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FOLIAR AND SOIL NUTRIENT DISTRIBUTION IN CONIFER FORESTS OF MOIST TEMPERATE AREAS OF HIMALAYAN AND HINDUKUSH REGION OF PAKISTAN: A MULTIVARIATE APPROACH

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Abstract

Foliar nutrient concentration for the dominant conifer species (*Pinus wallichiana*, *Abies pindrow* and *Cedrus deodara*) of moist temperate areas of Himalayan and Hindukush region of Pakistan was evaluated. Soils samples and conifer needles were collected from forests at 41 sites in the study area. Six macro and seven micronutrients were analyzed for both soils and tissue. The mean nutrient levels and variability for each species was evaluated. The gradients in tissue nutrients were exposed by means of correspondence analysis (CA) and canonical correspondence (CCA), for each species. The first CA axis of *Pinus wallichiana* data was significantly correlated with soil N, P and K ($p<0.05$). The second CA axis was correlated with P, B and Ca, while the third was correlated with K and Mg ($p<0.05$). The first CA axis of *Abies pindrow* was not correlated with any soil nutrients, but the second axis showed correlation with soil Ca ($p<0.05$) and the third with S, Fe and N (p at the most 0.05). *Cedrus deodara* CA axes were not markedly correlated with soil nutrients. Canonical correspondence analysis (CCA) exposed the correlation structure between tissue nutrient and soil nutrient matrices with similar results thereby supporting the results of CA.

Key words: Foliar and soil nutrients, Conifer forest, Moist temperate region, CCA, CA, Cluster analysis.

Introduction

The evaluation of nutrients of conifer species and their corresponding sites of moist temperate areas of Himalayan and Hindukush region of Pakistan is urgently required as no information is yet available on such important ecological and functional parameters. Such information is needed not only from the standpoint of forest management and decision making but is also invaluable for health concerns and designing operational fertilization programme (Moore *et al.,* 2004). In Pakistan foresters, silviculturalist and ecologists are trying to pay attention to evaluate the nutrient status of selected forest tree species and that of the associated soils. In developed countries one can find the critical values of macro and micro elements for particular plant species with relative ease, but no such values are ascertained for the tree species in Pakistan. A variety of techniques have been developed to assay forest nutrient status of which probably the most effective involves sampling and analysis of foliage of the tree species (Brockley & Sherman, 1994). Forest soils influence the composition of forest stands and ground cover, rate of tree growth, vigor of natural reproduction and other silviculturally important attributes (Moore *et al.,* 2004). Physico-chemical characteristics of forest soils vary in space and time because of variation in topography, climate, weathering processes, vegetation cover, microbial activity and also due to several other biotic and abiotic factors (Paudel & Sah, 2003). Vegetation itself plays an important role in soil formation, by way of breaking the larger particles into finer ones, building up the soil structure, increasing soil depth, elevating the organic matter content and so on (Chapman & Reiss, 1992). Thus, the nutrients are returned to the soil and exert a strong feedback on the ecosystem processes (Pastor *et al.,* 1984).

Plant tissues (above and below ground litter) are the main source of soil organic matter, which influences the physico-chemical characteristics of soil such as, texture, water holding capacity, pH and nutrient availability (Johnston, 1986). The vegetation influences the physico-chemical properties of the soil largely by improving the soil structure, infiltration rate, water retaining capacity, hydraulic conductivity and aeration (Ilorkar & Totey, 2001).

Nutrient supply varies widely among ecosystems (Binkly & Vitousek, 1989), resulting in differences in plant community structure and its production. The nature of soil profile, pH and nutrient cycling between the soils and trees are the important dimensions to determine the site quality (Moore *et al.,* 2004; Sheikh & Kumar, 2010). To relate vegetation to environmental factors, it is imperative to examine the nutrition status of soils to determine the nutrient regime prevailing in the area. The plant nutrient analysis helps in the diagnosis of nutrient deficiencies if any, and consequently the prediction of fertilizer or nutrient requirements of the associated soils. It is also shown that the nutrient content varies with season (Bates, 1971). The diagnosis and recommendation of integrated system (DRIS) (Walworth & Sumner, 1987) and compositional nutrients diagnosis (CND) emphasized by Parent *et al.,* (2009). When growth requirements other than nutrients are adequate, tissue contents below a critical concentration are associated with deficiencies of that element resulting in less than maximum yield. Tissue nutrient contents above a critical concentration have no further effect on yields and for this reason are referred to as luxury consumption. The importance of nutrients in the functioning of ecosystems has been increasingly recognized (Bates, 1971; Duarte, 1990).

Studies dealing with tissue nutrient content in Pakistan are scarce. The only notable study is that of Ahmed *et al.,* (1990) who investigated the variation in the levels of P, N, K, Mn and Zn in the tissue of five different phenotypes of juniper tree *Juniperus excelsa.* However, no extensive investigation has yet been conducted to evaluate the status of nutrients in soils and dominant conifer tree species in the forests of Indo-Pak subcontinent. The primary objective of this study is to analyze the distribution of nutrients in the major plant tissues such as the leaves (needles) of the dominant conifers namely *Pinus wallichiana* A. B. Jackson, *Abies pindrow* Royle and *Cedrus deodara* (Roxb.) G. Don., those are common in the moist temperate zone forests of northern Pakistan and relate them to the nutrient composition in the soils supporting these forests.

Climatic estimation: Siddiqui *et al.,* (2013) described the climate of moist temperate area of Pakistan, using the data of 33 years (1976 to 2008). The data were obtained from Meteorological Department, Karachi and formatted to mean monthly, maximum and minimum temperature and monthly and yearly precipitation. For each study area biotemperature was computed in accordance with Holdridge (1947).

Materials and Methods

Soil and plant sampling: Foliage samples were collected during a two year period from 2005 to 2006 from unfertilized trees of maximum height and diameter growing under natural conditions at 41 different localities from moist temperate area of Pakistan during summer (July to October). Potential study sites were selected from a catalogue of 85 sites. The criterion of site selection were : 1) sites should be relatively free from disturbance, 2) adequate density of trees of the selected species, 3) the trees should be undamaged and free from any plant disease, and 4) the sites should represent different altitudes. Twenty-four sites which met our selection criteria were selected while the number of stands was 41. Large sites had more than one stand. The stands within a site were selected on the basis of differences in aspect and slope angle. Attention was focused on three dominant conifer tree species, namely *Pinus wallichiana*, *Abies pindrow* and *Cedrus deodara*. Five to six foliage samples of the selected conifer species present in the stands were collected. The distribution of *Pinus wallichiana* being extensive, foliage samples were collected from 35 stands, *Abies pindrow* from 27 stands and *Cedrus deodara* from 22 stands. Thus nutrient levels of two forest type co-occurring in a stand reflect their inherent difference but not the difference due to environmental variability.

Foliage was collected during summer following bud set from dominant or co-dominant conifer species. All trees sampled were free from any sign of stress, disease, or insect infestation. A branch containing current year foliage was collected at the third whorl from the top of each sample tree, placed in a plastic bag, stored in an ice-cooled container, and expeditiously transported to the laboratory for deep-freeze storage. Samples were held in the freezer until analysis. Soil samples were collected from a depth of 0 - 30 cm, using a soil auger. Samples were placed in cloth bags, sealed and brought to laboratory.

Sample preparation and analysis: In the laboratory current year needles were stripped from each sample branch. Three repetitions of 30 or 50 needles were weighed. The separated needles were then dried at 70 °C for 24 hours and ground to a fine consistency in a grinder to prepare for chemical analysis.

Foliar nutrient concentrations analyzed were: N, P, K, Ca, Mg, S, Na, Mn, Fe, Zn, B, Cu and Mo. Foliar analyses were performed in the Plant Ecology Laboratory, Federal Urdu University, Karachi. For all elements except N and in some cases P, laboratory protocols included either wet ash or dry ash preparation of the samples (Anderson, 1996). Wet ash methods typically employed a predigestion in nitric acid, followed by digestion in hydrogen peroxide, and dilution by either mild hydrochloric acid or deionized water. Dry ash methods included high temperature ashing followed by digestion in nitric acid (HNO_3) and dilution with deionized water. Soil sample (0.4- 0.5g) was digested with a mixture of 6ml $HClO_4$- HF (1:2) on a hot plate at about 195ºC till dried. The mixture was cooled acidified with HNO_3 (2 ml) and then 5 ml distilled water was added. It was warm enough to dissolve all salts and cooled again and the solution made up to 100 ml with deionized distilled water. The same elements mentioned above were analyzed using atomic absorption spectrophotometer (PG - 990, England). Micro-Kjeldahl method (Horneck & Miller, 1998) was used to analyze total Nitrogen.

Data analysis: Individual tree nutrient concentration levels were used to calculate means and coefficients of variation for each selected species for each study site. The coefficients of variation thus obtained were further summarized, yielding an average coefficient of variation for each nutrient-tree species combination. Descriptive statistics is represented by means of box-plots prepared by SPSS version 10. Correspondence analysis (CA) (Hill, 1973) was used to expose the overall data structure and to seek the similarity structure inherent in the tissue nutrient data matrix while Canonical Correspondence analysis (CCA) (Ter Braak, 1986) was employed to seek the overall structure contained between the two matrices (tissue nutrient and soil nutrient matrices) and to disentangle the covariation (correspondence) existing between tissue nutrient matrix and the corresponding soil nutrient matrix. The computations were performed using the program PC - ORD (version 6.0) (McCune & Grace, 2002; Peck, 2010). According to Gégout & Houllier (1996), the following ratio can be used as a means of assessing the relative efficiency of CCA versus CA:

$$e_m = \sum_{k=1}^{m} \lambda_{CCA,k} \Big/ \sum_{k=1}^{m} \lambda_{CA,k} \leq 1$$

where, λ is the eigenvalue associated to the *kth* ordination axis of CCA or CA and e_m can be considered as the empirical index that measures the efficiency of the nutrient variables used in predicting the influence of soil nutrient variables. The closer the eigenvalues of the *m* first axes of CCA are to the *m* first axes of CA, the greater the efficiency of foliar nutrient variables and the closer e_m is to 1. The efficiency of the different sets of nutrient variables (same for all three species) to explain the soil nutrient composition of the stands was achieved by means of this e_m ratio.

Results

Table 1 shows the location of sampling sites in relation to their ecological characteristics while Fig. 1 shows locations where sampling was performed. Box whisker plots (Fig. 2) illustrate the descriptive statistics pertaining to amounts of foliar nutrient concentrations (only macronutrient) in three conifer species (*Pinus wallichiana*, *Abies pindrow* and *Cedrus deodara*) while the descriptive statistics of micro nutrient is presented in Table 2.

