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AGE AND GROWTH RATES OF DOMINANT CONIFERS FROM MOIST TEMPERATE AREAS OF HIMALAYAN AND HINDUKUSH REGION OF PAKISTAN

MUHAMMAD FAHEEM SIDDIQUI[1]*, SYED SHAHID SHAUKAT[2], MOINUDDIN AHMED[2*], NASRULLAH KHAN[3] AND IMRAN AHMED KHAN[4]

[1]*Department of Botany, University of Karachi, Pakistan*
[2]*Laboratory of Dendrochrolonogy and Plant Ecology, Department of Botany, Federal Urdu University, Pakistan*
[3]*Department of Botany, University of Malakand at Chakdara, Dir Lower, Pakistan*
[4]*Department of Geography, University of Karachi, Karachi 75270, Pakistan*
**Corresponding author e-mail: mfsiddiqui2011@yahoo.com*

Abstract

Dendrochronological studies were conducted based on the data of 41 different mature stands of moist temperate areas of southern Himalayan and Hindukush region of Pakistan. Wood samples as cores were obtained from 222 trees including those of *Pinus wallichiana* A.B. Jackson, *Abies pindrow* Royle, *Cedrus deodara* (Roxb.) G. Don., *Picea smithiana* (Wall.) Boiss., and *Taxus fuana* Nan Li & R.R. Mill., using an increment borer. Age and growth rates of these trees were estimated. Correlations were sought between the diameter / age, diameter / growth rate and age and growth rate on the basis individual stands and on an overall basis. More than 50% correlations were found to be significant. Relationship between the growth rate of dominant conifer species with environmental factors (soil nutrients, edaphic factors and topographic factors) was also sought. In general, they disclosed poor relationships. Growth rate of *Abies pindrow* showed weak correlation ($p<0.1$) with salinity, total dissolved salts and water holding capacity while that of *Cedrus deodara* also exhibited weak correlation ($p<0.1$) only with total nitrogen of soil. These significant correlations did not show any particular trend of growth and development of dominant conifer species and may be spurious. *Pinus wallichiana* is widely distributed species in the moist temperate area but its growth rate did not exhibit any relationship with the measured environmental variables. It is shown that largest tree, in terms of diameter, is not necessarily the oldest. Highest growth rate (1.7 ± 0.5 years/cm) was recorded for *Pinus wallichiana* while slowest growth rate (8.4 ± 0.7 years/cm) was recorded for C*edrus deodara*.

Introduction

Dendrochronological investigations are frequently used in silviculture, forestry, ecology, structure and population dynamics studies. Initially Champion *et al.,* (1965); Khan (1968) and Sheikh (1985) estimated the age of some trees from different mountainous areas of Pakistan but they did their estimates of age and growth rates were imprecise due to lack of application of modern dendrochronological techniques. Despite the enormous importance of age and growth rate estimates, there are a few published data available for Pakistani tree species. Ahmed (1988a); Ahmed *et al.,* (1990a, 1990b); Ahmed & Sarangzai (1991, 1992) employed dendrochronological techniques to estimate the age and growth rate of trees but the studies were invariably restricted to small geographical locations. The present study is based on a broad sample size and covering a wide area within the moist temperate part of Pakistan.

According to Lafon & Speer (2002) the science of dendrochronology has enhanced our understanding of environmental change, succession and forest stand dynamics. Tree-ring studies in old-growth forests are valuable sources of information regarding the natural history of forest species (Rentch *et al.,* 2003a, b), as well as the natural disturbance dynamics and development patterns for forest types in a region. Currie (1991) advocated that the forest structure and composition are strongly correlated with environmental factors such as climate and topography. Fricker *et al.,* (2006) demonstrated that age structure of a stand provides an understanding of important ecological processes taking place during stand development. The age of trees has been estimated by historical records, estimation from tree size, ring counting at breast height and ground level, pith node counting, and dendrochronological cross dating (Cook & Kairiukstis, 2010). Nonetheless, no attempt is made to correlate the growth rate of conifer species with the environmental factors. The objects of the current study were: 1) to estimate the age and growth rates of five conifer species including *Pinus wallichiana*, *Abies pindrow*, *Cedrus deodara*, *Picea smithiana*, and *Taxus fuana* using cores obtained from 41 stands sampled in the study area, 2) to disclose the relationships, if any between diameter / age, diameter / growth rate and age / growth rate of the dominant conifer species on individual stand basis as well as on an overall basis, 3) to seek correlations between growth rate and soil nutrients and to model the meaningful relationships in the form of regression equations.

