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Effect of Altitude and Aspect on Soil Physico-Chemical Characteristics in Shankaracharya Reserved Forest

Shazmeen Qasba[1], T. H. Masoodi[1], S. J. A. Bhat[1*], P. A. Paray[1], Amir Bhat[1] and Mehraj ud din Khanday[2]

[1]Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Benihama, Ganderbal (J&K), India-191 201

[2]Division of Soil Science, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar Srinagar-190 025

*Corresponding Author E-mail: javaidforest11@gmail.com

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ABSTRACT

The present investigation entitled "Effect of altitude and aspect on soil physico-chemical characteristics in Shankaracharya forest" was carried out, during the year 2011 and 2012. The soil was slightly acidic in reaction with mean soil pH value of 6.4. The soil chemical properties viz. Available Nitrogen (N), Available Phosphorus (P) and Available Potassium (K) varied significantly and increased with the increase in altitude. The maximum values for these characteristics were recorded at upper elevation (N =211.6 kg ha^{-1}, P = 18.5 kg ha^{-1} and K = 183.1 kg ha^{-1}) followed by middle elevation (N = 207.3 kg ha^{-1}, P = 14.8 kg ha^{-1} and K = 175.1 kg ha^{-1}) and lower elevation (N= 194.3 Kg ha^{-1}, P = 12.3 kg ha^{-1} and K =171.8 kg ha^{-1}). Significant variations were also recorded among these parameters on different aspects and the corresponding soil depth. In general, soil fertility was high at the higher altitudes, where thick organic surface layer was prevailing, in contrast to the thin layer at lower altitude.

Key words: *Altitude, Aspect, Soil physico-chemical, Shankaracharya, Reserved forest*

INTRODUCTION

The soil and vegetation have a complex inter-relation 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[1]. Concentration of elements in the soils is thus a good indicator of their availability to plants[2]. Similarly, less soil moisture evaporation under the canopy of trees particularly on north facing slopes exhibits numerous effects on different soil properties resulting in less organic matter decomposition and consequently more organic carbon and total nitrogen accumulation[3].

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Consequently, the soil nutrient pool and general fertility on north facing slopes becomes greater than those on south facing slopes, which leads to high variability in plant species, vegetation type and plant community existing on the same site[4]. The development of soil at different aspects and altitudes is under the influence of climax species. The growth rate of these forests with respect to standing volume and biomass attained under protected conditions with minimum biotic interference can provide significant information on carbon storage[5]. Process based models are thus increasingly applied in forestry for determining tree growth with respect to soil properties[5, 6, 7, 8].

The present study was; therefore, undertaken to study physico-chemical characteristics of this unique man made reserved forest soil which now comprises of both tropical and temperate origin. The information generated from this study has helped to classify this reserved forest hillock on the basis of some edaphic characteristics. The study which focused on the physic-chemical properties has provided basis for formulating future management and silvicultural plan for this reserve forest grove.

MATERIALS AND METHODS

The present investigations were carried out on Shankaracharya hillock which stands declared as a reserve forest under Section 11 of the Forest Act of 1987 and a Game Sanctuary under Section 5 of the Game Prevention Act of 1998[9]. The hillock is maintained by the Forest Department, Government of Jammu and Kashmir for religious, aesthetic and recreational purposes. The study site is located between 34°04′ 35.56″ to 34°05′ 25.08″ N latitude and 74°50′ 03.16″ to 74°51′ 08.63″ E longitude (Table 1). Spread over an area of 141.93 ha, this forest grove lies in South-Eastern side of Srinagar and presents a marvelous view of world famous Dal Lake and other adjoining environs. The altitude of the study site varies from 1575 to 1967 m asl (Table 1) with entire hillock serving as a catchment area to Dal Lake.

Soil analysis

A total of 18 soil samples were collected at two depths viz., 0-15 and 15-30 cm at each sampling site a small amount of soil was combined from three randomly located points. The soil samples were air dried and processed through a 2mm sieve whilst twigs, roots and gravel were removed. The sieved fraction of soil was homogenized and used for analysis of different physico-chemical parameters as per standard procedures described by[10, 11].

Soil pH

The pH of soil samples was measured at 20 ^{o}C with the help of a digital pH meter (model AP × 175 E/C). Twenty five gram (25 g) of air dry soil sample was thoroughly mixed with 50 ml of distilled water (1:2 w/v) and the reading for pH of the soil samples was taken after 30 minutes. The pH meter was calibrated before use with Standard pH buffers (pH 4 and pH 7)[12].

$$\text{Soil pH} = \log \frac{1}{H^+} = \log (H^+)$$

H+ is expressed as g ions/lt.

Electrical conductivity (µS/cm)

The conductivity of soil samples was measured at 20 ^{o}C with the help of a digital CD-601 Conductivity meter. Twenty five gram (25 g) of air dried soil sample was thoroughly mixed with 50 ml of distilled water (1:2 w/v) and conductivity of the soil samples was recorded after 30 minutes. The conductivity meter was calibrated before use with standard 0.01M potassium chloride solution. The results were expressed as µS/cm at 20^{o}C[13].