Comparison of foliar nutrients in three conifer species: Maximum levels of N (2.865%), Zn (0.0091%) and B (0.0088%) were recorded from the tissues of *Pinus wallichiana* from stand 1, while P (1.652%) from stand 39 whereas the minimum concentration of B (0.00386 %) and Mo (0.000037%) were also recorded for the same species from the stands 21 and 22 respectively. Levels of Ca (1.875 %), Na (0.1231 %) and Mn (0.1258 %) were highest in *Abies pindrow* from stand 1 while Mg (1.854 %), Fe (0.0267 %) and Cu (0.00215 %) had highest concentrations in stands 10, 39 and 3 respectively in the same species. The lowest amounts of P (0.348 %) and K (0.481 %) were recorded from stand 21 while Mg (0.328 %), Zn (0.00438 %) and Cu (0.000124 %) from stands 20, 41 and 24 respectively also from *A. pindrow*. *Cedrus deodara* attained the highest concentration of K (2.756 %), S (0.563 %) and Mo (0.000212 %) in the stands, 40, 1 and 1 respectively while it attained the lowest amount of N (0.452 %), Ca (0.325 %), S (0.032 %), Na (0.0152 %), Fe (0.0189 %) and Mn (0.0091 %) in the stands 6, 28, 39, 40, 38 and 39 respectively. With respect to mean tissue concentration in *Pinus wallichiana*, K attained the highest value (1.305 %) followed by N > Mg > Ca > P > S > Mn > Na > Fe > Zn > B > Cu > Mo. *Abies pindrow* disclosed the order N > K > Ca > Mg > P > S > Mn > Na > Fe > B > Zn > Cu > Mo while *Cedrus deodara* showed K > N > Mg > Ca > P > S > Na > Mn > Fe > Zn > B > Cu > Mo.

Nutrient concentrations of soils in the forests corresponding to conifer species: Figure 3 (Box whisker plots) shows the concentration of soil nutrients (only macronutrient) in the stands corresponding to three dominant species. Similar concentrations for micro nutrients are presented in Table 3. Among the soil nutrients the greater level of N (2.102 %) and K (1.563 %), Fe (0.0687 %), Zn (0.0043 %), B (0.00368 %), Cu (0.000685 %) and Mo (0.000652 %) were recorded from forests of corresponding to *Pinus wallichiana* while the minimum concentrations of three elements (Ca 0.132 %, S 0.00775 % and Mn 0.00453 %) were also recorded from the corresponding sites of the same species. Highest level of P (0.682 %), Ca (0.978 %), Mg (0.951 %) and Mn (0.0687 %) and lowest concentrations of P (0.186 %), K (0.241 %), Mg (0.223 %), S (0.00775 %), Na (0.012 %), Fe (0.00378 %), Zn (0.00251 %), B (0.00164 %), Cu (0.000178 %) and Mo (0.000011 %) were recorded from the forests of *Abies pindrow*. Maximum concentrations of Ca (0.978 %), Na (0.0564 %) and Mn (0.0687 %) while the minimum concentration of N (0.213 %), K (0.241 %) and Ca (0.132 %) were recorded from the sites where *Cedrus deodara* was a dominant species.

Ordination

Pinus wallichiana

CA of tissue nutrients: The first, second and third axes of CA explained 29.4, 24.3 and 21.1 percent of the total variance respectively (Table 4). All 2 - dimensional ordination configurations depicted continuity in nutrient regimes (Fig. 4a, 4b, 4c). The first CA axis was significantly correlated with soil N, P and K ($p<0.05$) while Mn, Zn, B and Cu showed weak correlation ($p<0.1$) (Table 5). The second CA axis showed significant correlation with P and B ($p<0.05$) while Ca and Cu at $p<0.001$ and $p<0.1$ respectively. The third CA axis gave significant correlation with K and Mg ($p<0.05$). All the significant correlations were positive.

CCA of tissue and soil nutrients: The eigenvalues, percentage explained variance and cumulative percentage variance for the first three canonical axes are given in Table 6. Together the first three canonical axes accounted for 46.2 percent of the total variance. The ordination biplots showed continuity in the foliage nutrient levels (Fig. 5a, 5b, 5c). The Pearson correlation between the first canonical pair (U_1, V_1) was 0.832 while Kendall's rank correlation was 0.597 indicating that the tissue nutrients are highly correlated with soil nutrients for *Pinus wallichiana.* The Pearson correlation between the second canonical pair (U_2, V_2) was 0.812 (rank correlation of 0.580). The Pearson correlation between the third canonical pair (U_3, V_3) was 0.828 while the rank correlation was 0.610. Additionally, an e_m *(CCA / CA)* value of 0.6125 provides evidence of great efficiency of nutrient variables employed to predict the influence of soil nutrient variables. Inter-set correlations (Table 7) provide the correlations between soil nutrients and the three canonical axes. The first canonical axis was positively correlated with macro-nutrients (N, P and K) while Ca was negatively correlated ($p<0.05$). The second axis was positively correlated with P, Ca and Cu ($p<0.01$) while S, Na and Mn were positively correlated ($p<0.05$); interestingly, B showed highly significant positive correlation ($p<0.001$). The third canonical axis exhibits a positive significant correlation ($p<0.01$) with only K. The CCA biplot presented in Fig. 5a, shows correlation of canonical axes with Ca, Na, B, Cu, P and Mn, particularly with axis 2. Biplot (Fig. 5b) shows correlation with Ca and P with axis 3 while N and K with axis 1. Figure 5c showed correlation of Ca, Mn, Na, B and Cu with axis 2 while P and K with axis 3. Correlation coefficient of real data 0.832 for canonical axis 1 of tissue-soil nutrient data was found highly significant ($p<0.001$) by a Monte Carlo test (based on 998 random simulations) (Table 8).

Table 1. The sample location and characteristics of conifer species in moist temperate Himalayan and Hindukush region of Pakistan. The forest type (*Pinus, Cedrus* and *Abies*) were indicated for each location.

S. No.	Main locations and sites	Latitude (N)	Longitude (E)	Elevation (m)	Slope (º)	Aspect	Canopy
	1. Malakand Division						
1.	Kumrat, (Dir Upper)	35º 54'	72º 14'	2400	R. Top	R. Top	Closed
2.	Pana Kot	35º 16'	71º 50'	2200	40	W	Closed
3.	Malam Jabba 1 (Swat)	35º 12'	72º 81'	2600	34	W	Moderate
4.	Malam Jabba 2	35º 20'	72º 40'	2350	30	N W	Open
5.	Miandam	35º 09'	72º 30'	2600	49	N	Moderate
	2. Azad Kashmir						
6.	Keran, District Neelam	34º 56'	73º 12'	1960	30	N E	Open
7.	Chikar, District Baagh	34º 54'	73º 10'	1930	28	N W	Moderate
8.	Sudhan Gali 1,	34º 20'	73º 22'	2450	22	E	Moderate
9.	Sudhan Gali 2	34º 22'	73º 28'	2500	32	N	Partly closed
10.	Sudhan Gali 3	34º 19'	73º 25'	2420	38	West	Moderate
	3. Muree, Rawalpindi Division						
11.	Ghora Gali	33º 52'	73º 20'	2100	29	N	Moderate
12.	Patreata Top 1	33º 50'	69º 56'	2300	40	S E	Closed
13.	Patreata Top 2	33º 50'	69º 56'	2300	25	S W	Moderate
14.	Nia, Near Patriata	33º 52'	69º 57'	2000	39	S	Moderate
15.	Kashmir Point	34º 54'	73º 24'	2500	39	S	Closed
	4. Abbot Abad, Hazara Division						
16.	Ghora Dhaka 1	34º 02'	73º 26'	2500	36	N E	Closed
17.	Ghora Dhaka 2	34º 04'	73º 24'	2500	32	S E	Closed
18.	Ghora Dhaka 3	34º 07'	73º 25'	2800	40	S W	Moderate
19.	Ghora Dhaka 4	34º 09'	73º 27'	2800	40	W	Closed
20.	Ghora Dhaka 5	34º 11'	73º 28'	2600	37	S W	Closed
21.	Khaira Gali	33º 57'	73º 23'	2730	42	S E	Closed
22.	Changla Gali 1	33º 59'	73º 23'	2650	47	W	Open
23.	Changla Gali 2	33º 59'	73º 23'	2670	35	S	Closed
24.	Kuzah Gali 1	34º 02'	73º 24'	2560	R. Top	R. Top	Moderate
25.	Kuzah Gali 2	34º 02'	73º 24'	2560	28	S E	Closed
26.	Nathia Gali, Lalazar 1	34º 54'	73º 46'	2640	35	S	Moderate
27.	Nathia Gali, Lalazar 2	34º 54'	73º 46'	2630	33	N W	Open
28.	Thandyani 1	34º 14'	73º 22'	2320	31	S	Moderate
29.	Thandyani 2	34º 14'	73º 22'	2300	38	S	Moderate
	5. Kaghan Valley, District Mansehra						
30.	Paye	34º 47'	73º 30'	3100	38	S	Closed
31.	Sri	34º 47'	73º 30'	2900	39	N	Closed
32.	Shogran 1	34º 37'	73º 28'	2400	27	S W	Closed
33.	Shogran 2	34º 37'	73º 28'	2400	23	S	Closed
34.	Shogran 3	34º 37'	73º 28'	2500	33	S	Closed
35.	Paras, Malkandi Pine Park	34º 41'	73º 35'	1600	20	N E	Closed
36.	Khanian	34º 47'	73º 32'	2000	35	E	Closed
37.	Shinu 1, Near Jurait Park	34º 38'	73º 26'	1900	39	N W	Moderate
38.	Shinu 2, Near Jurait Park	34º 38'	73º 26'	1650	43	W	Closed
39.	Naran, River Belt 1	34º 53'	73º 39'	2500	R. Top	N W	Moderate
40.	Naran, River Belt 2	34º 53'	73º 39'	2500	R. Top	N W	Moderate
41.	Lalazar (Naran)	34º 53'	73º 39'	3000	45	N W	Closed

Key to abbreviations: R. Top = Ridge top, E = East, W = West, N = North, S = South