Materials and Methods

Dendrochronology: Forty-one different sites, dominated by conifers were selected in the range of moist temperate area for coring the selected tree species, namely *Pinus wallichiana*, *Abies pindrow*, *Cedrus deodara*, *Picea smithiana* and *Taxus fuana*. Diameter at breast height (dbh) of trees in the stands was recorded. For coring purpose trees were selected randomly to estimate age and growth rate. However, only healthy and straight growing trees were sampled. Wood samples of certain species were not collected from all the forty-one stands because of the following reasons: 1) the slope was steep enough to prohibit coring of the tree trunk, 2) the tree species was rare in the particular forest, 3) some trees release a large quantity of resin upon coring, thereby restricting the coring activity and 4) the particular species was absent in the stand area.

Coring techniques and sample preparation were carried out in accordance with the methods outlined by Stokes & Smiley (1996). A total 222 cores from the five selected conifer species were obtained from the 41 old growth moist temperate stands, ignoring small trees (<10 cm dbh). Dendrochronological methods (Fritts, 2001) were followed for the determination of ages and growth rates of dominant conifer trees. Since ring boundaries and annual nature of rings of angiospermic trees of Pakistan are not determined, therefore only gymnosperms are included in age and growth rate studies. Samples were taken from those conifer trees which were sound**,** free from severe competition and situated on dry ground. At least two cores (uphill and down hill) per tree were taken using a hand operated Swedish increment borer**.** The diameter at breast height (dbh) and the height of the core were measured and the bark thickness was recorded on four sides of each tree using a Swedish bark gauge**.** Every sampled tree and core was numbered. The core was kept in drinking straws to prevent possible damage and was air dried. Later**,** the cores were glued in a grooved mount so that tracheids were in a vertical position and were allowed to dry. These cores were sanded with a sanding machine and progressively finer grades of sand papers were utilized until a suitable polished surface was achieved**.** An attempt was made to establish cross-dating visually under the variable power binocular microscope following the method explained by Stokes & Smiley (1996). The radial uniformity of the tree, and the ring-width pattern of the site**,** was checked by cross-matching the cores between the same tree and among different trees. During this process missing rings and false rings were identified in their correct sequence and each ring was properly dated in the year of its formation**.** Few sections were obtained from breast height on small saplings in each stand**.** The rings on these sections were counted. It was assumed that the average height, growth rate shown by these saplings could be used to approximate the time required for the tree to reach the height at which wood samples were taken (Ogden, 1981)**.** These years were added to the age of each core to obtain the total age of the tree**.** In most cases**,** cores do not pass through the center or pith of the tree so, following Ogden (1980)**,** an allowance was made to calculate the number of rings in the missing portion of the core**.** The missing radius was obtained by subtracting the core length from the crude radius of the tree and the missing years were calculated from the growth rate of the innermost twenty rings and added to the total age of the core. In this case the "reliability" of the core was also calculated by dividing the core length by the crude radius and expressing it as a percentage. This measure gives an approximate idea of how near the end of the core is to the presumed tree center and hence how reliable the age estimate is. The length of the core was divided by the number of rings present in the core and the average growth rate in centimeter per year was calculated.

Soil nutrients: Essential nutrients of soils from 41 stands were analyzed. Five to six soil samples were randomly collected from each stand to a depth of 25cm using a soil auger and pooled to make a composite soil sample. Some parameters were measured in the field (see below). Soil samples were stored in labeled polythene bags and brought to the laboratory for analysis. In laboratory the soils were air dried, passed through a 2 mm (10 mesh) sieve size and again stored in clean plastic bottles. Subsequently, these soils were used for different analyses.