Available nitrogen (kg ha^{-1})

The distillation process helps liberate ammonia which is absorbed in boric acid. The distillate is titrated with standard acid (N/10HCL) and the nitrogen is calculated using the exact titre value of the acid[14].

Take 5 g soil in Kjeldhal tube

↓

Add a little distilled water and 25 ml $KMnO_4$

↓

Place a conical flask (250 ml) containing 25ml boric acid solution in such a way that the end of condenser tube dips into the boric acid solution.

↓

Connect the Kjeldhal tube to the distillation assembly and add about 25ml sodium hydroxide (2.5%)

↓

Set the process time 15-18 minutes (about 150ml distillation is collected in receiving flask) and Test with red litmus paper to ensure total distillation

↓

Titrate the distillate with standard 0.02N $H_2SO_4$to wine red end point

Run a blank in the same way

$$\text{Available nitrogen (kg ha}^{-}\text{)} = \frac{(\text{ sample titre-blank titre})0.02 \times 14 \times 2.24 \times 10^6}{\text{Weight of soil sample (g)} \times 1000}$$

Available phosphorus (kg ha^{-1})

Olsen's method 1954[15] was used to determine available phosphorus in soil samples.

Take 1 g of soil

Add↓

20ml$NaHCO_3$

↓

Shaking on a mechanical shaker for 30 minutes

Add↓

5 ml extract in 25ml U/F

Add↓

5 ml Ammonium Molibdate

Add↓

10 ml D/W

Add↓

1 ml stannous chloride and dilute to 25 ml-Blue colour on spectro photometer
Reading at 660 W/I % AB

The concentrations of available phosphorus were calculated by reference to a calibration graph plotted from the standard phosphorus (KH_2PO_4) solution. Blanks were run in the same manner without soil.

Available potassium (kg ha^{-1})

The available potassium was estimated by N-Ammonium Acetate Method[10] using Digital Flame Photometer (Model CL 22D).

Take 5 g soil

Add↓

25 ml Ammonium acetate solution

↓

Shake for 5minutes

↓

Filter

↓

Feed on flame photometer

Record the readings

Statistical analysis

The data collected in the field was statistically analysed according to well designed procedures prescribed by [16].

RESULTS

The results of present investigation entitled "Effect of altitude and aspect on soil physico-chemical characteristics in Shankaracharya forest" are presented in under the following main headings:

Soil pH

The data on soil characteristics (Table 2) depicts that the mean soil pH values on lower altitude (1575-1705m) were 6.0, 6.1 and 6.7 on NorthWest, North East and South East aspects respectively. The mean values of soil pH were 6.4 and 6.1 along the soil depth of 0-15 and 15-30 cm. The interaction values for soil pH between altitude, aspects and soil depths were significantly different ($p\leq 0.05$) with each other. The mean pH values at middle altitudinal range of 1705-1835 m were in order of 6.1, 6.2 and 6.9 on NorthWest, North East and South East aspects respectively. Again, the pH values differed significantly ($p\leq 0.05$) from 6.5 to 6.3 at 0-15 and 15-30 cm of soil depth.The mean pH values on upper altitudinal range (1837-1967 m) were 6.3, 6.4 and 7.0 on NorthWest, North East and South East aspects respectively. The pH values decreased from 6.5 to 6.3 with increase in soil depth from 0-15 cm and 15-30 cm. The overall average soil pH of Shankaracharya hillock was 6.3.

Electrical conductivity (EC dScm^{-1})

The mean values of electrical conductivity (Table 2) on lower altitudinal gradient of 1575-1705m were 0.24, 0.22 and 0.32 dS cm^{-1} on NorthWest, North East and South East aspects respectively. The mean values of EC recorded with respect to soil depth were 0.27 and 0.24 at 0-15cm and 15-30 cm respectively. The variation in EC was also evident on middle altitudinal range of 1705-1835 m. The average values of EC at this altitude were in order of 0.26, 0.24 and 0.33 dScm^{-1} on North West, North East and South East aspects respectively. The EC values exhibited significant variation ($p\leq 0.05$) between the two soil depths with mean electrical conductivity values of 0.30 and 0.25 dS cm^{-1} at 0-15 and 15-30 cm of soil depth at the available aspects. The mean values at the upper altitudinal range of 1837-1967 m were 0.28, 0.26 and 0.36 ($p\leq 0.05$) on NorthWest, North East and South East aspects respectively. The EC values decreased significantly along the soil depth on all the available aspects with mean values of 0.32 and 0.27 dScm^{-1} at the soil depth of 0-15 to 15-30 cm respectively. The overall average EC values along an altitudinal gradient on all the available aspects in each soil depth on Shankaracharya hillock was 0.27 dScm^{-1}.

