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Studies on soil physico-chemical properties at different locations and elevations of *Quercus leucotrichophora* forests

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Abstract
The present investigation entitled "Studies on soil physico-chemical properties at different locations and elevations of *Quercus leucotrichophora* forests" was carried out during the year 2018-19 to know the soil physico-chemical properties in Chail forests of district Solan, Kufri forests of district Shimla, Sarahan and Churdhar forests in Sirmaur district of Himachal Pradesh with three elevations i.e., E1 (<1500 m), E2 (1500-1800 m) and E3 (>1800 m) in each. Composite samples were collected from 15 cm depth for soil and biochemical analysis. Among locations, the thickness of forest litter layer, microbial activity, available K and P content showed a decreasing trend as: Kufri forest soils > Chail forest soils > Churdhar forest soils > Sarahan forest soils. Among elevations, the thickness of forest litter layer and Organic C followed the trend as: E3 > E2 > E1 whereas, soil pH, bulk density, available N, P and K content fell as E1 > E2 > E3. Maximum available N, soil EC and Bulk density was found in Chail forest. Kufri forest soils have shown best results for all soil parameters.

Keywords: Soil physico-chemical properties, elevation, microbial activity etc.

Introduction

Forests are one of the Earth's greatest treasures – rich habitats teeming with animal and plant species, herbs, fungi, microorganisms and soils. Forests occupy a paramount importance in ecology which needs to be quantified for their variability to describe ecosystems, the functional attributes of which are enhanced by the occurrence of varied edaphic, topographic and meteorological features. A complex of site factors visually vegetation type, slope, aspect, edaphic factors, and altitude (Sharma *et al.* 2009, Sharma *et al.* 2010a; Gairola *et al.* 2011a) [37, 38, 14] determines the community composition, structure, and distribution pattern of diversity in mountain vegetation (Kessler 2001; Schmidt *et al.* 2006) [19, 35]. Forest soils influence the composition of the forest stand and ground cover, rate of tree growth, vigour of natural reproduction and other silvicultural important factors (Bhatnagar 1968) [5]. Physiochemical characteristics of forest soils vary in space and time due to variations in topography, climate, physical weathering processes, vegetation cover and microbial activities (Paudel and Sah 2003) [33]. Plant tissues (from above ground litter and below ground root detritus) are the main source of soil organic matter, which influence physico-chemical characteristics of soils such as pH, water holding capacity, texture and nutrient availability (Kumar *et al.* 2004) [21, 22]. It is important to study the physico-chemical and biological properties of these forests because the soils in the forests determine the growth and quality of vegetation. In the present study, soils from different locations and elevations were collected from 15 cm depth and analysed the variation among the soils in different locations and elevations by which the vegetation growth can be estimated.

Material and methods

The present investigation entitled "Studies on soil physico-chemical properties at different locations and elevations of *Quercus leucotrichophora* forests" was carried out during the year 2018-19 to know the soil physico-chemical properties in Chail forests of district Solan, Kufri forests of district Shimla, Sarahan and Churdhar forests in Sirmaur district of Himachal

Pradesh with three elevations i.e., E1 (<1500 m), E2 (1500-1800 m) and E3 (>1800 m) in each. For soil studies, composite samples from 0-15 cm depth were collected from each site and at each elevation. Samples was collected, sieved and dried Samples were air dried in shade, grinded in wooden pestle, passed through 2 mm sieve and stored in cloth bags for further laboratory analysis. Keeping in mind the life of microorganisms, microbial activity was observed earlier within a week of collection.

The details of methods employed for estimating different soil parameters are as follow:

Sr. No.	Particular Method	Method employed
1.	Bulk density (g cm^{-3})	Specific gravity method (Singh 1980).
2.	Organic carbon (%)	Walkley and Black method (1954) [8].
3.	Thickness of forest litter layer (cm)	With the help of scale and knife.
4.	Organic matter (%)	% OM = 1.724 * OC
5.	Available nitrogen (kg ha^{-1})	Alkaline potassium permanganate method of Subbiah and Asija (1956).
6.	Available phosphorous (kg ha^{-1})	Olsen *et al.* (1954).
7.	Available potassium (kg ha^{-1})	Flame photometer method of Merwin and Peach (1951).
8.	Soil Ph	(1:2.5) Soil: water suspension, with the help of digital pH meter (Jackson, 1973).
9.	Soil EC (dS m^{-1})	(1:2.5) Soil: water suspension, with the help of digital conductivity bridge (Jackson 1973).
10.	Microbial activity (μg CO_2 gm^{-1} soil).	CO_2 evolution method (Parmer and Schmidt, 1964)