Preparation of the extract: Soil sample (0.4 - 0.5g) was digested with the mixture of 6ml $HClO_4$- HF (1:2) on hot plate at about 195ºC till dried. Cool acidified with HNO_3 (2 ml) and then distilled water was added. It was warm enough to dissolve all salts and cooled again and the solution was made up to 100 ml with deionized distilled water.

Estimation of Calcium, Magnesium, Sodium and Potassium: Hitachi Z-8000 atomic absorption Spectrophotometer with Zeeman background correction and a data processor was used for elemental analysis. All the parameters were set according to the manufactures instructions using flame atomization. The dilution of standard and the test solutions were made such as to keep the concentrations within the linear range of absorbance. Estimation of all elements was made against their respective standard solutions. The concentration was determined by the following formula:

$$\text{Concentration of element (\%)} = \frac{X \times A \times B}{C \times 10000}$$

where,
X = observed concentration (ppm), A = original volume
B = dilution factor and C = weight of sample

Estimation of nitrogen, phosphorus, organic matter and water holding capacity: Kjeldahl method was used for analysis of soil N (Horneck & Miller, 1998) while the method outlined by Tan (1996) used for the analysis of soluble phosphorus. Organic matter of soil was estimated in by the loss-on-ignition method (Heiri *et al.,* 2001) after making allowance for carbonate and clay content. The maximum water holding capacity was determined in accordance with the method of Keen (1931) as modified by Shaukat *et al.,* (1976).

Other soil characteristics: Total dissolved salts, pH (1:5 soil: distilled water), Salinity and Conductivity were measured in the field with the portable instrument, Multiparameter [Model Sension TM 105, U.K].

Topographic measurements: GPS was used to record elevation, position of stands**,** while degree of slope was recorded from clinometer, aspect estimated by Compass and canopy of trees was also recorded by observing the forest richness.

Statistical analysis: Data were subjected to statistical analysis following Zar (1998). Correlation and regression analyses were performed to seek the relationship between diameter / age, diameter / growth rate and age / growth rate. Correlations between growth rate (cm / year) of dominant conifer species with ecological factors (soil nutrients, edaphic factors and topographic factors) were also performed.

Results

Figure 1 shows the main locations (districts), close to the sampling sites. Main locations, sampling sites and topographic factors (elevation, slope angle, aspect and soil compaction of each forest) are presented in Table 1.

Age estimation: Minimum and maximum diameter and age of five conifer species from different sites are shown in Table 2. The oldest tree of *Pinus wallichiana* (229 years) attained 130 cm dbh recorded from Naran valley (stand 39) whiles another old tree (228 years) considerably smaller diameter at breast height (74 cm) was recorded from Ghora Dhaka-3 (stand 18). Fast growing species *Pinus wallichiana* attained 153 cm dbh in 129 years at Neelam valley of Azad Kashmir, while same species from Sudhan Gali-2 takes 112 years to attain the size of 112.8 cm dbh. An age of 46 years was calculated from *Abies pindrow* tree of 61.5 cm dbh, while the oldest tree (325 years) was considerably small-sized tree (77.5 cm dbh) from Malam Jabba-1. The oldest tree (422 years) of *Cedrus deodara* with 127 cm dbh was recorded from Panah Kot, District of Upper Dir. A 74.3 cm dbh tree of *Cedrus deodara* was estimated 314 years old from Thandyani (Abbottabad) while another tree had 35 rings with larger (68.6 cm) dbh, recorded from Khanian, Kaghan valley (stand 36). Oldest tree of *Picea smithiana* (324 yr) with 88.4 cm dbh was recorded from Ghora Dhaka-5 (Hazara division). A large tree (95.4 cm dbh) of *Picea smithiana* with 123 years age was recorded from Naran Valley, while another largest tree of same species attained 247 years with smaller size (114 cm dbh) was recorded from the Paye, Kaghan valley. A rare species *Taxus fuana* cored from one stand (Ghora Gali, Murree) attained maximum age 168 years with 68.4 cm diameter at breast height while 61.8 cm dbh tree of the same species reached 108 years age.