Available nitrogen (N kg ha^{-1})

The results on available N are summarized in Table 2. The mean values of available Nitrogen on lower altitudinal range of 1575-1705m were 245.5, 247.5 and 89.5 kg ha^{-1} on North West, North East and South East aspects respectively. The data further reveals that available N values decreased significantly ($p\leq 0.05$) with increase in respective soil depth from 218.6 kg ha^{-1} in 0-15 cm to 167.3 kg ha^{-1} in 15-30 cm. The available Nitrogen values at middle altitudinal range of 1705-1835m were in order of 257, 260 and 105 kg ha^{-1} at NorthWest, North East and South East aspects respectively. The value of available nitrogen decreased from 236.6 to 178.3 kg ha^{-1} at 0-15 and 15-30 cm of soil depths respectively. The data further reiterates that available Nitrogen values differed significantly ($p\leq 0.05$) with respect to altitude, aspect and soil depth on the upper altitudinal range of 1837-1967 m. The mean available Nitrogen values were 256, 267.5 and 111.5 kg ha^{-1}on NorthWest, North East and South East aspects respectively. The variation in availability of Nitrogen with respect to soil depth was also significantly different ($p\leq 0.05$) and decreased from 241.6 to 181.6 kg ha^{-1} in 0-15 and 15-30 cm respectively. The overall availability of Nitrogen in Shankaracharya reserved forest hillock was 203.87 kg ha^{-1}.

Available phosphorus (kg ha^{-1})

Results presented in Table 2 reveals that mean values of available phosphorus at lower altitudinal gradient of 1575-1705 m were 13, 15 and 9 kg ha^{-1} on North West, North East and South East aspects respectively. The available Phosphorus levels at the depth of 0-15 and 15-30 cm were 13.3 and 11.3 kg ha^{-1} respectively. The mean values of available Phosphorus on middle altitudinal gradient of 1705-1835m were in order of 15, 18.5 and 11 kg ha^{-1} on North West, North East and South East aspects respectively. Available Phosphorus exhibited significant ($p \leq 0.05$) change with respect to soil depth and varied between 16.3 to 13.3kg ha^{-1} at the respective soil depth of 0-15 and 15-30 cm. The available Phosphorus values at the upper altitudinal range of 1837-1967 m were in order of 20, 21.5 and 14 kg ha^{-1} on North West, North East and South East aspects respectively. The available Phosphorus levels decreased significantly ($p \leq 0.05$) from 19.6 to 17.3 kg ha^{-1} at the soil depth of 0-15 and 15-30 cm respectively. The overall availability of Phosphorus in Shankaracharya reserved forest soil was 15.17 kg ha^{-1}.

Available potassium (kg ha^{-1})

Data in Table 2 depicts that mean available potassium content on lower altitudinal range of 1575-1705m was 184, 186.5 and 145 kg ha^{-1} on NorthWest, North East and South East aspects respectively. The mean values of available Potassium recorded with respect to soil depth were significantly ($p \leq 0.05$) different and decreased from 181 kg ha^{-1} at the depth of 0-15 cm to 162.6 kg ha^{-1} at 15-30 cm respectively. The mean available K values at middle altitudinal range of 1705-1835m were in order of 187.5, 191.5 and 146.5 kg ha^{-1} on North West, North East and South East aspects respectively. Again, the available Potassium content differed significantly ($p \leq 0.05$) and decreased from 186.3 to 164 kg ha^{-1} with an increasing soil depth from 0-15 cm to 15-30 cm respectively. The available Potassium content on upper altitudinal range of 1835-1967 m was 192.5, 201.0 and 156.0 kg ha^{-1} on NorthWest, North East and South East aspects respectively. The available Potassium values decreased significantly ($p \leq 0.05$) from 196.6 kg ha^{-1} in 0-15 cm to 168.3 kg ha^{-1} in 15-30 cm of soil depth. The overall Potassium content in Shankaracharya forest soils was 176.43 respectively.

Table 1: Geographical attributes and Lithology of Shankaracharya Reserve Forest

Altitude	Aspect	Longitude	Latitude	Lithology	Slope
1575-1705 m asl	North West	34^o 04′ 35.36″ N	74^{o}50′03.132″E	Deep loam	Steep
	North East	34^{o}05′25.38″ N	74^{o}50′03.145″E	Fine loam	Steep
	South East	34^{o}05′ 25.396″ N	74^{o}50′03.148″E	Silty loam	Very steep
1705-1835 m asl	North West	34 ^{o}04′ 35.44″ N	74^{o}50′03.160″E	Deep loam	Steep
	North East	34^{o}05′25.46″ N	74^{o}50′03.155″E	Fine loam	Very steep
	South East	34^o 05′ 25.490″N	74^{o}50′03.158″E	Silty loam	Steep
1835- 1967 m asl	North West	34^{o}04′35.508″ N	74^{o}50′03.16″E	Deep loam	Very steep
	North East	34^{o}04′35.563″N	74^{o}50′03.16″	Fine loam	Very steep
	South East	34^{o}05′25.083″	74^{o}51′ 08.63″E	Silty loam	Very steep