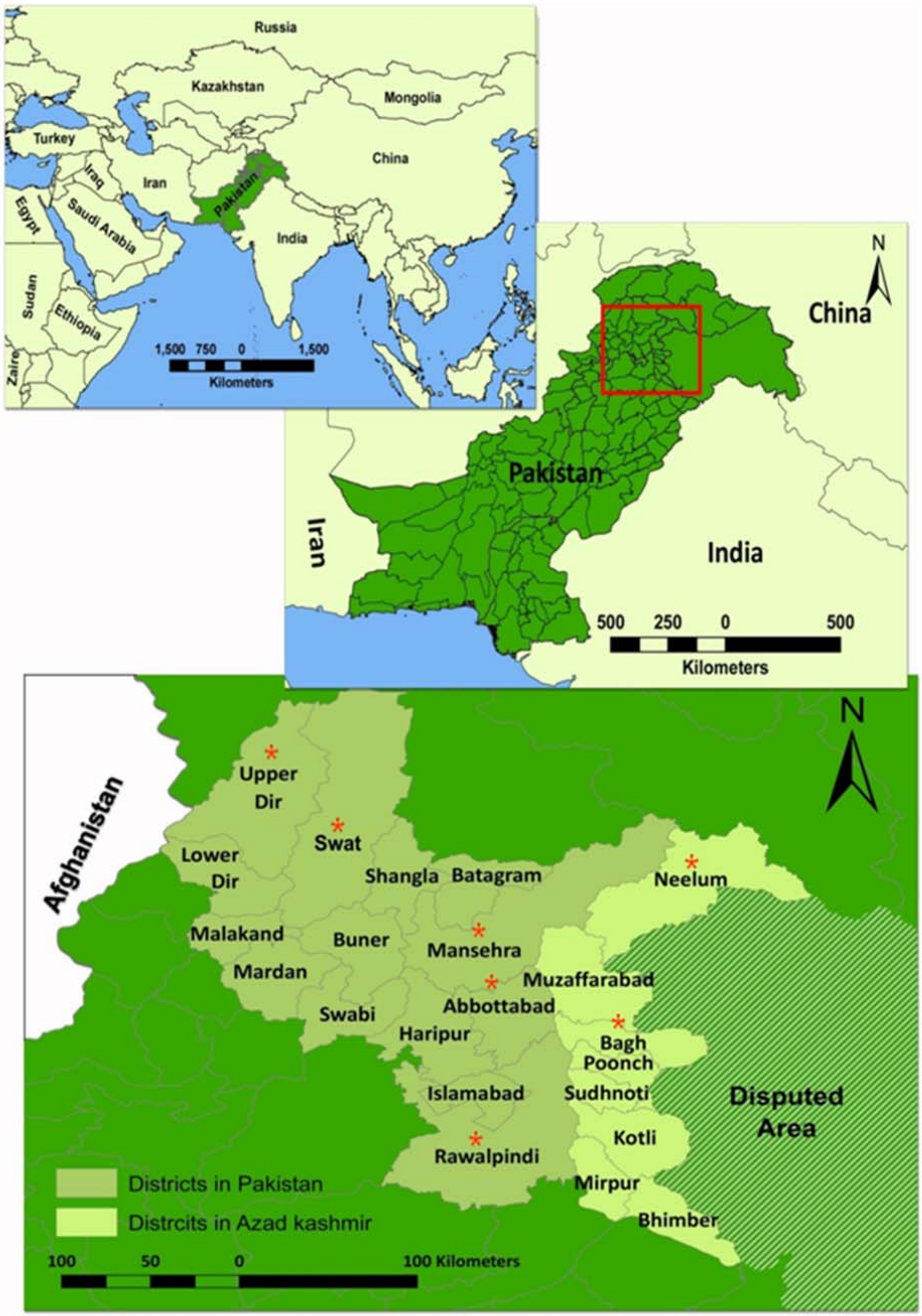

Fig. 1. Study Area Map; * showing the main locations (district) where moist temperate forests were studied Siddiqui *et al.,* (2013). Details of the sites and stands are given in Table 1.

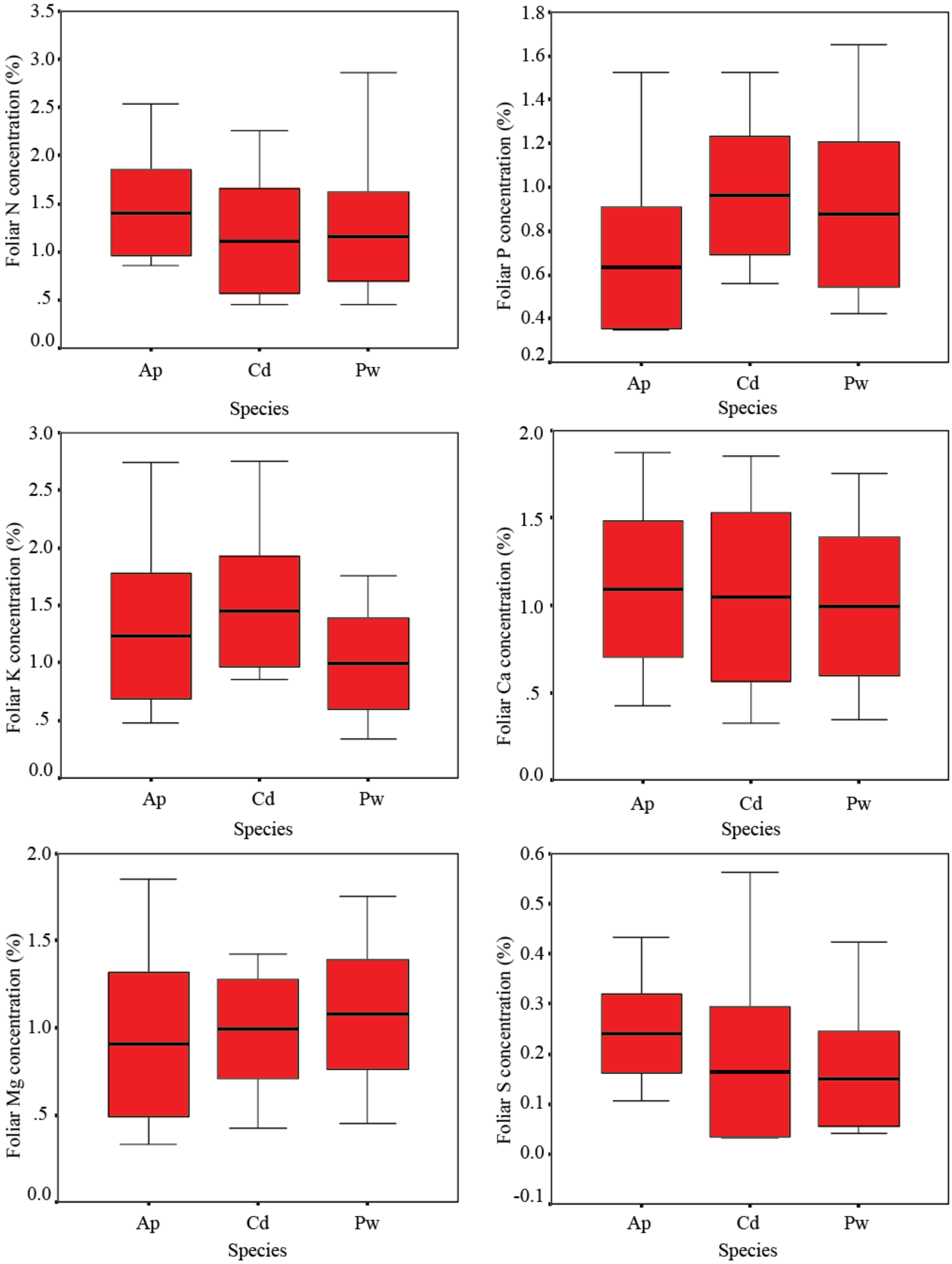

Fig. 2. Box plots of *Pinus wallichiana, Abies pindrow* and *Cedrus deodara* tissue nutrient concentration levels in the moist temperate area of Pakistan. The solid line within the box represents the mean, the upper and lower ends of the box are mean ± Sd, the end of the Whiskers represent maximum or minimum level of tissue nutrient concentration distribution, respectively.

Key to abbreviations: *Ap = Abies pindrow, Pw = Pinus wallichiana* and *Cd = Cedrus deodara.*

Note: SPSS version 10 used to prepare the Box plots.

Table 2. Concentration of seven tissue micro nutrients of dominant conifer species (*Pinus*, *Cedrus* and *Abies*) of the moist temperate area of Himalayan and Hindukush region of Pakistan. Minimum, maximum, mean and standard deviation for each nutrient is computed using the values from forty one stands.

Serial No.	Nutrients	Minimum concentration (%)			Maximum concentration (%)		
		Pw	*Ap*	*Cd*	*Pw*	*Ap*	*Cd*
1.	Na	0.0212	0.0298	0.01520	0.095	0.1231	0.0871
2.	Mn	0.0205	0.0421	0.01890	0.108	0.1258	0.1245
3.	Fe	0.011	0.0108	0.00905	0.0203	0.0267	0.0251
4.	Zn	0.00524	0.00438	0.00543	0.0091	0.00854	0.0089
5.	B	0.00386	0.00462	0.00537	0.0088	0.00875	0.0081
6.	Cu	0.000354	0.000124	0.00065	0.00134	0.00215	0.0013
7.	Mo	0.000037	0.0000745	0.00011	0.000175	0.000192	0.000212
		Mean			**Standard deviation**		
1.	Na	0.0475	0.0601	0.0535	0.017327	0.022133326	0.01839
2.	Mn	0.0506	0.0806	0.0518	0.0185	0.018065217	0.02623
3.	Fe	0.0145	0.0164	0.0167	0.002652	0.004055797	0.00415
4.	Zn	0.0069	0.0061	0.0069	0.000992	0.000932583	0.00102
5.	B	0.0061	0.0066	0.0064	0.001276	0.000948984	0.00081
6.	Cu	0.0009	0.0008	0.0009	0.000249	0.000383707	0.00019
7.	Mo	0.0001	0.0001	0.0002	4.270E - 05	3.15259E - 05	0.00003

Key to abbreviations: *Pw* = *Pinus wallichiana*, *Ap* = *Abies pindrow, Cd* = *Cedrus deodara*, Na = Sodium, Mn = Manganese, Fe = Iron, Zn = Zinc, B = Boron, Cu = Copper and Mo = Molybdenum

Table 3. Concentration of seven soil micro nutrients of corresponding conifer species (*Pinus*, *Cedrus* and *Abies*) of the moist temperate area of Himalayan and Hindukush region of Pakistan. Minimum, maximum, mean and standard deviation for each nutrient is computed using the values from forty one stands.

Serial No.	Nutrients	Minimum (%)			Maximum (%)		
		Pw	*Ap*	*Cd*	*Pw*	*Ap*	*Cd*
1.	Na	0.0132	0.012	0.014	0.052	0.052	0.0564
2.	Mn	0.00453	0.0102	0.0123	0.01078	0.0688	0.0687
3.	Fe	0.0103	0.00378	0.00385	0.0687	0.01078	0.01078
4.	Zn	0.00276	0.00251	0.00291	0.0043	0.00418	0.00418
5.	B	0.00188	0.00164	0.00193	0.00386	0.00385	0.00385
6.	Cu	0.000198	0.000178	0.000185	0.000684	0.000686	0.000684
7.	Mo	0.000016	0.000011	0.000018	0.000652	0.000098	0.000098
		Mean			**Standard deviation**		
1.	Na	0.030217	0.028752	0.031895	0.173266	0.022133	0.01839
2.	Mn	0.007289	0.026456	0.028423	0.185001	0.018065	0.02623
3.	Fe	0.027003	0.007079	0.007325	0.026521	0.004056	0.00415
4.	Zn	0.003539	0.003475	0.003630	0.009916	0.000933	0.00102
5.	B	0.002892	0.002794	0.002927	0.012757	0.000949	0.00081
6.	Cu	0.000437	0.000415	0.000447	0.002493	0.000384	0.00019
7.	Mo	0.00014	0.000054	0.000061	0.000427	3.15E - 05	0.00003

Table 4. Correspondence analysis (CA) of foliar nutrients of dominant conifer species of moist temperate area of Himalayan and Hindukush region of Pakistan.