Results and Discussion

The soil samples were tested in the laboratory of Department of Silviculture and agroforestry and the results are analyzed. Soil physico-chemical properties *viz.*, bulk density (g cm^{-3}), organic carbon (%), pH, EC (dS m^{-1}) available macro-nutrients N, P, K (kg /ha) and microbial activity (mg CO_2 g^{-1}soil) as observed in 0-15 cm soil layer under different forest locations and elevations have been depicted in the following sections.

A perusal of data in table 1-3 revealed that mean pH, EC, bulk density (g/cm^3), available Nitrogen (kg/ha), P (Kg/ha), K (Kg/ha) as well as microbial activity of soils in *Q. leucotrichophora* forest decreased along the elevation from E1 to E3. While on the contrary OC (%) and OM (%) and thickness of forest litter layer improved with increasing altitude.

Soil pH

Soil pH showed a significant effect due to locations and elevations only. The highest mean pH value in different locations (6.19) was noted for Chail forest whereas the lowest pH was recorded for Kufri and Sarahan forests (5.88). The pH under different forest elevations followed the trend E1 (6.44) > E2 (6.05) > E3 (5.46). On the contrary, interaction effect on different forest locations and elevations was found to be non-significant.

It has been observed from the data that pH level in all forest types was acidic to neutral and could be ascribed to accumulation and decomposition of organic matter and release of organic acids during the decomposition of leaf litter resulting to more acidity in soil. Pandey *et al.* 2018 analysed pH value of three forest types (Oak, Pine, Sal) at different soil depths of Betalghat region of Kumaun Himalaya and their pH values were 5.57±0.04 to 5.66±0.03 for Ban oak, 6.66±0.05 to 6.80±0.05 for Pine and 6.18±3.31 to 6.31±2.55 for Sal forests. The difference in soil pH between different forest locations may also be attributed to variation in parent material and rainfall.

Soil EC (dS m^{-1})

The results indicate that the effect of different forest locations and elevations was significant. Maximum soil EC (0.20 dS m^{-1}) was recorded under Chail forest which proved significantly higher to all other forests. The effect of elevations showed significant reduction in soil EC from 0.20 dS m^{-1} to 0.18 dS m^{-1} with increasing elevation. The interaction effect was non – significant. The variations in pH across forest locations and elevations can be assigned to change in parent material rainfall as well as content of Organic matter.

Bulk density (g cm^{-3})

It is evident from the Table 1 that bulk density was maximum in Chail forest (1.33 g cm^{-3}) which was found to be significantly better amongst all. It was followed by Kufri forest (1.17 g cm^{-3}), Churdhar forest (1.13 g cm^{-3}) and the minimum value for bulk density (1.12 g cm^{-3}) was recorded under Sarahan forest.

Irrespective of forest locations, the bulk density tended to decrease from E1 to E3. The interaction between forest locations and elevation was found to be significant with highest value (1.43 g cm^{-3}) at E1 of Chail forests (1.33 g cm^{-3}) followed by E2 of Chail forests and minimum (1.01 g cm^{-3}) at E3 of Sarahan forests. Thus the findings clearly indicated that the value of bulk density varies with forest locations and elevations.

Soil organic carbon (%)

Soil organic carbon (%) varied significantly under different forest and their elevations. Maximum value (3.55%) was depicted under Kufri forest followed by Churdhar forests (3.30%), Sarahan forests (3.05%) and Chail forests (2.76%). Soil organic carbon varied significantly with elevations where E_3 recorded maximum value of 3.68 followed by E2 (3.37) and least at E1 elevation (2.44). The interaction effect between forest sites and elevations was found to be significant with highest value (4.12) in Kufri forests at E2 elevation which was statistically alike to E3 of Kufri (4.05), E3 of Sarahan (4.00), E2 elevation of Churdhar (3.92) and E1 (3.92) of Sarahan forests while the least value (2.39) was recorded at E1 elevation of Chail forests. The differences across forest locations and elevations are perhaps due to variations in flora, litter fall, quantum and OM decomposition rate.