Table 2: Soil physico-chemical characteristics of Shankaracharya Reserve Forest across the available aspects along an altitudinal gradient

Parameters	**Depths (cm)**	**Altitude (amsl)**												**CD (P≤0.05)**					
		1575-1705				**1705-1835**				**1837-1967**									
		Aspect				**Aspect**				**Aspect**									
		NW	**NE**	**SE**	**Mean**	**NW**	**NE**	**SE**	**Mean**	**NW**	**NE**	**SE**	**Mean**	**A**	**B**	**C**	**A×B**	**A×C**	**B×C**
pH	0-15	6.1	6.2	6.9	**6.4**	6.3	6.4	7.0	**6.5**	6.4	6.5	7.1	**6.6**						
	15-30	5.9	6.0	6.6	**6.1**	6.0	6.1	6.8	**6.3**	6.2	6.3	6.9	**6.4**	**0.09**	**0.11**	**0.17**	**0.12**	**0.19**	**0.29**
	Mean	**6**	**6.1**	**6.7**		**6.1**	**6.2**	**6.9**		**6.3**	**6.4**	**7**							
EC (dSm^{-1})	0-15	0.25	0.23	0.35	**0.27**	0.28	0.26	0.37	**0.30**	0.30	0.28	0.40	**0.32**						
	15-30	0.23	0.22	0.29	**0.24**	0.24	0.23	0.30	**0.25**	0.26	0.25	0.32	**0.27**	**0.011**	**0.015**	**0.013**	**0.017**	**0.022**	**0.025**
	Mean	**0.24**	**0.22**	**0.32**		**0.26**	**0.24**	**0.33**		**0.28**	**0.26**	**0.36**							
Available N ($kg\ ha^{-1}$)	0-15	275	279	105	**218.6**	288	290	132	**236.6**	290	295	140	**241.6**						
	15-30	212	216	74	**167.3**	226	230	79	**178.3**	222	240	83	**181.6**						
	Mean	**245.5**	**247.5**	**89.5**		**257**	**260**	**105**		**256**	**267.5**	**111.5**		**1.6**	**1.6**	**1.3**	**2.8**	**2.3**	**2.3**
Available P ($kg\ ha^{-1}$)	0-15	14	16	10	**13.3**	17	20	12	**16.3**	21	23	15	**19.6**						
	15-30	12	14	8	**11.3**	13	17	10	**13.3**	19	20	13	**17.3**						
	Mean	**13**	**15**	**9**		**15**	**18.5**	**11**		20	21.5	14		**2.1**	**2.5**	**2**	**2.2**	**2.4**	**2.5**
Available K ($kg\ ha^{-1}$)	0-15	190	193	160	**181**	198	200	161	**186.3**	208	212	170	**196.6**						
	15-30	178	180	130	**162.6**	185	175	132	**164**	173	190	142	**168.3**						
	Mean	**184**	**186.5**	**145**		**187.55**	**191.5**	**146.5**		**192.5**	**201**	**156**		**3**	**3**	**2**	**5.2**	**4.3**	**4.3**

DISCUSSION

The spatial variation in soil properties is influenced by both abiotic and biotic factors viz., topography-induced microclimate differences, altitude, parent material and vegetation community[17]. The microclimatic variations with altitude dramatically influence the weathering rates and leaching intensity, resulting in feedback on soil properties such as amount and quality of organic matter [18, 19]. Aspect is a potential significant factor in generating differences in edaphic characteristics [20, 21]. For example, the hydrological and solar energy regimes of mountainous topography differ according to aspect, leading to divergence in soil formation and organic matter decomposition[22]. Aspect also induces local variations in microclimate, which along with chemical and physical composition of the substrate are the main regulators of decomposition rates of soil organic matter[23, 24]. Thus any change in land use pattern through afforestation/ reforestation may influence the natural phenomena and ecological processes, leading to a significant change in soil physical and chemical properties[25].

It has been reported that forest soils should be slightly acidic for nutrient supply to be balanced[26]. A fertile soil generally has a pH range between 5.5 and 7.2, which makes the essential elements and nutrients available to the plant. The mean pH values recorded at the lower altitudinal gradient were in order of 6.0 on North Western aspect, 6.1 on North Eastern aspect and 6.7 South Eastern aspect (Table 2). At middle altitude the pH values varied between 6.1 on North Western aspect, 6.2 on North Eastern aspect to 6.9 on South Eastern aspect. The soil pH values at higher altitudinal gradient of 1835-1967m was 6.3 on North Western aspect, 6.4 on North Eastern aspect and 7.0 on South Eastern aspect. The reduction in pH can be attributed to accumulation and subsequent slow decomposition of organic matter, which releases acids[27]. The values of pH in present study are lower than the values of pH recorded by[28] for Kumaun Himalaya. [29]has also recorded near to moderate alkine pH in soils of Shankaracharya hills. Similarly, pH in the range of 5.5 - 6.5 was reported by [30] in coniferous forests of Central Himalaya. Various studies have also shown that litter quality changes soil pH differently with increasing acidity for coniferous species and decreasing acidity for deciduous and herbaceous litter[31, 32]. The results from the present study are consistent with findings by[33] in the northern highlands of Ethiopia.