Serial No.		Axis 1	Axis 2	Axis 3
	1. *Pinus wallichiana*			
1.	Eigenvalue	0.021	0.016	0.014
2.	% of variance explained	29.4	24.3	21.1
3.	Cumulative % explained	29.4	53.7	74.8
	2. *Abies pindrow*			
1.	Eigenvalue	0.023	0.019	0.015
2.	% of variance explained	33.7	29.1	22.1
3.	Cumulative % explained	33.7	62.8	84.9
	3. *Cedrus deodara*			
1.	Eigenvalue	0.027	0.021	0.015
2.	% of variance explained	33.1	25.7	18.3
3.	Cumulative % explained	33.1	58.8	77.1

Abies pindrow

CA of tissue nutrients: The first, second and third axes of CA explained 33.7, 29.1 and 22.1 percent of the total variance respectively. The 2 - dimensional ordination planes showed continuity in nutrient levels (Fig. 6a, b, c). Soil nutrients of *Abies pindrow* corresponding stands showed weak correlation with CA ordination axes. The first CA axes didn't show any significant correlation with soil nutrients while second CA axes showed significant correlation only with Ca ($p<0.05$) (Table 6). Third CA axis exhibited some significant correlations with total N ($p<0.001$), S and Fe ($p<0.05$) while Mn and Cu ($p<0.1$). All the significant correlations were positive.

Table 5. Correlation coefficient between the soil nutrients of dominant conifer species and correspondence analysis axes (plot scores) of moist temperate areas of Himalayan and Hindukush region of Pakistan.

Sr. No.	Nutrients	Axis 1	p-value	Axis 2	p-value	Axis 3	p-value
				1. *Pinus wallichiana*			
1.	N	0.332	p<0.05	- 0.088	ns	- 0.001	ns
2.	P	0.415	p<0.05	0.344	p<0.05	0.188	ns
3.	K	0.342	p<0.05	- 0.177	ns	0.052	p<0.05
4.	Ca	- 0.159	ns	0.523	p<0.001	- 0.043	ns
5.	Mg	- 0.038	ns	0.003	ns	0.002	p<0.05
6.	S	0.239	ns	0.268	ns	0.022	ns
7.	Na	0.196	ns	0.237	ns	0.052	ns
8.	Mn	0.285	p<0.1	0.213	ns	0.084	ns
9.	Fe	0.103	ns	0.203	ns	0.028	ns
10.	Zn	0.283	p<0.1	0.181	ns	0.093	ns
11.	B	0.308	p<0.1	0.328	p<0.05	0.238	ns
12.	Cu	0.283	p<0.1	0.282	p<0.1	0.121	ns
13.	Mo	0.243	ns	- 0.037	ns	- 0.069	ns
				2. *Abies pindrow*			
1.	N	0.033	ns	0.061	ns	0.493	p<0.01
2.	P	- 0.108	ns	- 0.011	ns	0.052	ns
3.	K	- 0.118	ns	0.157	ns	0.128	ns
4.	Ca	- 0.051	ns	0.391	p<0.05	0.059	ns
5.	Mg	0.038	ns	0.186	ns	0.112	ns
6.	S	0.082	ns	0.204	ns	0.384	p<0.05
7.	Na	- 0.068	ns	0.228	ns	0.292	ns
8.	Mn	- 0.065	ns	0.235	ns	0.315	p<0.1
9.	Fe	- 0.072	ns	0.055	ns	0.409	p<0.05
10.	Zn	0.11	ns	0.276	ns	0.121	ns
11.	B	0.002	ns	0.021	ns	0.279	ns
12.	Cu	- 0.041	ns	- 0.006	ns	0.339	p<0.1
13.	Mo	0.107	ns	0.014	ns	0.209	ns
				3. *Cedrus deodara*			
1.	N	- 0.104	ns	- 0.009	ns	- 0.02	ns
2.	P	0.27	ns	- 0.215	ns	0.359	p<0.1
3.	K	0.244	ns	0.215	ns	- 0.161	ns
4.	Ca	0.353	p<0.1	0.277	ns	0.229	ns
5.	Mg	0.286	ns	0.033	ns	- 0.061	ns
6.	S	- 0.024	ns	0.201	ns	0.155	ns
7.	Na	0.114	ns	- 0.026	ns	0.131	ns
8.	Mn	- 0.069	ns	0.0021	ns	0.202	ns
9.	Fe	- 0.268	ns	- 0.133	ns	0.143	ns
10.	Zn	0.117	ns	- 0.005	ns	0.25	ns
11.	B	0.031	ns	0.059	ns	0.265	ns
12.	Cu	- 0.012	ns	0.058	ns	0.132	ns
13.	Mo	0.079	ns	- 0.011	ns	0.073	ns

Key to abbreviations: N = Nitrogen, P = Phosphorus, K = Potassium, Ca = Calcium, Mg = Magnesium and S = Sulphur

Table 6. CCA of foliar and soil nutrients data of dominant conifer species of moist temperate area of Himalayan and Hindukush region of Pakistan.

Serial No.		Axis 1	Axis 2	Axis 3
	1. *Pinus wallichiana*			
1.	Eigenvalue	0.013	0.01	0.008
	Variance in tissue and soil nutrients data			
2.	% of variance explained	19.4	15.4	11.3
3.	Cumulative % explained	19.4	34.9	46.2
4.	Pearson correlation	0.832	0.812	0.828
5.	Kendall (Rank) correlation	0.597	0.58	0.61
	2. *Abies pindrow*			
1.	Eigenvalue	0.014	0.011	0.007
	Variance in tissue and soil nutrients data			
2.	% of variance explained	20.2	16.7	10.1
3.	Cumulative % explained	20.2	36.9	47.0
4.	Pearson correlation	0.848	0.723	0.703
5.	Kendall (Rank) correlation	0.675	0.493	0.350
	3.*Cedrus deodara*			
1.	Eigenvalue	0.016	0.01	0.008
	Variance in tissue and soil nutrients data			
2.	% of variance explained	20.4	12.3	9.9
3.	Cumulative % explained	20.4	32.7	42.6
4.	Pearson correlation	0.811	0.796	0.824
5.	Kendall (Rank) correlation	0.593	0.619	0.636

CCA of tissue and soil nutrients: The eigenvalues, percentage explained variance and cumulative percentage variance for the first three canonical axes together accounted for 47.0 percent of the total variance (Table 6). The ordination biplots in general exhibited continues change in the nutrient levels (Fig. 7a, b). The Pearson correlation between the first canonical pair (U_1, V_1) was 0.848 while Kendall's rank correlation was 0.675 indicating that the tissue nutrients are highly correlated with soil nutrients for *Abies pindrow.* The second canonical pair (U_2, V_2) exhibited a Pearson correlation of 0.723 and a rank correlation of 0.493 while the third canonical pair (U_3, V_3) had a Pearson's correlation of 0.703 and a rank correlation of 0.350. Moreover, an e_m *(CCA / CA)* value of 0.5636 depicts a high efficiency of nutrient variable employed to predict the influence of soil variables. Similar relationships are shown in inter-set correlations given in Table 7. The first and second canonical axes did not show any significant correlation while the third canonical axis exhibited a positive significant correlation with total N and S ($p<0.01$) and Na, Mn and Fe ($p<0.05$). The biplot of Canonical axes 1 and 2 did not show significant correlation with any of the soil variable (figure not shown) while biplot of canonical axes 1 and 3 showed some correlations with Fe, S, N and Mn (Fig. 7a). Canonical axis 2 and 3 (Fig. 7b) showed significant correlation with S, N, Mn, Fe and Na. The randomization test for the first CCA axis of *Abies pindrow* foliar-soil nutrient data was found significant ($p<0.001$).

Cedrus deodara

CA of tissue nutrients: The first, second and third axes of CA explained 33.1, 25.7 and 18.3 percent respectively. Continuous change in the nutrient regime was depicted in the ordination planes (Fig. 8a, b, c). All three CA axes showed poor relationship with soil nutrients. The soil Ca and P showed a weak correlation ($p<0.1$) with CA axis 1 and 3 respectively (Table 5).

CCA of tissue and soil nutrients: Together the first three canonical axes accounted for 42.6 percent of the total variance (Table 6). Ordination biplots depicted continuity in nutrient levels (Fig. 9a, b, c). The Pearson correlation between the first canonical pair (U_1, V_1) was 0.811 while Kendall's rank correlation was 0.593 indicating that the tissue nutrients are highly correlated with soil nutrients for *Cedrus deodara.* The second canonical pair (U_2, V_2) exhibited a Pearson correlation of 0.796 and a rank correlation of 0.619 while the third canonical pair (U_3, V_3) had a Pearson's product-moment correlation of 0.824 and rank correlation of 0.636. Further, an e_m value of 0.5636 depicts a high efficiency of nutrient variables used to predict the influence of soil variables. Similar relationships to that of canonical correlations are depicted in inter-set correlations (Table 7) that provide correlations between soil nutrients and the three canonical axes. The first and third canonical axes were negatively correlated with only Ca and P ($P < 0.001$) while second axis showed a positive significant correlation with K ($P < 0.05$). The CCA biplot of canonical axes 1 and 2 (Fig. 9a) showed significant (P at the most 0.05) correlation with Ca and K while the biplot of axes 1 and 3 (Fig. 9b) showed positive correlation of Ca with the first canonical axis while a significant negative correlation for P with the second canonical axis. Biplot of canonical axes 2 and 3 (Fig. 9c) exhibited correlation with P and K. The Monte Carlo test of correlation for the first axis of CCA of foliar-soil nutrient data of *Cedrus deodara* was significant ($p<0.001$).