Table 1: Effect of locations and elevations on soil parameters of ban Oak forests

	pH of soil				EC (dS m^{-1}) of soil				Bulk Density (g/cm^3)				OC (%)			
Elevations(E) / Locations(L)	**E1 <1500 m**	**E2 1500-1800m**	**E3 >1800 M**	**Mean**	**E1 <1500 M**	**E2 1500-1800m**	**E3 >1800 m**	**Mean**	**E1 <1500 m**	**E2 1500-1800m**	**E3 >1800 M**	**Mean**	**E1 <1500 m**	**E2 1500-1800m**	**E3 >1800 m**	**Mean**
Chail Forests	6.70	6.27	5.60	6.19	0.22	0.21	0.18	0.20	1.43	1.33	1.21	1.33	2.39	2.71	3.17	2.76
Kufri Forests	6.37	6.00	5.27	5.88	0.20	0.18	0.19	0.19	1.26	1.08	1.18	1.17	2.48	4.12	4.05	3.55
Churdhar forests	6.43	5.90	5.63	5.99	0.20	0.19	0.19	0.19	1.12	1.06	1.20	1.13	2.47	3.92	3.51	3.30
Sarahan forests	6.27	6.03	5.33	5.88	0.19	0.17	0.17	0.18	1.17	1.16	1.01	1.12	2.41	2.74	4.00	3.05
Mean B	6.44	6.05	5.46		0.20	0.19	0.18		1.25	1.16	1.15		2.44	3.37	3.68	

$CD_{0.05}$
(L) 0.16 0.01 0.06 0.17
(E) 0.14 0.01 0.05 0.15
(L X E) NS NS 0.11 0.30

Thickness of forest litter layer (cm)
The thickness of forest litter layer varied significantly with elevations. The thickness of forest litter layer at different forest elevations followed the trend E3 (4.29 cm) > E2 (3.55 cm) > E1 (2.87 cm). Kufri forests displayed significantly maximum thickness of forest litter layer (3.71 cm) however least value was recorded in Sarahan forest soils (3.49 cm). The thickness of forest litter layer was recorded non-significant for elevations and (L x E) interaction, respectively.

Available Nitrogen (kg /ha)
Available nitrogen of soil was significantly influenced due to forest loctions and elevations. Maximum available nitrogen (349.06 kg /ha) was recorded under Chail followed by Kufri Ban Oak forest (326.68 kg /ha), Churdhar forest (325.04 kg /ha) and Sarahan (303.05 kg /ha). Among elevations, E1 showed the maximum available nitrogen (363.64 kg /ha) followed by E2 elevation as compared to E1 (332.54 kg /ha) and E3 (281.69 kg /ha). The interaction effect between different forest locations and elevations was found to be significant with highest value (369.78 kg /ha) in Chail forest at E1 elevation which was ststistically alike with E1 elevation of Kufri forests (359.97 kg /ha), Churdhar forests (361.10 kg /ha) and Sarahan forests (363.73 kg /ha) and E2 elevation of Kufri forests (357.61 kg/ha) however minimum (257.05 kg /ha) was at E3 elevation of Sarahan forests.

Available Phosphorus (kg /ha)
Significant differences were observed in available phosphorus content under different forest locations (Table 2). Available phosphorus content was recorded maximum (142.68 kg /ha) in Kufri forests followed by Chail forests (120.22 kg /ha), Churdhar forests (117.95 kg /ha) whereas Sarahan forest (80.58 kg /ha) recorded lowest values. The mean elevations values were noted maximum at E1 (139.49 kg /ha) followed by E2 elevation (119.79 kg /ha) and the minimum available phosphorus (86.78 kg /ha) was recorded at E3 elevation. Among locations and elevations, the maximum value (166.13 kg /ha) was observed at E_1 elevation of Kufri forest followed by E1 (151.07 kg /ha) of Churdhar forets and minimum at E3 elevation (61.37 kg /ha) of Sarahan forests.