Growth rate estimation: Growth rate (year/cm and cm/year) of five conifer species from different stands of the moist temperate area of Himalayan and Hindukush region of Pakistan are also presented in Table 2. Growth rates are based on all cores of individual species of a particular site. *Pinus wallichiana* showed highest growth rate (1.1 years/cm) from Patriata-1, Murree hills while its lowest growth rate (8.8 years/cm) was recorded from Shinu-2, Kaghan valley. *Abies pindrow* from Kuzah Gali-1(Abbottabad) produced most narrow (11.8 years/cm) rings while it showed wide rings (1.4 year/cm) at Malam Jabba-1, Swat valley. Highest growth rate (1.4 years/cm) of *Cedrus deodara* recorded from two forest, Shinu and Naran, Kaghan valley while the minimum growth rate (10.17 year/cm) recorded from Patriata 1 (stand 12). *Picea smithiana* did not show wide variance in growth rate. Maximum growth (2.4 years/cm) recorded from the tree of Shogran-3 while minimum growth rate (8.6 years/cm) was recorded from a tree at Sri, Kaghan valley. *Taxus fuana* almost showed similar growth rate i.e., 3 years/cm and 4.2 years/cm in Ghora Gali, Murree hills.

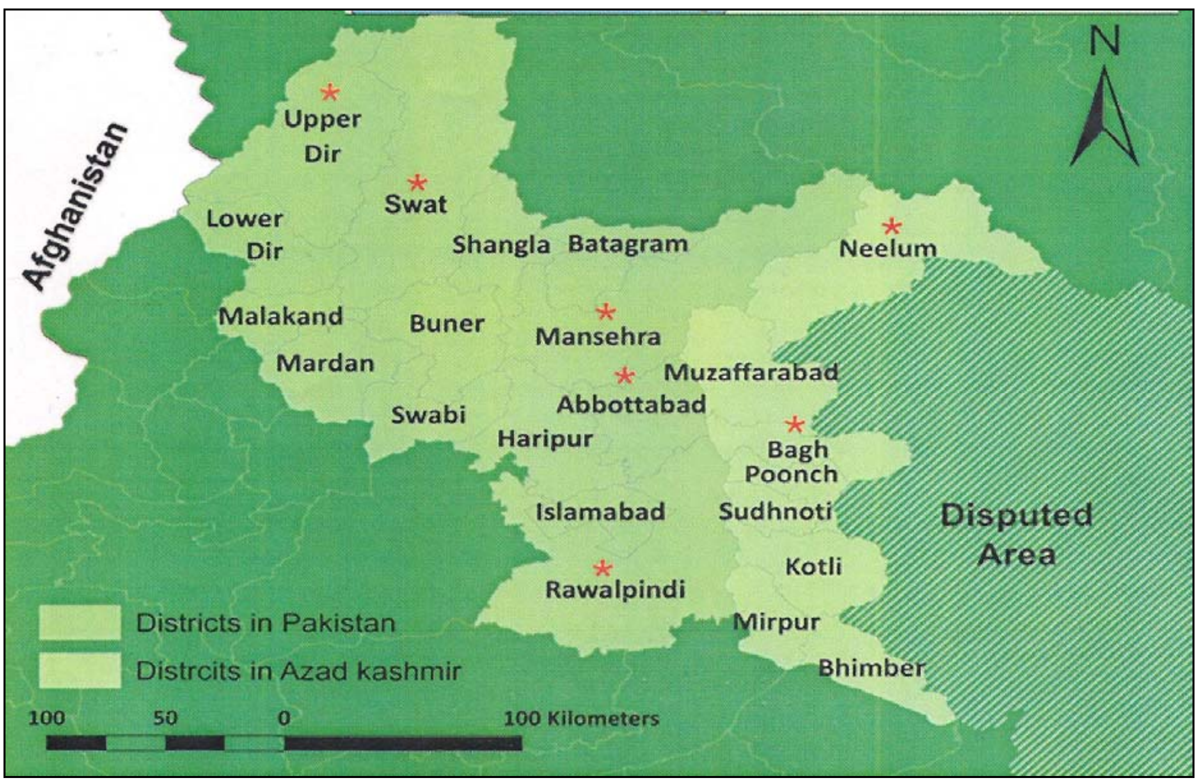

Fig. 1. Study Area Map; * showing the main locations (district) where moist temperate forests were studied (Siddiqui *et al.*, 2011). Details of the sites and stands are given in Table 1.