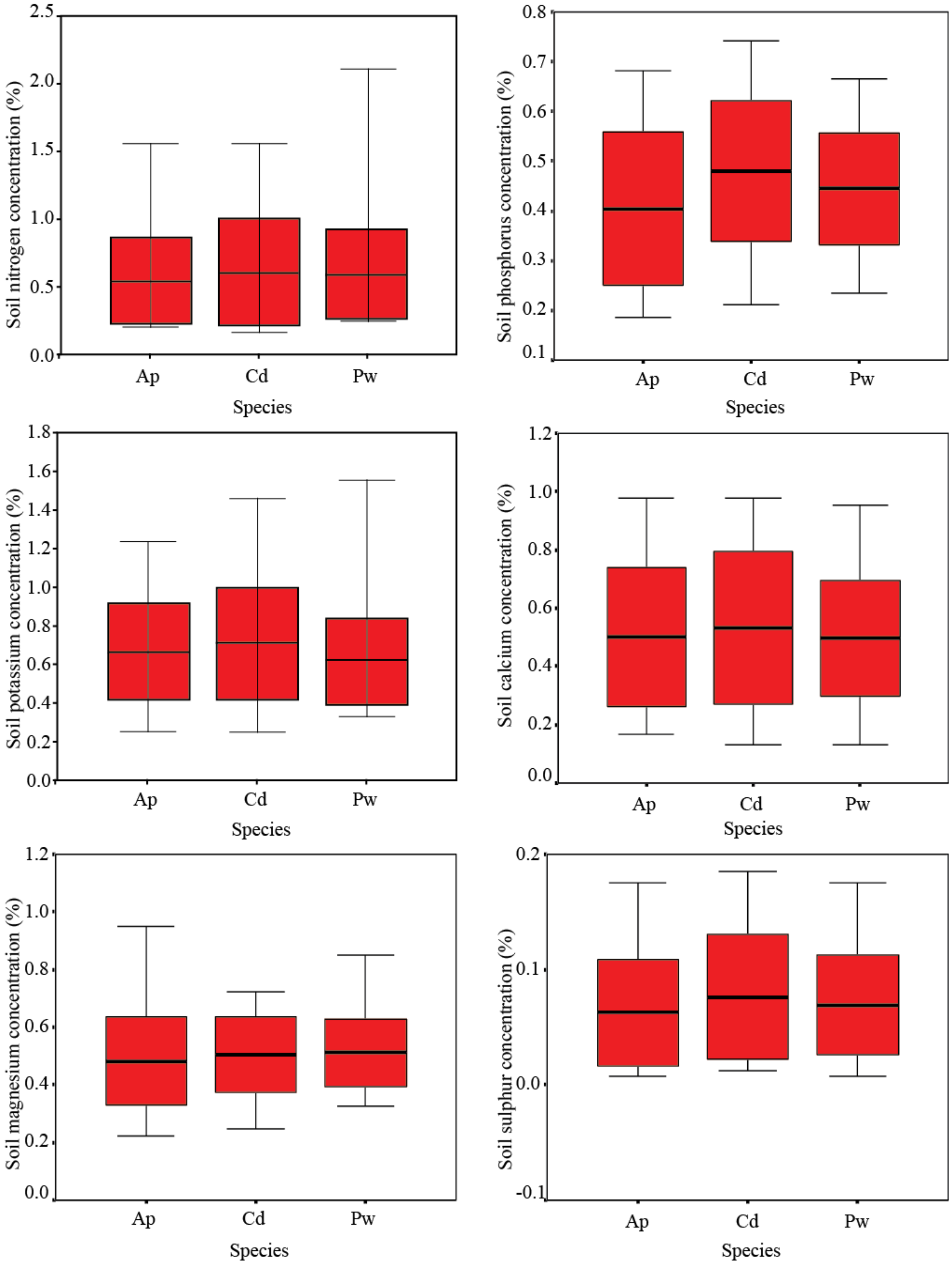

Fig. 3. Box plots of nutrient concentration levels in the soil of the corresponding conifer species (*Pinus wallichiana, Abies pindrow* and *Cedrus deodara*) of moist temperate area. The solid line within the box represents the mean, the upper and lower ends of the box are mean ± Sd, the end of the Whiskers represent maximum or minimum level of tissue nutrient concentration distribution, respectively.

Note: SPSS version 10 was used to prepare the Box plots.

Table 7. Inter-set correlations for 13 nutrients of dominant conifer species of the moist temperate area of Himalayan and Hindukush region of Pakistan.

Serial No.	Nutrients	Axis 1	p value	Axis 2	p-value	Axis 3	p-value
	1. *Pinus wallichiana*						
1.	N	0.401	p<0.05	0.147	ns	0.28	ns
2.	P	0.337	p<0.05	0.471	p<0.01	- 0.289	ns
3.	K	0.409	p<0.05	0.124	ns	0.418	p<0.01
4.	Ca	- 0.322	p<0.05	0.469	p<0.01	0.203	ns
5.	Mg	- 0.05	ns	- 0.053	ns	- 0.025	ns
6.	S	0.231	ns	0.339	p<0.05	- 0.151	ns
7.	Na	0.153	ns	0.357	p<0.05	0.021	ns
8.	Mn	0.248	ns	0.408	p<0.05	0.067	ns
9.	Fe	0.116	ns	0.285	ns	0.093	ns
10.	Zn	0.282	ns	0.318	ns	- 0.162	ns
11.	B	0.234	ns	0.528	p<0.001	- 0.02	ns
12.	Cu	0.233	ns	0.442	p<0.01	- 0.039	ns
13.	Mo	0.281	ns	0.14	ns	0.324	p<0.05
	2. *Abies pindrow*						
1.	N	0.095	ns	0.137	ns	0.569	p<0.01
2.	P	0.011	ns	0.119	ns	0.023	ns
3.	K	- 0.04	ns	0.223	ns	0.219	ns
4.	Ca	- 0.321	ns	0.187	ns	0.282	ns
5.	Mg	- 0.115	ns	0.062	ns	0.129	ns
6.	S	- 0.056	ns	0.109	ns	0.485	p<0.01
7.	Na	- 0.087	ns	0.232	ns	0.395	p<0.05
8.	Mn	- 0.077	ns	0.217	ns	0.446	p<0.05
9.	Fe	0.106	ns	0.183	ns	0.443	p<0.05
10.	Zn	- 0.189	ns	0.049	ns	0.307	ns
11.	B	0.078	ns	0.095	ns	0.313	ns
12.	Cu	0.128	ns	0.135	ns	0.324	ns
13.	Mo	0.044	ns	- 0.024	ns	0.33	ns
	3. *Cedrus deodara*						
1.	N	0.032	ns	0.16	ns	- 0.263	ns
2.	P	- 0.232	ns	-0.24	ns	- 0.418	p<0.05
3.	K	- 0.32	ns	0.461	p<0.05	- 0.32	ns
4.	Ca	- 0.438	p<0.05	0.153	ns	0.075	ns
5.	Mg	- 0.316	ns	0.044	ns	- 0.019	ns
6.	S	- 0.122	ns	0.137	ns	- 0.019	ns
7.	Na	- 0.16	ns	0.095	ns	- 0.331	ns
8.	Mn	- 0.031	ns	-0.015	ns	- 0.089	ns
9.	Fe	0.181	ns	-0.13	ns	- 0.091	ns
10.	Zn	- 0.225	ns	-0.094	ns	- 0.027	ns
11.	B	- 0.105	ns	0.061	ns	- 0.229	ns
12.	Cu	- 0.079	ns	0.125	ns	- 0.202	ns
13.	Mo	- 0.106	ns	0.119	ns	- 0.225	ns

Table 8. Monte Carlo generated empirical distribution tests of correlations obtained by CCA of foliar and soil nutrients concentration of dominant conifer species of moist temperate area of Himalayan and Hindukush region of Pakistan.

Axis	Real data	Significance level	Randomized data		
			Monte Carlo Test, 998 runs		
	Species-environment correlation		Mean	Min	Max
	1. *Pinus wallichiana*				
1.	0.832	p<0.001	0.764	0.570	0.902
2.	0.812		0.676	0.471	0.868
3.	0.828		0.586	0.379	0.814
	2. *Abies pindrow*				
1.	0.848	p<0.001	0.828	0.602	0.947
2.	0.723		0.731	0.519	0.908
3.	0.703		0.637	0.394	0.868
	3. *Cedrus deodara*				
1.	0.811	p<0.001	0.787	0.644	0.955
2.	0.796		0.722	0.560	0.966
3.	0.824		0.697	0.541	0.951

Discussion

Sixteen elements are considered to be essential for growth and development in higher plants (Salisbury & Ross, 1969). Present study covers the nutrient ecology of thirteen elements of plant and soil including six macro and seven micro-elements. Nutrients, such as N, P, a series of anions and cations and various trace elements are essential for plant nutrition and act as determinants of the composition, structure and productivity of vegetation (Bell, 1982). The base richness of the parent material is initially important in determining soil fertility and biological activities which in turn are essential for creation and maintenance of localized areas of enhanced soil fertility, often on base-poor substrates (Scholes, 1991). Nutrients are generally absorbed against a concentration gradient consequently respiratory energy is required for nutrient uptake (Jones, 1983). The macronutrients are consumed in larger quantities and are present in plant tissue in quantities from 0.2% to 4.0% on a dry matter basis (Salisbury & Ross, 1969) but in the present study minimum concentration of S from all three conifers were found somewhat lesser than these while the maximum values more or less approached the reported levels. According to Taiz & Zeiger (2002) micronutrients are present in plant tissue in quantities less than 0.02% dry weight which accords well with our data. Turner & Lambert (1979) stated that the exact requirements of conifers for nutrients are not known, and they require relatively lesser nutrient levels, and that *Pinus wallichiana, Abies pindrow* and *Cedrus deodara* are no exception to this rule.

Comparisons of foliar and soil nutrients: This study illustrates important species differentiation in foliar nutrient concentrations for three conifer species that either grows on the same or at a distant site within the moist temperate study area. However, the differences in the tissue nutrients among species are focused rather than among sites. For example, *Abies pindrow* had considerably higher concentration of Ca and Mg compared to the other two conifer species examined. Although *Abies pindrow* had higher concentration of these two nutrients but also attained the lowest value of P, K and Mg though with wide variation. Perhaps lower nutrient concentration reflects different adaptive strategies for various seral stages (Moore *et al.,* 2004). *Pinus wallichiana* had higher levels of N and P compared to other species tested while it did not attain minimum value of any of the macro-element which indicates its lower requirement (Ahmed *et al.,* 1990) for nutrients and grows well in the forests investigated and even dominated the other tree species. *Cedrus deodara* attained higher concentrations of K and S while the minimum value of three macro-nutrients (N, Ca and S) was also recorded from the tissues of this species. Apparently *C. deodara* does not require a high nutrient regime to flourish and survive under moist temperate conditions.

According to Salisbury & Ross (1969) the normal N content in higher plant is 1.5 % which is closely similar to the mean values found in all three conifer species. Results of some other workers who have evaluated N content in plants (or associated soils) especially in conifers are compared here. Moore *et al.,* (2004) estimated the N level in four conifer species i.e., Douglas-fir (1.4%), Grand fir (1.15%), Ponderosa pine (1.10%), and Lodgepole pine (1.20%). Krzic *et al*., (2001) estimated the N concentration from Lodgepole pine between 1.2 to 1.3% from the forest of southern British Columbia; they suggested that N is somewhat deficient in the trees in their study sites. Sheikh & Kumar (2010) reported 0.19% N from the soil of pine forests of Garhwal, Himalaya. Our values of foliage N (0.15 to 3.85%) and soil N (0.15 to 1.25%) lie within the reported ranges. McJannet *et al.,* (1995) estimated P concentration that ranged from 0.13 to 1.07% from the 41 plant species of Canada. Swan (1972) observed low concentration of P i.e., 0.13-0.14% while concentration of K, Ca and Mg were adequate in pine forests of Canada. Sheikh & Kumar (2010) reported that available P in the soils of oak forest (India) was higher (17.99 kg ha^{-1}) than in pine forest (16.88 kg ha^{-1}). The P concentration estimated from conifers and soils of the present study is more or less closely similar to those analyzed by other workers (i.e., 0.15% to 0.98%). However, even if P content is low, N content of soil is presumably a more limiting factor for tree growth (Ballard & Carter, 1986).