Table 2: Effect of locations and elevations on soil parameters of *ban Oak forests*

Locations (l)	Thickness of forest litter layer (cm)				N (Kg/ha)				P (Kg/ha)				K (Kg/ha)			
Elevations(E) / Locations(L)	**E1 <1500m**	**E2 1500-1800m**	**E3 >1800m**	**Mean**	**E1 <1500m**	**E2 1500-1800m**	**E3 >1800m**	**Mean**	**E1 <1500m**	**E2 1500 1800m**	**E3 >1800m**	**Mean**	**E1 <1500m**	**E2 1500-1800m**	**E3 >1800m**	**Mean**
Chail forests	2.87	3.67	4.20	3.58	369.78	349.13	328.27	349.06	140.40	130.88	89.37	120.22	389.08	331.47	253.23	324.59
Kufri forests	3.07	3.57	4.50	3.71	359.97	357.61	262.47	326.68	166.13	138.25	123.65	142.68	408.09	357.43	329.77	365.10
Churdhar forests	2.93	3.50	4.07	3.50	361.10	335.05	278.97	325.04	151.07	130.03	72.74	117.95	373.12	312.53	235.81	307.15
Sarahan forests	2.60	3.47	4.40	3.49	363.73	288.37	257.05	303.05	100.38	79.98	61.37	80.58	388.92	331.95	195.53	305.47
Mean E	2.87	3.55	4.29		363.64	332.54	281.69		139.49	119.79	86.78		389.80	333.35	253.59	

$CD_{0.05}$
(L) NS 8.62 5.37 23.61
(E) 0.19 7.46 4.65 20.45
(L X E) NS 14.92 9.30 40.90

Available Potassium (kg /ha)
Available potassium fluctuated significantly under different forest locations and elevations (Table 2). The maximum available potassium content (365.10 kg /ha) was recorded under Kufri forest which was followed by Chail forest (324.59 kg /ha), Churdhar forest (307.15 kg /ha) and Sarahan forest (305.47 kg /ha). Among elevations available potassium tended to decline significantly from E1 to E3. Higher available phosphorus content was 389.80 kg /ha at E1, 333.35 kg /ha at E2 and 253.59 kg /ha at E3 elevation. Interaction between different forest locations and elevations were found to be significant with highest value at E1 of Kufri forest (435.74 kg /ha) and lowest at E3 of Sarahan forests (195.53 kg /ha).

Organic matter (%)
A scrutiny of data presented in (Table 3) reveals that Organic matter content varied significantly under different forest locations and elevations. Kufri forest displayed significantly higher Organic matter (6.11) than all other forest locations under investigation whereas least value was recorded in Chail forest soils (4.74). Maximum organic matter (6.33) was recorded at E3 followed by E2 (5.80) and lowest at E1 (4.19). The interaction effect was significant on orgnic matter where it was significantly higher at E_2 elevation (7.09) of Kufri forests which was at par with (6.97) E3 elevation of Kufri forests, E2 elevation of churdhar forests (6.75) and E3 elevation of Sarahan forest (6.87) while the least value was found in Chail forests at E1 elevation (4.12).

Microbial activity (mg CO_2 g^{-1}soil)

Analysis of data on microbial activity of soil in *Q. leucotrichophora* forests is presented in Table 70. The results indicate that different forest locations exercised significant variation in values. Mean microbial activity of soil under different forest locations was in the order: Kufri forests (22.51 mg CO_2 g^{-1}soil) > Chail forests (21.44 mg CO_2 g^{-1}soil) > Churdhar forests (19.67 mg CO_2 g^{-1}soil) > Sarahan forests (18.08 mg CO_2 g^{-1}soil) suggesting that Kufri forests support good microbial growth and distribution as compared to other three forests. In regard to elevation, the sequence was: E1 (21.90 mg CO_2 g^{-1}soil) > E2 (20.86 mg CO_2 g^{-1}soil) > E3 (18.52 mg CO_2 g^{-1}soil) suggesting a decreasing trend with increasing altitude.

The effect of interaction locations x elevations was found to be significant with highest value (24.60 mg CO_2 g^{-1}soil) at E1 of Kufri, followed by E2 of Kufri forests (23.30 mg CO_2 g^{-1}soil) and lowest (15.90 mg CO_2 g^{-1}soil) at E3 of Sarahan forests.