Table 1. Distribution of conifer species in moist temperate Himalayan and Hindukush region of Pakistan. Site characteristics of the sampling area.

Stand No.	Location and sites	Elevation (m)	Slope (°)	Aspect	Soil compaction (TIP)
	1. Malakand Division				
	(a) Dir Upper				
1.	Kumrat	2400	5	R. Top	165
2.	Pana Kot	2200	40	W	150
	(b) Swat				
3.	Malam Jabba 1	2600	34	W	175
4.	Malam Jabba 2	2350	30	N W	200
5.	Miandam	2600	49	N	150
	2. Azad Kashmir				
6.	Keran, District Neelam	1960	30	N E	250
7.	Chikar, District Baagh	1930	28	N W	150
8.	Sudhan Gali 1,	2450	22	E	200
9.	Sudhan Gali 2	2500	32	N	130
10.	Sudhan Gali 3	2420	38	West	110
	3. Muree, Rawalpindi Division				
11.	Ghora Gali	2100	29	N	150
12.	Patreata Top 1	2300	40	S E	210
13.	Patreata Top 2	2300	25	S W	110
14.	Nia, Near Patriata	2000	39	S	150
15.	Kashmir Point	2500	39	S	150
	4. Abbot Abad, Hazara Division				
16.	Ghora Dhaka 1	2500	36	N E	130
17.	Ghora Dhaka 2	2500	32	S E	170
18.	Ghora Dhaka 3	2800	40	S W	180
19.	Ghora Dhaka 4	2800	40	W	220
20.	Ghora Dhaka 5	2600	37	S W	170
21.	Khaira Gali	2730	42	S E	120
22.	Changla Gali 1	2650	47	W	180
23.	Changla Gali 2	2670	35	S	150
24.	Kuzah Gali 1	2560	5	R. Top	210
25.	Kuzah Gali 2	2560	28	S E	210
26.	Nathia Gali, Lalazar 1	2640	35	S	160
27.	Nathia Gali, Lalazar 2	2630	33	N W	190
28.	Thandyani 1	2320	31	S	140
29.	Thandyani 2	2300	38	S	140
	5. Kaghan Valley, District Mansehra				
30.	Paye	3100	38	S	250
31.	Sri	2900	39	N	90
32.	Shogran 1	2400	27	S W	170
33.	Shogran 2	2400	23	S	190
34.	Shogran 3	2500	33	S	150
35.	Paras, Malkandi Pine Park	1600	20	N E	160
36.	Khanian	2000	35	E	195
37.	Shinu 1, Near Jurait Park	1900	39	N W	180
38.	Shinu 2, Near Jurait Park	1650	43	W	120
39.	Naran, River Belt 1	2500	5	N W	190
40.	Naran, River Belt 2	2500	5	N W	170
41.	Lalazar (Naran)	3000	45	N W	150

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

Table 2. Age and growth rate of individual conifer species in 41 stands of study area.