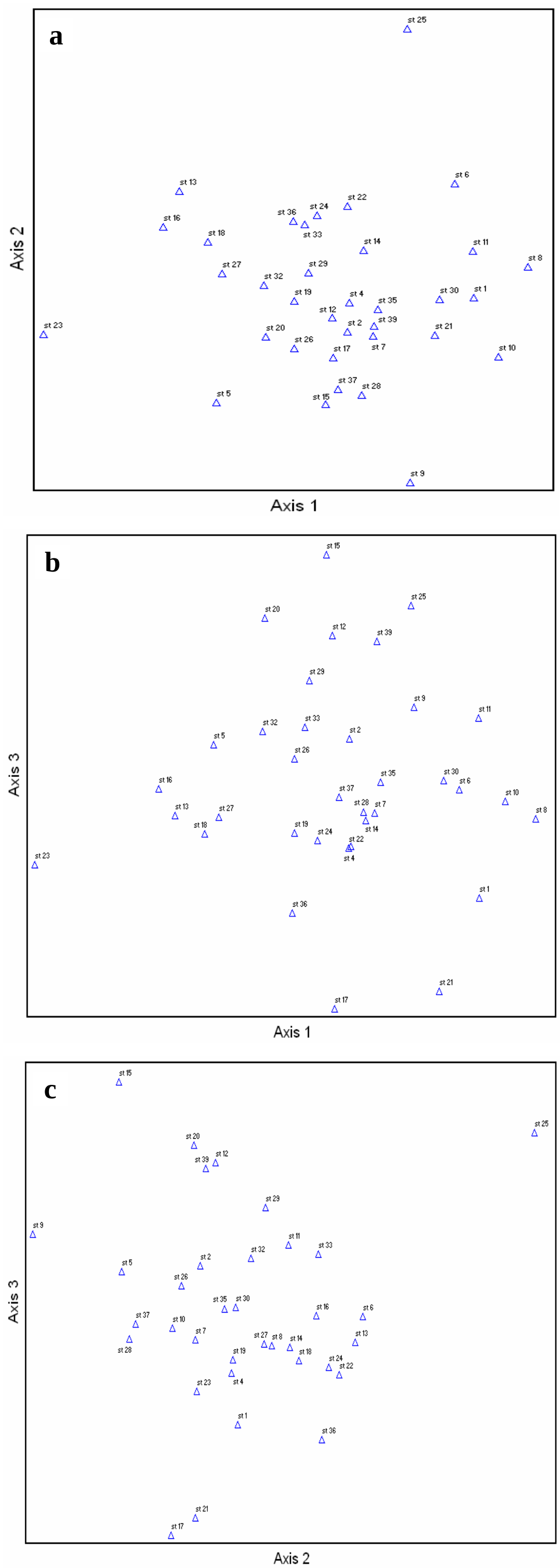

Fig. 4. Two-dimensional correspondence analysis (CA) ordinations of tissue nutrients of *Pinus wallichiana* from moist temperate area of Himalayan and Hindukush region of Pakistan: (a) axis 1-2, (b) 1-3 and (c) 2-3.

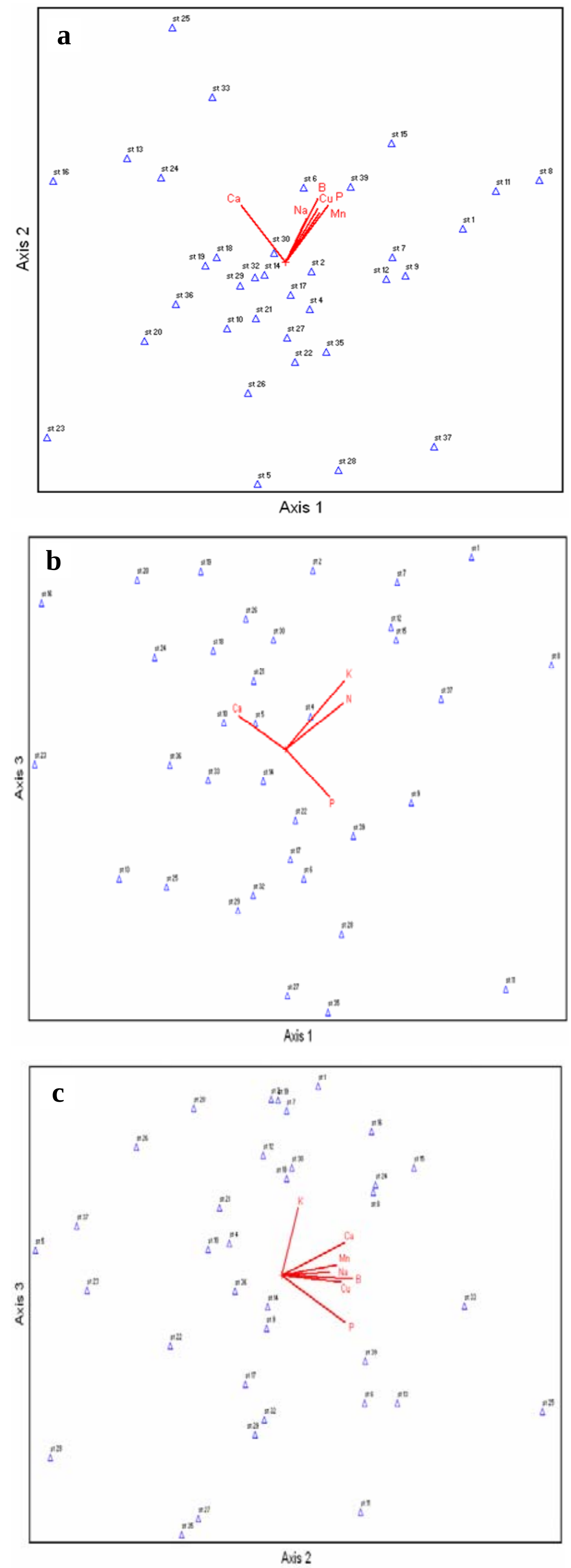

Fig. 5. Two dimensional canonical correspondence analysis (CCA) biplots, showing stand and the correlations (directed lines) of *Pinus wallichiana* tissue nutrients with the soil variables. (a) axis 1-2, (b) 1-3 and (c) 2-3.

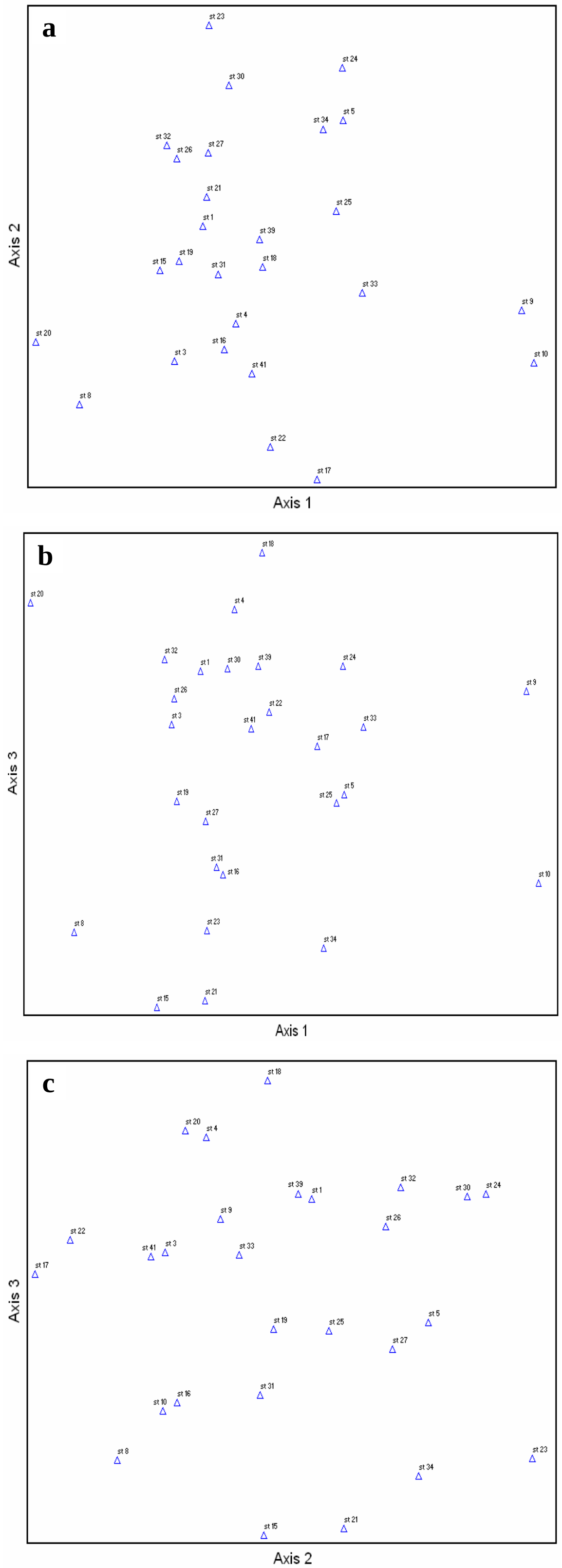

Fig. 6. Two-dimensional correspondence analysis (CA) ordinations of tissue nutrients of *Abies pindrow* from moist temperate area of Himalayan and Hindukush region of Pakistan. (a) axis 1-2, (b) 1-3 and (c) 2-3.