Soil EC is known to be influenced by a number of factors, including soil water holding capacity, concentration of ions in soil, type and amount of clay and soil bulk density[34]. Generally, it is believed that higher the concentration of ions in the soil solution more is its electrical conductance[35]. The lower electrical conductivity values in soil are characteristic to the lesser release of ions from mineral weathering under different temperature and moisture regimes[36]. The mean Electrical Conductivity values recorded in Shankaracharya Forest at lower altitudinal gradient was 0.24dsm^{-1}on North Western aspect, 0.22 dsm^{-1} on North Eastern aspect and 0.32 dsm^{-1} on South Eastern aspect. At middle altitude, the electric conductivity values were in order of 0.24 dsm^{-1} on North Eastern aspect, 0.26 dsm^{-1} on North Western aspect and 0.33 dsm^{-1} on South Eastern aspect. Similarly at higher altitudinal gradient, the electric conductivity values 0.28 dsm^{-1} on North Western aspect, 0.26 dsm^{-1} on North Eastern aspect and 0.36 dsm^{-1} on South Eastern aspect. The EC recorded at different altitudes fall within the range of values reported by[37] in low and high altitude soils of Kashmir Valley.

Soil nitrogen available as ammonical, nitrate and nitrite form is taken up and utilized directly by plants[38] to influence growth[39]. The content of nitrogen significantly promotes productivity, species diversity, community succession and sustainability of forest ecosystems[40]. Although it is estimated that more than 90% of the soil N reserves are in the soil organic pool which acts as a potential source of soil available N through mineralization, this element usually acts as a limiting factor for the productivity of forest ecosystems[41]. The processes of N uptake by vegetation and its return to soil through periodic litter fall is one of the basic features of forest ecosystem[42]. The available N values in the soil of Shankaracharya reserve forest are summarized in table 2. The results of the present study also reveal that the available nitrogen content decreased with decrease in depth on all the aspects at each of the altitudinal gradient. This depth wise distribution of available N content can be attributed to the fact that most nitrogen forms part of the soil organic matter which is higher in surface soils[43]. A similar trend of decrease in availability of N content with depth is in consonance with [44] who recorded respective mean available nitrogen content of 158 and 138 ppm in the surface and sub-surface soils of Himachal Pradesh.

Phosphorus exists in a number of organic forms including chelates of iron and aluminum phosphate which increase its availability to plants. [45] found that soil phosphate levels are higher in soils under tree cover when other soil forming factors are kept constant. It has; however, been reported that a large proportion of P is stored in the forms that are unavailable to plants [46], for example, H_2PO_4, which becomes available at low pH values and suffers from fixation by hydrous oxides and silicate minerals [47]. While studying the forest sites of the Eastern Himalaya, [48] reported that the distribution of phosphorus followed no definite trend, though soils at higher altitude exhibited higher available phosphorus content. In natural ecosystems, the concentration and chemical nature of soil organic phosphorus is mainly determined by a combination of major soil forming factors like parent material, climate, topography and micro-organisms [49]. The long term dynamics of phosphorus in the soil environment is said to be closely related to the dynamics of organic carbon, nitrogen and sulphur [50, 51].

The available P values in the soil of Shankaracharya reserve forest are summarized in Table 2. The mean available P levels at the lower altitudinal gradient of 1575-1705 m was 13 kg ha^{-1} on North Western aspect, 15 kg ha^{-1} on North Eastern aspect and 9 kg ha^{-1} on South Eastern aspect. At middle altitude (1705-1835 m), the availability of P was in order of 15.0, 18.5 and 11.0 kg ha^{-1} on North Western, North Eastern and South Eastern aspects respectively. The P values at upper altitudinal gradient of 1835-1967m were in order of 20 kg ha^{-1} on North Western aspect, 21.5 kg ha^{-1} on North Eastern aspect and 14.5 kg ha^{-1} on South Eastern aspect. [52, 53] have reported respective available phosphorus levels ranging from 2.35 to 25.66 kg ha^{-1} and 13.72 to 45 kg ha^{-1} in some surface soils of Jammu and Kashmir. The results of the present study also reveal that the Available P content decreased with decrease in depth on all the aspects at each altitudinal gradient. This depth wise distribution of available P content can be attributed to higher levels of organic matter in surface soils[43]. A similar trend of decrease in availability of P content with depth has been reported by [44, 54, 55, 56].