Table 3: Effect of elevation and locations on microbial activity (mg CO_2 g^{-1}soil) of *Quercus leucotrichophora* forests

Elevations(E) / Locations(L)	OM (%)				Microbial Activity (mg CO_2 g^{-1}soil)			
	E1	E2	E3	Mean L	E1	E2	E3	Mean L
	<1500m	1500-1800m	>1800m		<1500m	1500-1800m	>1800m	
Chail forests	4.12	4.66	5.45	4.74	21.40	21.40	21.53	21.44
Kufri forests	4.27	7.09	6.97	6.11	24.60	23.30	19.63	22.51
Churdhar forests	4.25	6.75	6.03	5.68	21.53	20.47	17.00	19.67
Sarahan forests	4.14	4.71	6.87	5.24	20.08	18.27	15.90	18.08
Mean E	4.19	5.80	6.33		21.90	20.86	18.52	

$CD_{0.05}$

(L)	0.29	0.69
(E)	0.26	0.60
(L X E)	0.51	1.20

Himalayan forests play an important role in tempering the inclemency of the climate, in cooling and purifying the atmosphere, in protecting the soil, in holding the hill slopes in position, and in buffering up huge reserves of soil nutrients. The Himalaya has vast variations in the flora and fauna, climate, topography, parent material and soil conditions, which form a very complex ecosystem. The variation in bulk density under different oak forest locations can be owed to their varying rate of leaf litter decomposition and deposition. The bulk density of the soil reflects the level of compaction and amount of pore space in the soil. Devi (2011) [11] recorded higher bulk density (2.96 g/ cm^3) under Oak and Pine forest. Bulk density in natural ecosystems could be altered due to fine root mat formation with microbial and arthropod activities that subsequently lead to aeration of the soil (Jobbagy and Jackson 2000) [17]. Bulk density was dependent on available macronutrients and micronutrients in the soil. It decreases as the total macronutrient or total micronutrient contents in the soil increases. Results of bulk density showed that soil bulk density differed significantly among forest locations and elevations. Yimer *et al.* (2006) [48] opined that soil bulk density can be quite variable in different forest types and changes in bulk density in the forest floor can alter SOC stocks. Bulk density is also variable with soil texture; sandy soils have higher bulk density than fine textured clayey soils.

Soil bulk density in the range of 0.89-1.44 g/cm^3 in different vegetation systems of Himalaya has been reported by many workers (Sanneh 2007; Bhardwaj *et al.* 2013; Mahato 2013; Gupta *et al.* 2015; Bhutia 2017; Yadav 2017) [34, 4, 26, 16, 6, 7]. Thadani and Ashton (1995) [44] reported soil organic carbon values ranging from 1.88 to 4.00% in Kumaun Himalaya for *Q. leucotrichophora* forest. Semwal (2006) [36] reported organic carbon values between 0.87 and 1.01% in Pauri Garhwal for *Q. leucotrichophora* forest. Kumar *et al.* (2004) [21, 22] recorded soil organic carbon values ranging from 1.30 to 1.90% in Tehri Garhwal for *Q. leucotrichophora* forest.

Soil pH influences the availability of plant nutrients and it is a good indicator of forest fertility (Black 1968) [8]. In the present study pH values of soil ranged between 5.27 and 6.70 (table 1). Sharma *et al.* (2010) reported pH values ranging from 5.80 to 6.70 in Pauri Garhwal for *Q. semecarpifolia* forest. Khera *et al.* (2001) [20] reported pH values between 7.20 and 8.0 in a mixed broadleaved forest of Kumaun Himalaya. Semwal (2006) [36] reported pH values ranging from5.90 to 6.30 in Pauri Garhwal for *Q. leucotrichophora* forest. Kumar *et al.* (2004) [21, 22] reported pH values ranging from 5.40 to 5.70 for *Q. leucotrichophora* forest.

Usman *et al.* (2000) [45] reported pH value of 6.40 for *Q. leucotrichophora* forest in Kumaun Himalaya. These findings on soil organic carbon and soil pH are close to the findings of the present study. The soil pH for all forest types was reported slightly acidic to neutral and in a few instances it was more acidic. Sheikh and Kumar (2010) [41] reported acidic nature of soil in oak forest. Soil pH variations across forest locations and elevations may be attributed to difference in parent material, rainfall as amount and type of forest litter.

Soil organic matter is responsible for building a major portion of the soil organic carbon pool, which regulates the soil properties *viz.*, physical, chemical and biological properties. The higher soil organic carbon (SOC) in Oak forest and Oak mixed forest could be due to higher inputs of litter which enriches SOC (Anuradha 2014) [2]. Soils holding highest carbon percentage in both the soil layers may be attributed to high addition of leaf litter and slow decomposition rates of organic residues under low light penetration to the soil surface (Dimri *et al.* 1997) [12]. However, low litter production in addition with high wind velocity and lack of overstorey vegetation results in faster decomposition of litter may be the reason for lower values of soil organic carbon.