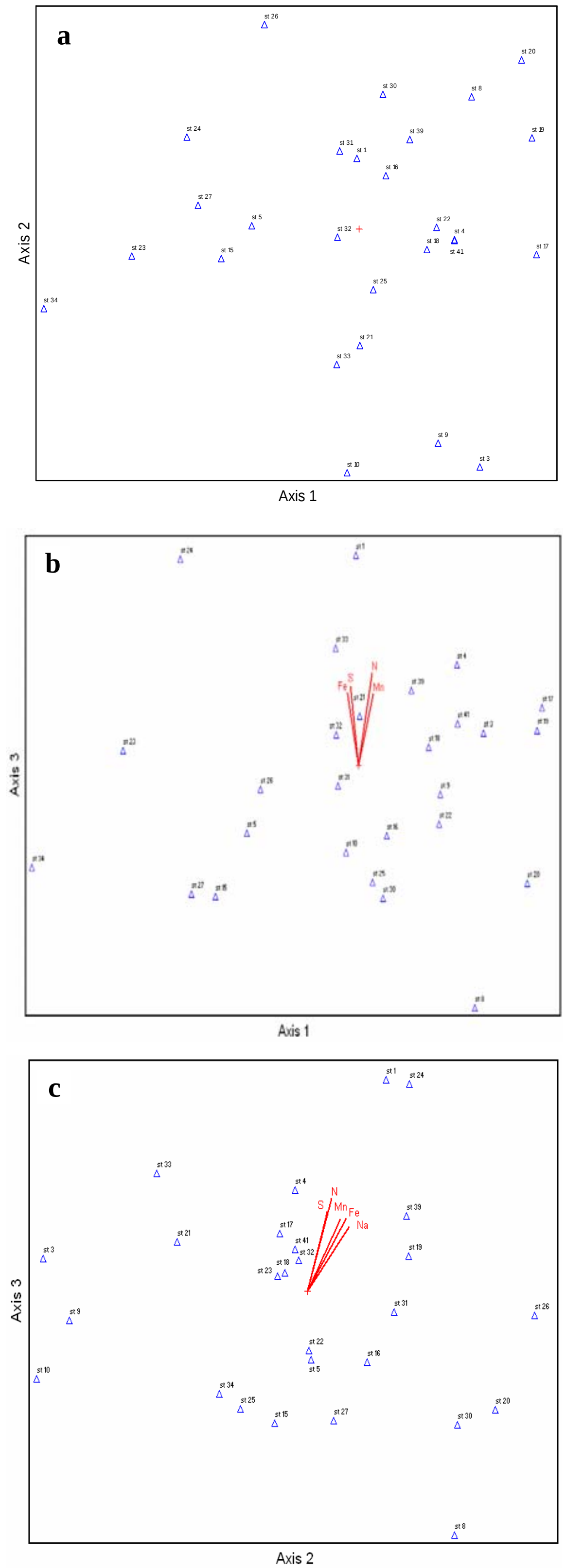

Fig. 7. Two dimensional canonical correspondence analysis (CCA) biplots, showing stand and the correlations (directed lines) of *Abies pindrow* nutrients with the soil variables. (a) axis 1-2, (b) 1-3 and (c) 2-3.

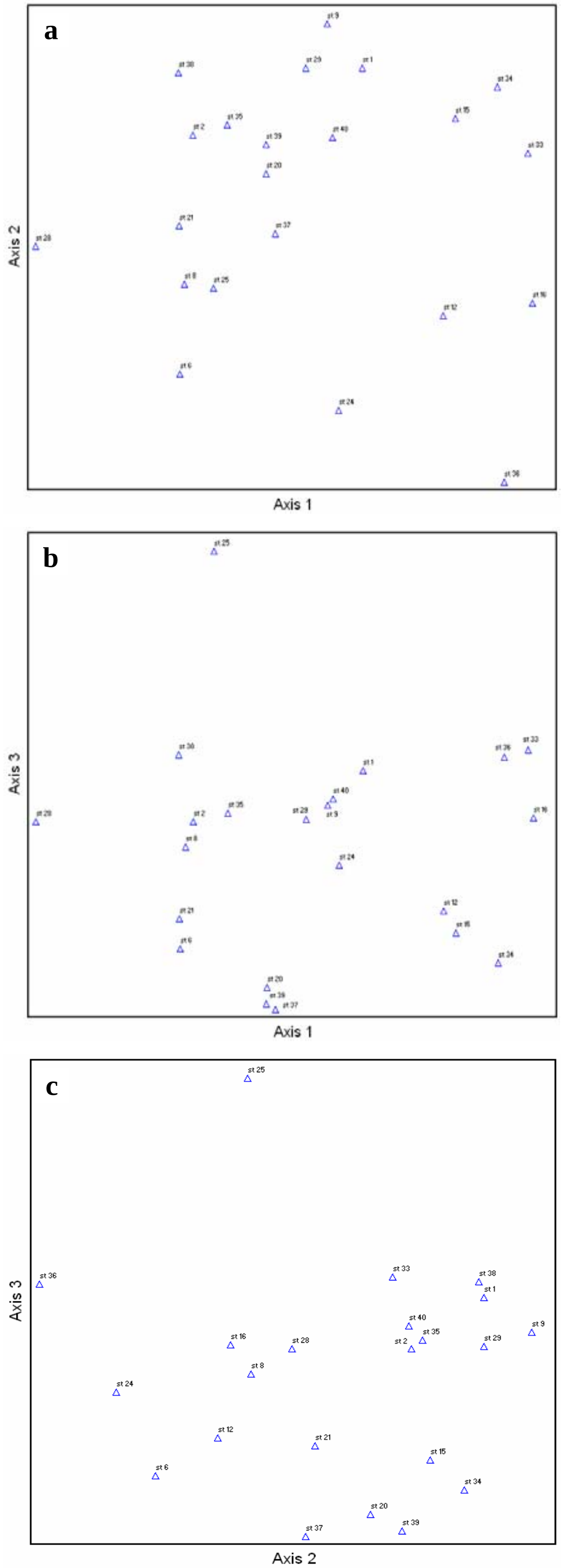

Fig. 8. Two-dimensional correspondence analysis (CA) ordinations of tissue nutrients of *Cedrus deodara* species from moist temperate area of Himalayan and Hindukush region of Pakistan. (a) axis 1-2, (b) 1-3 and (c) 2-3.

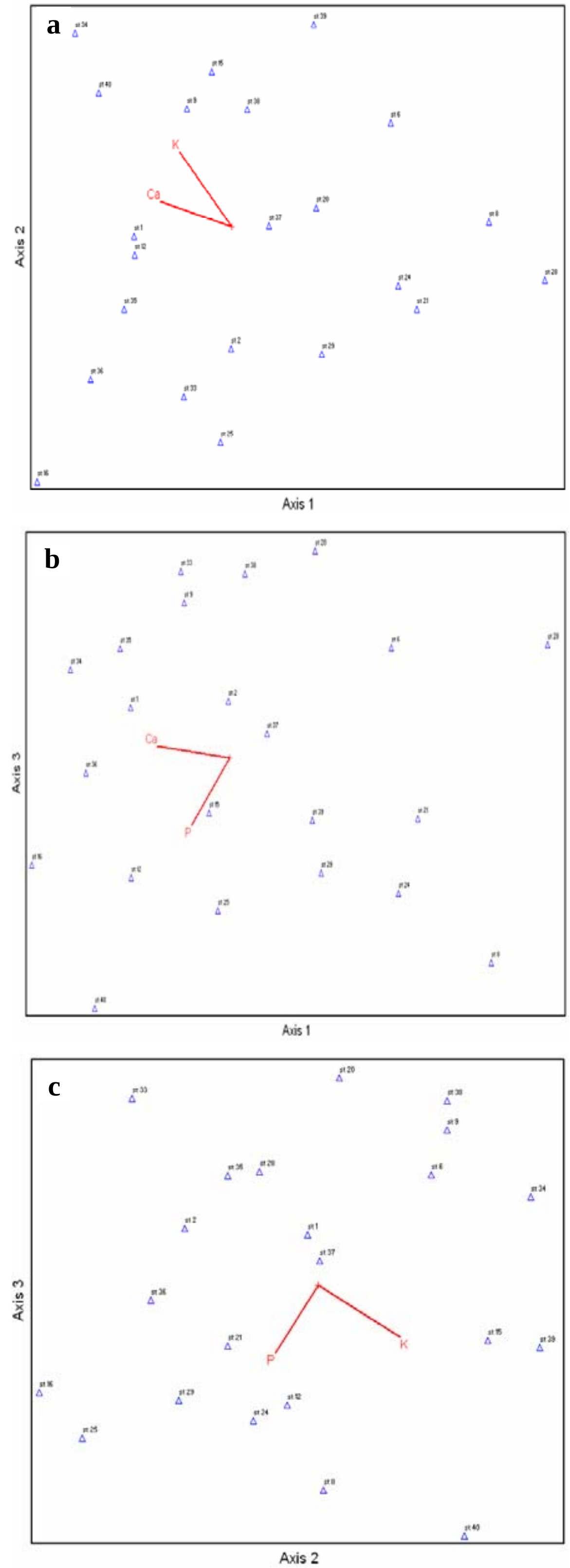

Fig. 9. Two dimensional canonical correspondence analysis (CCA) biplots, showing stand and the correlations (directed lines) of *Cedrus deodara* nutrients with the soil variables. (a) axis 1-2, (b) 1-3 and (c) 2-3.

Malik *et al.,* (2007) recorded K in tissues of *Cedrus deodara* in the range 100 to 500 ppm in Pir Chinasi hills (moist temperate area), Azad Kashmir while Sheikh & Kumar (2010) reported exchangeable K as 188.92 kg ha^{-1} in oak forest and 166.43 kg ha^{-1} in pine forest in Garhwal, Himalaya. In the present study the range of K concentration was 0.481 to 2.76% in the three conifers while its concentration in corresponding soils was 0.324 to 1.563% which seems adequate for conifer growth.

In this study the range of Ca concentration was 0.325 to 1.875% in three conifers while its concentration in soil was 0.132 to 0.978% which is comparable to those estimated by other workers (Tareen & Qadir, 2000). The range of Mg concentration was 0.328 to 1.854% in three conifers and its concentration in soil was 0.223 to 0.852% whereas Qadir & Ahmed (1989) found Mg content of 1.46 % from the soil of Hazargangi National Park Quetta. The observed differences between these two studies could be due to differences in soils under differing parent rocks. In addition, the two areas are climatically different; the former is dry temperate area while the latter is a moist temperate area.

Information available on S content of conifers is meager. Turner & Lambert (1979) found that S deficiencies were more common on basalt parent materials, as demonstrated in the present study where underlying bed-rock in some localities comprises of basalt. Foliar S dilution following N treatments has also been demonstrated in other studies (Turner & Lambert, 1979; Hayek *et al.,* 1999). Although Critical Range (CR), Deviation from Optimal Percentage (DOP), Nutrient Element Balance (NEB) and Diagnosis and Recommendation Integrated System (DRIS) have been proposed as useful conceptual procedures for evaluating foliage nutrient regimes, they have certain disadvantages such as ignoring the interactions between nutrient elements (Luyssaert *et al.,* 2004). Currently, in the area surveyed the paucity of data does not permit any of these conceptual systems to be applied and monitored on a regular basis. Our study provides the necessary fundamental data that can be extended by further investigations.

As far as micro-nutrients are concerned, the maximum concentrations of Na, Fe, Mn and Cu were recorded from the tissues of *Abies pindrow* while the minimum concentrations of Zn and Cu were also recorded from the tissues of the same species. Because of the low concentrations of micronutrient requirements, such variation seems to be attributable to a random component and at this stage hard to interpret Taiz & Zeiger (2002).