Potassium plays an important role in photosynthesis, water regulation of cells, enlargement of fruit size and resistance to diseases. Potassium performs very vital processes like regulating transpiration and respiration, influencing enzyme action and synthesis of carbohydrates and proteins [57]. The mean available K values on lower altitudinal gradient were 184.0, 186.5 and 145.0 kg ha^{-1} on North West, North East and South East aspects respectively (Table 2). The K levels on middle altitude was 191.5, 187.5 and 146.5 kg ha^{-1}on North Western, North Eastern and South Eastern aspects. Similarly, the K content at upper altitudinal gradient was in order of 190.5 kg ha^{-1} on North Western, 201 kg ha^{-1} on North Eastern and 156 kg ha^{-1} on South Eastern aspect respectively. The values of available K recorded in the present study are within the range 145 to 201 kg ha^{-1} reported by [58]. The results of our study are also in conformity with those reported by [59] for mixed conifer broadleaved forests of Garhwal Himalaya. The results on increase in availability of K with increase in altitude are similar to those reported by [60, 61] in Garhwal Himalaya. [61] reported that total soil potassium differs according to different altitudes and the higher content of available potassium is found in surface soil in the form of exchangeable potassium which later converts as soil solution. [62] reported that available potassium along an altitudinal gradient on PirPanjal and Siwalik (Rajouri) ranges on Northern aspect at Hill base were 102, 126 and 136 kg ha^{-1} between 500-700 m, 98, 110 and 127 kg ha^{-1} on hill slope between 700-900 m and 136, 121 and 153 kg ha^{-1} on hill top between 900-1200 m along the soil depth of 0-10, 10-20 and 20-30 cm respectively.

CONCLUSION

There is evidence that enrichment plantings help to perk up carbon, nitrogen cycling and soil biological activities which inturn indicates that ecosystem functioning is improving. The overall results of this study can be concluded as the fertility status with substantial addition of major nutrient elements viz. N, P and K in Shankaracharya forest has significantly increased with the increase in elevation.

REFERENCES

1. Singh, A.K., Parsad, A. and Singh, B., Availability of phosphorus and potassium and its relationship with physico-chemical properties of some forest soils of Pali-range (Shahodol, M.P.). *Indian Forestry* **112(12):** 1094-1104 (1986).
2. Pandit, B.R. and Thampan, S., Total concentration of P, Ca, Mg, N and C in the soils of reserve forest near Bhavnagar (Gujarat State). *Indian Journal of For.* **11(2):** 98-100 (1988).
3. Rezari, S. and Gilkes, R., The effect of landscape attributes and plant community on soil chemical properties in Rangelands. *Geoderm* **125:** 145-154 (2005).
4. Kutiel, P. and Lavee, H., Effect of slope aspect on soil and vegetation properties along an aridity transect. *Israel Journal of Plant Science* **47:**169-178 (1999).
5. Kursten, E. and Burschell, P., Co_2 mitigation by agroforestry, water, air and soil pollution **70:** 533-544 (1993).
6. Whittaker, R.H., and Marks, P.L., Methods of assessing terrestrial productivity. **In** : *Primary Productivity of the Biosphere*, Springer, New York. (Eds. H. Lieth and R. H. Whittaker). *Ecological Studies* **14:** 55-118 (1975).
7. Makela, A., Virtanen, K. and Nikinma, E., The effect of ring width, stem position and stand density on relationship between foliage biomass and sapwood area in Scots pine (*Pinus sylvestris*). *Canadian Journal Forest Research* **25:** 970-977 (1995).
8. Grote, R., Foliage and branch biomass estimation of coniferous and deciduous tree species. *Silva Fennica* **36(4):** 779-788 (2002).
9. Sidiq, R., *Forest Records*, of J and K (1987).
10. Jackson, M.L., Soil-chemical analysis, 498 pp. Prentice-Hall of India- Pvt. Ltd., New Delhi (1967).
11. Mishra, R., Ecology work Book. Oxford and I.B.H. Publishing Co. New Delhi, 244 (1968).
12. Jackson M.L., Soil Chemical Analysis. Prentice Hall Inc., New Jersey, USA (1958).
13. Jackson, M.L., *Soil Chemical Aanalysis*. Prentice Hall of India, Pvt. Ltd. New Delhi (1973).
14. Subbiah, B.V. and Asija, G.L., A rapid procedure for the estimation of available nitrogen in soils. *Current Science* **25:** 259-260 (1956).
15. Olsen, S.R., C.V., Watanabe, F.S. and Dean, L.A., Estimation of available phosphorus in Soil by extraction with sodium bicarbonate.*U. S. Department of Agricultural Circular*, 939 (1954).
16. Gomez, K.A. and Gomez, A.A., Statistical procedures for agricultural research. John Viley and Sons, New York 304-308 (1984).
17. Johnson, C.E., Ruiz-Mendez, J.J. and Lawrence., Forest soil chemistry and terrain attributes in a cat skills watershed. *Soil Sci. Soc. Amer. J*. **64:** 1804-1814 (2000).