Forests soil influences the composition of forest stand, ground cover, rate of tree growth and other factors. Physico-chemical characteristics of forest soils vary in space and time due to variations in topography, climate, physical weathering processes, vegetation cover, microbial activities, and several other biotic and abiotic variables. The physical properties of soil are generally influenced by vegetation (Sharma *et al.* 2010).

Gosain *et al.* (2015) in their study on eighteen forest stands dominated by *Pinus roxburghii* and *Quercus leucotrichophora* forests in Almora, Central Himalaya also reported that soil organic matter was highest in Oak forests. Differences in carbon stocks in top soil in different ecosystems reflect the differences in the quantity and quality of the litter input, litter carbon decomposition, and litter biomass carbon (Mo *et al.* 2002) [27]. Bhutia (2017) [6, 7] reported SOC in soils of different vegetation systems of north-west Himalaya in the range of 1.68 to 2.10 . Many workers have reported comparable soil organic carbon in similar vegetation in north-west Himalaya (Devi *et al.* 2013; Kumar *et al.* 2013; Singh and Rawat 2013; Kanime *et al.* 2013; Arora *et al.* 2014; Negi *et al.* 2015) [10, 23, 42, 18, 3, 28].

The availability of soil nutrients depends to a larger extent on the amount and properties of organic matter. Availability of soil nutrients (N, P, K, Cu, Fe, Mn and Zn) could be due to differential leaf litter deposition and decomposition rates, nodulation behaviour, availability of water and nutrient status of the site. Soil microbial biomass indicates the living portion of soil organic matter and is mainly responsible for the conversion of complex into available form of nutrients. The soil microbial status is emphasized by the microbial biomass and activity (Altieri 1999) [1]. The decrease in microbial activity with an increase in elevation in this present study is in accordance with Pandey and Palni (2007) [31]. Bryant *et al.* (2008) [9] also reported that bacterial taxon richness and phylogenetic diversity decreased monotonically from the lowest to the highest elevations. Soil microbial communities and extracellular enzymes play critical roles in organic matter decomposition and nutrient cycling of carbon, nitrogen, sulfur, and phosphorus, and both microbial communities and enzyme activity can change quickly in response to changes in the environment (Liu *et al.* 2018 and Parvin *et al.* 2018) [25, 32]. Therefore, changes in microbial communities or enzyme activities can influence soil biochemical processes and, consequently, soil fertility and plant growth.

The microbial population in this study decreased with an increase in elevation: E1 (21.90 mg CO_2 g^{-1}soil) > E2 (20.86 mg CO_2 g^{-1}soil) > E3 (18.52 mg CO_2 g^{-1}soil). As elevation increases, the soil is under cold and harsh conditions and the tree root exudates tend to become more acidic, and exert a negative influence on the microbial population as reported in forests of temperate and sub alpines areas which might be the cause of decrease in bacteria and actinomycetes count as observed in the present studies. Lejon *et al.* (2005) [24]; Snajdr *et al.* (2008) [43] found that Oak forest harboured highest microbial population. Zhang *et al.* (2013) [49] concluded that soil pH and C/N ratio were the most important drivers for microbial community structure.

Many other studies also reported a decreasing microbial activity with an increasing elevation [Vare *et al.* 1997] [46] (in northern Finland); Niklinska and Klimek (2007) [29] (in Polish Carpathians)]. The significant decrease in mean winter soil temperatures with increasing elevation can strongly reduce winter soil microbial activity at high altitudes compared with the least elevated sites (Drotz *et al.* 2010; Nikrad *et al.* 2016) [13, 30].

Conclusion

It can be concluded from the present study that mean pH, EC, bulk density (g/cm^3), available Nitrogen (kg/ha), P (Kg/ha), K (Kg/ha) as well as microbial activity of soils in *Q. leucotrichophora* forest decreased along the elevation from E1 to E3. While on the contrary OC (%) and OM (%) and thickness of forest litter layer improved with increasing altitude. Among locations, Kufri forests soils have shown best results for all soil parameters followed by Chail forests soils and least in soils of Sarahan forest. By this, best growth can be expected in Kufri ban oak forests than other forests locations.

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