Stand No.	Number of cores	Sampling Dbh range		Age range		Growth rate year / cm		Growth rate year / cm	Growth rate cm / year
		Min.	Max.	Min.	Max.	Min.	Max.	Mean ± SE	Mean ± SE
	1. *Pinus wallichiana*								
1	2	82.5	93.2	97	101	2.6	2.7	2.65 ± 0.05	0.365 ± 0.005
2	4	38	74.7	49	88	1.6	4	2.8 ± 0.50	0.398 ± 0.083
4	3	56.6	67.8	67	112	1.7	3.6	2.4 ± 0.59	0.45 ± 0.089
6	7	52.2	153.2	91	139	2.2	6.3	3.5 ± 0.73	0.322 ± 0.048
7	4	77.4	88	86	122	2.4	2.8	2.6 ± 0.08	0.388 ± 0.013
8	4	39.1	53.2	42	59	1.3	2	1.7 ± 0.15	0.59 ± 0.062
9	7	67.6	112.8	78	164	1.9	7.4	3.7 ± 0.83	0.333 ± 0.060
10	8	38.2	79.7	69	116	2.2	3.9	2.9 ± 0.30	0.344 ± 0.032
11	4	41.5	80.5	68	113	2.3	3.8	3 ± 0.30	0.345 ± 0.037
12	4	44.8	52.4	36	69	1.1	2.7	1.7 ± 0.50	0.677 ± 0.164
13	3	50.6	61.5	33	71	1.3	2.6	1.8 ± 0.40	0.617 ± 0.119
14	5	22.8	32.6	22	35	1.9	3	2.5 ± 0.32	0.42 ± 0.59
15	5	53.4	65.6	134	181	4.7	5	4.9 ± 0.08	0.205 ± 0.003
17	4	66.8	87.5	94	105	2.7	3	2.8 ± 0.10	0.35 ± 0.015
18	4	74	98.5	91	228	2.8	7	5.5 ± 1.30	0.213 ± 0.068
21	5	57.6	85.7	87	106	2.6	3.5	3.1 ± 0.26	0.32 ± 0.026
22	4	51.2	65.7	97	138	3.2	6.3	4.8 ± 1.55	0.235 ± 0.075
23	4	81.6	91.8	97	99	2.7	2.7	2.7 ± 00	0.36 ± 0
30	5	77.3	74.8	78	88	2.2	2.4	2.3 ± 0.10	0.425 ± 0.015
37	4	62.5	82.5	77	124	2.2	8.8	4.5 ± 2.20	0.98 ± 0.735
39	4	125.5	130	218	229	5.4	5.5	5.5 ± 0.05	0.185 ± 0.005
	2. *Abies pindrow*								
3	7	61.5	104	46	112	1.4	8	4.52 ± 1.12	0.306 ± 0.105
4	3	68.2	102	75	272	2.1	7.6	5.4 ± 1.7	0.25 ± 0.11
5	4	75	79	84	98	2.5	2.7	2.6 ± 0.1	0.375 ± 0.015
8	5	53	65.5	142	189	4.7	5	4.9 ± 0.08	0.198 ± 0.005
9	7	68.8	112	131	185	4.39	7.4	5.3 ± 0.46	0.194 ± 0.012
15	3	67.8	76.5	83	107	3	3.4	3.2 ± 0.12	0.307 ± 0.009
16	4	84.4	95.5	151	232	4.9	7.2	6.2 ± 0.67	0.16 ± 0.021
17	5	76.4	137	108	193	5.3	8.9	7.3 ± 0.76	0.138 ± 0.015
18	4	54.9	91.5	100	159	3.3	4.5	3.7 ± 0.4	0.267 ± 0.024
19	5	75.2	118.8	84	212	2.5	5.8	4.0 ± 0.82	0.278 ± 0.058
20	4	71.5	88.4	176	324	5.8	8.4	7.2 ± 0.76	0.137 ± 0.018
22	3	80.5	135.4	51	188	3.2	5.3	4.6 ± 0.7	0.223 ± 0.043
23	5	112.5	135.6	242	268	7.7	9.1	8.4 ± 0.7	0.115 ± 0.005
24	4	74.4	77.5	100	149	2.6	11.8	7.2 ± 4.6	0.225 ± 0.145
25	4	92.7	133	143	210	4.3	9.7	7.0 ± 1.6	0.157 ± 0.038
26	4	94.6	133	68	184	3.1	6.4	4.6 ± 0.7	0.228 ± 0.036
27	6	62	102	235	272	6.2	9.1	7.4 ± 0.4	0.132 ± 0.007
30	4	47	117.4	65	168	2.8	4.8	3.9 ± 0.42	0.26 ± 0.032
31	3	76.4	117.8	171	252	4.6	9	7.1 ± 1.3	0.15 ± 0.031
32	5	62.4	68.3	109	167	3	4.2	3.6 ± 0.6	0.275 ± 0.045
41	5	62.6	90.3	238	325	6.2	9.1	7.6 ± 0.6	0.128 ± 0.009

Table 2. (Cont'd.).