18. Hutchins, R.L., Hill, J.D. and White, E.H., The influence of soil and microclimate on vegetation of forested slopes in eastern Kentucky. *Soil Science* **121:** 234-241 (1976).
19. Dahlgren, R.A., Singer, M.J., Huang, X., Oak tree and grazing impacts on soil properties and nutrients in California oak woodland. *Biogeochem* **39:** 45-64 (1997).
20. Sardinero, S., Classification and ordination of plant communities along an altitudinal gradient on the Presidential Range, New Hampshire, USA. *Plant Ecology* **148**: 81-103 (2000).
21. Takyu, M., Aiba, S. and Kitayama, K., Changes in biomass, productivity and decomposition along topographical gradients under different geological conditions in tropical lower montane forests on Mount Kinabalu, Borneo. *Oecologia* **134:** 397-404 (2003).
22. Hicks, R.R. and Frank, P.S., Relationship of aspect to soil nutrients, species importance and biomass in a forested watershed in West-Virginia. *Forest Ecology and Management* **8:** 281-291 (1984).
23. Liski, J. and Westman, C.J., Carbon storage in forest soils of Finland. *Biogeochem*. **36:** 239-260 (1997).
24. Mendoza-Vega, J., The influence of land use/land cover and soil types on amounts of soil organic carbon and soil characteristics. Doctoral thesis. Swedish University of Agricultural Sciences, Uppsala, Sweden (2002).
25. Turner, M.G., Landscape ecology: The effect of pattern and process. *Annual Review of Ecology and Systematics* **20:** 171-197 (1989).
26. Leskiw, L.A., Land capability classification for forest ecosystem in the oil stands region. Alberia Environmental Protection, Edmonton, deHann S. Humus, its formation, its relation with the mineral part of the soil and its significance for soil productivity. **In**: *Organic matter studies, International Atomic Energy Agency*, Vienna, 1977, **1:** 21-30 (1998).
27. de Hann S. H., 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 (1997).
28. Khera, N., Kumar, A., Ram, J. and Tewari, A., Plant biodiversity assessment in relation to disturbance in mid elevation forest of central Himalaya, India. *Tropical Ecology* **42:** 83-95 (2001).
29. Dhar, O., Jha, M.N. and Suri, S., Soils of the Shankaracharya hill Forest Research Range Natural Resources of Jammu & Kashmir. A case study published by Altaf Ahmad Bazaz for valley Book House, Srinagar (J&K) pp. 43-63 (2001).
30. Bisht, S. and Lodhiyal, L.S., Various aspects of soil and tree layer vegetation analysis in reserve forests of Kumaon in central Himalaya. *India Journal of Forestry* **28(1):** 37-50 (2005).
31. Sariyildiz, T., Anderson, J.M. and Kucku, M., Effects of tree species and topography on soil chemistry, litter quality and decomposition in northeast Turkey.*Soil Biol. Biochem.* **37:** 1695-1706 (2005).
32. Xu, J.M., Tang, C. and Chen, Z.L., The role of plant residues in pH change of acid soils differing in initial pH. *Soil Biol. Biochem.* **38:** 709-719 (2006).
33. Tegene, B., Characteristics and classification of soils of Gora Daget Forest, South Wollo highlands, Ethiopia. SINET: *Ethiopian Journal of Science* **23(1):** 35- 51 (2000).
34. Brune, D.E. and Doolittle, J., Locating lagoon with radar and electromagnetic survey. *Geology Water Science* **16:** 195-207 (1990).
35. Moieza, A. B., G.A. Bhat, Idrees, Y. D. and Mudasir A., Physico-chemical characteristics of the grassland soils of Yusmarg Hill Resort (Kashmir, India). *Ecologia Balkanica* **4(1):** 31-38 (2012).
36. Kaushal, R., Bhandari, A.R., Sharma, J.C. and Tripathi, D., Soil fertility status under natural deodar (*Cedrus deodara*) forest ecosystem of north-west Himalayas.

