree species affect soils?The warp and woof of tree-soil interactions, Biogeochemistry 42:89–106.

De Hann. S.1977. Humus, its formation, its relation with the mineral part of the soil and its significance for soil productivity. In: Organic matter studies, vol 1. International Atomic Energy Agency, Vienna, pp 21–30

Gairola S., Sharma CM., Ghildiyal SK. and Suryal S. 2012.Chemical properties of soils in relation to forest composition in moist temperate valley slopes of Garhwal Himalaya, Environmentalist. DOI 10.1007/s10669-012-9420-7

Gupta MK. and Sharma SD. 2008. Effect of tree plantation on soil properties, profile morphologyand productivity index I. Poplar in Uttarakhand. Annals of Forestry, 16(2):209–224

Gupta MK. and Sharma SD. 2008.Sequestrated carbon: organic carbon pool in the soils under different forest covers and land uses in Garhwal Himalayan Region of India. International Journal of Agriculture and Forestry, 1 (1): 14 – 20

Jackson ML. 1973. Soil chemical analysis. Prentice Hall, Inc., Englewood Cliffs

Jehangir A., Yousuf AR., Reshi ZA., Tanveer A. and Afteb A. 2012. Comparison of physical, chemical and microbial properties of soils in a clear-cut and adjacent intact forest in north western

Himalaya. International Journal of Soil Science, 7: 71-81

Khera N., Kumar A., Ram J. and Tewari A. 2001. Plant biodiversity assessment in relation to disturbances in mid-elevational forest of Central Himalaya, India. Tropical Ecology,42(1): 83–95

Olsen SR., Cole CL. Watanabe FS. and Dean DA. 1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA Circulation. 939 pp.

Pala NA., Negi AK., Vikarant KK., and Todaria N.P. 2013. Carbon storage in sacred groves – A Study from chanderbadni sacred grove in Garhwal Himalaya, Uttarakhand, India. Journal of Biodiversity and Ecological Sciences, 3(2): 77-79

Pande PK., Negi JDS and Sharma SC. 2001. Plant species diversity and vegetation analysis in moist temperate Himalayan forest. Indian Journal of Forestry, 24(4): 456–470

Sharma CM., Baduni NP, Gairola S, Ghildiyal SK and Suyal S. 2010. Tree diversity and carbon stocks of some major forest types of Garhwal Himalaya, India. Forest Ecology and Management, 260(12): 2170–2179

Singh AK., Parsad A. and Singh B.1986. Availability of phosphorus and potassium and its relationship with physico-chemical properties of some forest soils of Pali-range (Shahodol, M.P.). The Indian Forester, 112(12):1094–1104.

Singh JS. 2006. Sustainable development of the Indian Himalayan region: Linking ecologicaland economic concerns. Current Science;90(6):784-788

Stanford S. and English L. 1949. Use of flame photometer in rapid soil tests of K and Ca. Agronomy Journal, 4: 446-447

Subbiah BV and Asija GL. 1956. A rapid method for estimation of available N in soil. Current Science. 25: 259-260

Tiwari DM. 1994. *Distribution and Morphology*: A monograph on Deodar. International Book Distributors, Dehradun:14 p.

Troup RS. 1921. The silviculture of Indian trees vols, 1-111. Clarendom press, oxford,1995 pp.

Walkley A. and Black TA. 1934. An examination of the wet acid method for determining soil organic matter and proposed modification of the chromic acid titration method. Soil Science, 37: 29-38

Wani NR., Qaisar K.N. and Khan PA. 2014. Biomass, carbon stock and carbon dioxide mitigation potential of *Cedrus deodara* (Deodar) under temperate condition of Kashmir. Canadian journal of pure and applied science, 8(1): 2677 – 2684.