Moore *et al.,* (2004) working with four conifer species concluded that micronutrients were more variables than macronutrients, and it may be impractical to collect sufficient samples to produce adequate precise foliar concentration estimates from them, especially for Mn and Mo. Moore *et al.,* (2004) reported high concentration of nutrients of Zn in Ponderosa pine and Lodgepole pine. Since retranslocation of nutrients is usually low the nutrients capital in existing foliage constitute a long term nutrient reserve for the tree rather than a mobile nutrient pool (Everett & Thran, 1992).

Correlation structure: Species specific differences with regard to correlation between foliar and soil nutrients emerged in CA and CCA, while the results derived from the two techniques showed fairly high correspondence, corroborating and confirming the results of each other. *Pinus wallichiana* foliar nutrient complex showed positive correlations with soil N, P, K and Ca, whereas foliar nutrient gradient of *Abies pindrow* exhibited positive association with soil N, S and Ca. On the other hand, *Cedrus deodara* foliar nutrient status was correlated with soil P, K and Ca regime. Often soil Ca is found highly correlated with tissue N (Gégout & Houllier, 1996). Kutbay (2000) also found some important correlations between leaf and soil nutrient concentrations. The results of CCA can be considered more reliable than those of CA on the grounds that CA completely ignores the common covariance structure of foliar and soil nutrient data matrices.

Canonical correspondence analysis (CCA) is currently one of the most popular ordination techniques in community ecology. CCA has usually been used as an exploratory statistical technique to expose the vegetation-environmental relationships and to classify forest sites (Gégout & Houllier, 1996; McCune & Grace, 2002). The method is useful in detecting ecological gradients such as nutrient availability for particular species as observed in the present study. In the present context where it is used for disentangling the relationships between foliar and soil nutrients it allows an expression of foliar nutrient gradients, followed by an independent assessment of the importance of the soil nutrient variables (McCune & Grace, 2002). CCA does not explicitly calculate a distance matrix. But CCA, like CA and DCA, is implicitly based on the chi-squared distance measure where samples are weighted according to their totals (Minchin, 1987). This gives high weight to nutrients whose magnitude in the data matrix is low, thus exaggerating the distinctiveness of samples containing nutrients with low values such as micronutrients (Minchin, 1987).

In most previous studies of similar nature attention has been focused solely on foliar nutrients. Our results of foliar nutrients could be interpreted in greater depth with the integration of soil nutrient variables like N, P and K etc. which are the key determinants of species distribution patterns in other areas (Elgersma & Dhillion, 2002). Cutting, harvesting, grazing and other disturbances within stands can cause disturbance of soils and thereby soil nutritional characteristics and their availability. Nonetheless, under reasonable assumption of homogeneous disturbance (i.e. of same intensity and duration) along the ecological gradients, probably does not modify their ecological optimum, but presumably reduces the ecological interpretation and the projected dispersion on the CCA axes. Keeping this in view, still we found sufficiently high values of e_m *(CCA / CA).*

References

Ahmed, M., S.S. Shaukat and A.A. Buzdar. 1990. Population structure and dynamics of *Juniperus excelsa* in Balouchistan, Pakistan. *J. Veg. Sci*., 1: 271-276.

Anderson, K.A. 1996. Micro-digestion and ICP-AES Analysis for the determination of macro and micro elements in plant tissues. *Atom. Spectrosc*., 17: 30-33.

Ballard, T.M. and R.E. Carter. 1986. *Evaluating forest stand nutrient status*. B.C. Ministry of Forests, Victoria, B.C. Land Management Report No. 20.

Bates, T.E. 1971. Factors affecting critical nutrient concentrations in plants and their evaluation: A review. *Soil Sci.,* 112(2): 116-130.

Bell, R.H.V. 1982. *The effect of soil nutrient availability on community structure in African ecosystem*. In: *Ecological studies 42: Ecology of Tropical Savannas*. (Eds.): B.J. Huntley, B.H. Walker. Springer, Berlin, 193-216 p.

Binkly, D. and P.M. Vitousek. 1989. *Soil nutrient availability*. In: (Eds.): Pearey, R.W., J. Ehleringer, N.A. Mooney, P.W. Rundel. Plant physiological Field Methods and Instrumentation London; Chapman and Hall, 75-96 p.

Brockley, R.P. and F.J. Sherman. 1994. Foliar nutrient status and fascicle weight of Lodgepole pine after nitrogen and sulphur fertilization in the interior of British Columbia. *Can. J. For. Res.,* 24: 792-803.

Chapman, J.L. and M.J. Reiss. 1992. *Ecology: Principles and applications*. Cambridge University Press, Cambridge.

Duarte, C.M. 1990. *Seagrass nutrient content*. Marine Ecol. Prog. Series. 67: 201-207.

Elgersma, A.M. and S.S. Dhillion. 2002. Geographical variability of relationships between forest communities and soil nutrients along a temperature-fertility gradient in Norway. *For. Ecol. Manage*., 158: 155-168.

Everett, R.L. and D.F. Thran. 1992. Nutrient dynamics in single leaf pinyon (*Pinus monophylla* Torr & Frem.) needles. *Tree Physiol*., 10: 59-68.

Gégout, J.C. and F. Houllier. 1996. Canonical correspondence analysis for forest site classification. A case study. *Ann. Sci. For*., 53: 981-990.

Hayek, J.C., J.A. Moore and J.M. Mandzak. 1999. *Multi-nutrient Fertilization Responses Differs by Rock Type in Central Idaho Forests*. IFTNC Supplemental Report No. 4. University of Idaho, Moscow.

Hill, M.O. 1973. Reciprocal averaging: An eigenvector method of ordination. *J. Ecol.,* 61: 237-249.

Holdridge, L.R. 1947. Determination of world plant formations from simple climatic data. *Science*, 105: 367-368.

Horneck, D.A. and R.O. Miller. 1998. *Determination of total nitrogen*. p. 75-83. In: *Soil and Plant Analysis*. (Ed.): Kalra, V.P. CRC Press Boca Raton, F.L.

Ilorkar, V.M. and N.G. Totey. 2001. Floristic diversity and soil studies in Navegaon National Park (Maharashtra). *Ind. J. For.,* 24: 442-447.

Johnston, A.E. 1986. Soil organic matter; effects on soil and crops. *Soil Use Manage*., 2: 97-105.

Jones, J.B.Jr. 1983. *A Guide for the Hydroponic and Soilless Culture Grower*. Timber Press, Beaverton Oregon. pp. 124.

Krzic, M., T.M. Ballard, K. Broersma and R.F. Newman. 2001. Lodgepole pine nutrition and growth on grazed forest cutblocks in southern British Columbia. *B C. J. Ecosys. Manage.,* 1: 1-8.

Kutbay, H.G. 2000. Sclerophylly in *Fraxinus angustifolia* Vahl. subsp. *oxycarpa* (Bieb. ex Willd.) Franco & Rocha Afonso and *Laurus nobilis* L., and edaphic relations of these species. *Turk. J. Bot.,* 24: 113-119.

Luyssaert, S., M. Sulkava, H. Raitioa and J. Hollme. 2004. Evaluation of forest nutrition based on large-scale foliar surveys: are nutrition profiles the way of the future? *J. Environ. Monit.*, 6: 160-167.

Malik, N.Z., M. Arshad and S.N. Mirza. 2007. Phytosociological attributes of different plant communities of Pir Chinasi hills of Azad Jammu and Kashmir. *Inter. J. Agric. & Biol.*, 9: 569-574.

McCune, B. and J.B. Grace. 2002. *Analysis of Ecological Communities*. MjM Software, Gleneden Beach, Oregon. 97388.

McJannet, C.L., P.A. Keddy and F.R. Pick. 1995. Nitrogen and phosphorus tissue concentration in 41 wetland plants: a comparison across habitats and functional groups. *Func. Ecol.,* 9: 231-238.

Minchin, P.R. 1987. An evaluation of the relative robustness of techniques for ecological ordination. *Vegetatio.* 69: 89-107.

Moore, J.A., P.G. Mika, T.M. Shaw and M.I. Garrison-Johnston. 2004. Foliar nutrient characteristics of four conifer species in the interior Northwest United States. *West. J. Appl. For.*, 19: 13-24.

Parent, L.E., W. Natale and N. Ziadi. 2009. Compositional nutrient diagnosis of corn using the Mahalanobis distance as nutrient imbalance index. *Can. J. Soil Sci.,* 89: 383-390.

Pastor, J., J.D. Aber, C.A. McClaugherty and J.M. Metillo. 1984. Aboveground production and N and P cycling along a nitrogen mineralization gradient on Blackhawk Island, Wisconsin. *Ecology*, 65: 256-268.

Paudel, S. and J.P. Sah, 2003. Physiochemical characteristics of soil in tropical sal (*Shorea robusta* Gaertn.) forests in eastern Nepal. *Himalayan J. Sci.,* 1: 107-110.

Peck, J.E. 2010. *Multivariate analysis for community ecologists: Step-by-step using PC-ORD MjM Software Design,* Oregon.

Qadir, S.A. and S. Ahmed. 1989. Phytosociology of woodland communities of Hazarganji National Park, Quetta. *Pak. J. Bot.,* 21: 128-139.

Salisbury, F.B. and C. Ross. 1969. *Plant Physiology*. Wadsworth, Belmont, CA.

Scholes, R.J. 1991. *The influence of soil fertility on the ecology of South Africa dry savannas*. In: *Savanna Ecology and Management. Australian perspectives and intercontinental comparison*. (Ed.): Werner, P.A. Blackwell, London, pp. 71-76.

Sheikh, M.A. and M. Kumar. 2010. Nutrient status and economic analysis in oak and pine forests in Garhwal Himalaya. *J. Amer. Sci.,* 6: 117-122.

Swan, H.S.D. 1972. *Foliar nutrient concentrations in lodgepole pine as indicators of tree nutrient status and fertilizer requirement*. Pulp Pap. Res Inst Can, Woodlands Rep. pp. 42. 19.

Taiz, L. and E. Zeiger. 2002. *Plant physiology*. 3rd ed. Sinauer Associates, Georgia

Tareen, R.B. and S.A. Qadir. 2000. Phytosociology of the plains of diverse area ranging from Harnai, Sinjawi to Duki Regions of Pakistan. *Pak. J. Biol Sci*., 3: 21-35.

Ter Braak, C.J.F. 1986. Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. *Ecology,* 67: 1167-1179.

Turner, J. and M.J. Lambert. 1979. *Sulfur nutrition of conifers in relation to response to fertilizer nitrogen, to fungal infections and to soil parent materials*. In: *Forest soils and land use*. (Ed.): Youngberg, C.T. Proceedings of the 5th North Am. forest soils conf., Colorado State Univ., Ft. Collins, pp. 546-564.

Walworth, J.L. and M.E. Sumner. 1987. The diagnosis and recommendation integrated system (DRIS). *Adv. Soil Sci.,* NY. 6: 149-188.

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