Indian Journal of Forestry **20(2):** 105-111 (1997).
37. Sheikh, A.M., Studies on micro-nutrient cation in paddy growing soils of district Kupwara. M.Sc. Thesis submitted to Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar, pp. 59-65 (2006).
38. Schimel, J.P. and Bennett, J., Nitrogen mineralization: challenges of a changing paradigm. *Ecology* **85(3):** 591-602 (2004).
39. Reich, P.B., Grigal, D.F. and Aber, J.D., Nitrogen mineralization and productivity in 50 hardwood and conifer stands on diverse soils. *Ecology* **78(2):** 335-347 (1997).
40. Vitousek, P.M. and Howarth, R.W., Nitrogen limitation on land and in the sea: how can it occur? *Biogeochemistry* **13(2):** 87-115 (1991).
41. Cheng, B.R., Xu, G.S., Gen, X.Y. and Zhang, G.L., The nutrient cycling in the Korean pine-broad-leaved forest of the Changbai mountains. *Actapedologica Sinca*, **24(2):** 160-169 (1987).
42. Chen, C.R., Condron, L.M., Davis, M.R. and Sherlock, R.R., Effects of afforestation on phosphorus dynamics and biological properties in a New Zealand Grassland soils. *Plant and Soil*, **220:** 151-163 (2000).
43. Ganuza, A. and Almendros, G., Organic carbon storage in soils of representative ecosystems in the Basque country (Northern Spain) as related to climate, vegetation type and edaphic variables. *Biol. Fert. Soils* **37:** 154-162 (2003).
44. Sharma, U. and Bhandari, A.R., Survey of nutrient status of apple orchards in Himachal Pradesh. *Indian Journal of Horticulture* **49(3):** 234-241 (1992).
45. Johannessen, C., Higher phosphate values in soils under trees than in soils under grass. *Ecology* **39:** 373-374 (1958).
46. Murphy, H.P., The fertility status of some soils of Ethiopia. College of Agriculture, Jimma (1958).
47. Soromessa, T., Teketay, D. and Demissew, S., Ecological study of the vegetation in Gamo Gofa zone, Southern Ethiopia. *Tropical Ecology* **45:** 209-221 (2004).
48. Mandal, A.K., Nath, S., Gupta, S.K. and Banerjee, S.K., Characteristics and nutritional status of soils of middle hill and upper hill forest of the eastern Himalayas. *Journal of Indian Society of Soil Science* **38(1):** 100-106 (1990).
49. Smeck, M.E., Phosphorus dynamics in soils and landscapes. *Geoderma* **35:** 185-199 (1985).
50. Sood, R.D. and Kanwar, B.S., Distribution of organic and total phosphorous in some soil profiles of different agro-climatic zone of Himachal Paradesh. *Journal of Indian Society Soil Science* **34:** 404-406 (1986).
51. Stewart, J.W.B. and Tiessen, H., Dynamics of soil organic phosphorus. *Biogeochem* **4:** 41-60 (1987).
52. Dwivedi, S.K., Sharma, V.D. and Bhardwaj, V., Status of available nutrients in soils of cold arid region of Ladakh. *Journal of the Indian Society of Soil Science* **53(3):** 421-423 (2005).
53. Gupta, R.D., Studies on certain physico-chemical and microbiological properties of Ranbir Singh Pora soils of Jammu and Kashmir. *Technology* **11(2-3):** 227-230 (1974).
54. Singh, A.K. and Totey, N.G., Physico chemical properties of Bhata Soils of Raipur. *Journal of Tropical Forestry* **1:** 61-68 (1985).
55. Kunhikannan, C., R.K. Verma, R.J. Verma, P.K. Khatri and Totey, N.G., Ground flora, soil micro-flora and fauna diversity under plantation ecosystem on bhata land of Bilaspur, Madhya Pradesh. *Environ. Ecol.* **16:** 539-548 (1998).
56. Hillal, A., Plant diversity and regeneration status in Kandi range of Kamraj Forrest Division of Kashmir. Ph.D thesis submitted to Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar (2014).
57. Brady, N.C. The nature and properties of soil, 10th edn. Prentice Hall, New Delhi (1996).

58. Rao, A.P.V.P., Naidu, M.V.S., Ramavatharam, N. and Rao, G.R., Characterization, classification and evaluation of soils of different land forms in Ramachandrapuram Mandal of Chitpor district in Andhra Pradesh for sustainable land use planning. *Journal of the India Society of Soil Science* **50(1):** 23-33 (2008).
59. Gairola, S., Sharma, C.M. and Ghildiyal, S.K., 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 (2012).
60. Jha, M.N., Gupta, M.K. and Dimri, B.M., Impact of changing natural forest cover and site conditions on the soil resources in western Himalayan region. **In**: *Natural Resources of Western Himalaya* [Ed. Pandit Ashok K.], Valley Book House, Srinagar-190006, India. Department of Environmental Science, University of Kashmir, pp. 23-42 (2002).
61. Dimri, B.M., Jha, M.N. and Gupta, M.K., Soil potassium changes at different altitudes and seasons in upper Yamuna forest of Garhwal Himalayas. *Indian Forestry*, pp. 609-614 (2006).
62. Dangwal, L.R., Tajinder, S., Amandeep, S. and Antima, S., Plant diversity assessment in relation to disturbances in subtropical Chir pine forest of the western Himalaya of District Rajouri, J&K, India. *International Journal of Plant, Animal and Environmental Sciences* **2(2):** 206-213 (2012).