Stand No.	Number of cores	Sampling Dbh range		Age range		Growth rate year / cm		Growth rate year / cm	Growth rate cm / year
		Min.	Max.	Min.	Max.	Min.	Max.	Mean ± SE	Mean ± SE
	3. *Cedrus deodara*								
1	9	40.5	85.5	38	178	1.4	4.8	3.2 ± 0.344	0.348 ± 0.051
2	4	113	158	120	422	3.3	7.7	5.5 ± 0.9	0.19 ± 0.036
6	5	74.5	92.5	81	94	2.4	3.7	2.85 ± 0.3	0.348 ± 0.030
12	4	64.5	116.7	37	215	1.47	10.17	4.36 ± 2	0.368 ± 0.120
21	4	63.3	86.4	72	95	2.2	3	2.5 ± 0.25	0.397 ± 0.039
24	3	85.4	104.4	100	197	2.5	7.5	4.3 ± 1.6	0.29 ± 0.081
28	4	74.3	78.2	91	314	2.2	8.9	5.6 ± 3.4	0.275 ± 0.165
29	5	58.8	80.5	82	126	2.4	3.5	3.0 ± 0.3	0.333 ± 0.032
33	4	68.4	97.5	74	158	3	3.6	3.3 ± 0.18	0.293 ± 0.016
34	5	55.7	76.2	66	108	2	2.7	2.4 ± 0.2	0.403 ± 0.044
35	5	80.64	90.56	81	114	2.4	3.6	3.2 ± 0.4	0.32 ± 0.045
36	4	68.6	83.8	35	138	2.8	4.7	3.6 ± 0.6	0.287 ± 0.043
37	4	74.4	103.6	48	110	1.2	3.3	2.6 ± 0.7	0.473 ± 0.178
38	4	76	109	53	237	2.4	4.6	3.3 ± 0.7	0.327 ± 0.060
39	4	41	55	50	66	1.4	3.5	2.3 ± 0.6	0.497 ± 0.124
40	7	53.7	93.8	36	309	1.2	8.2	2.8 ± 2.8	0.52 ± 0.099
	4. *Picea smithiana*								
3	5	70.5	112	80	235	2.9	6.4	7.6 ± 0.59	0.212 ± 0.027
30	6	77.8	114	86	247	3.1	6.8	7.9 ± 0.62	0.218 ± 0.028
31	4	64.4	86.4	31	95	3.4	8.6	5.2 ± 1.7	0.223 ± 0.057
34	5	53.5	68.8	79	127	2.4	5.8	3.7 ± 0.7	0.295 ± 0.053
39	4	69.5	95.4	110	123	3.1	4.1	3.6 ± 0.5	0.275 ± 0.035
	5. *Taxus fuana*								
11	3	61.8	68.4	108	168	3	4.2	3.6 ± 0.6	0.275 ± 0.045

Key to abbreviations: SE = Standard error, dbh = Diameter at breast height

Correlation between diameter / age, diameter / growth rate and age / growth rate of four dominant conifer species in single stand

Diameter/age: Diameter of *Pinus wallichiana* did not show significant correlation with its age (Table 3). *Abies pindrow* in stand 3 and 9 exhibited a positive and negative significant correlations ($p<0.01$) and ($p<0.1$) respectively. In stand 1 and 40 *Cedrus deodara* showed a positive significant correlation at: $p<0.001$ and $p<0.01$ respectively between diameter and age. The coefficient of determination for regression equations (range, 0.82-0.91) of age on dbh in the plots was similar for *Cedrus deodara*. Cores of *Picea smithiana* taken from Paye (stand 30) also showed positive significant correlation ($p<0.01$).

Diameter/growth rate: Some significant relations were obtained between diameter and growth rate (Table 3). No significant correlation was observed between diameter and growth rate of *Pinus wallichiana*. In stand 3 and 27 *Abies pindrow* exhibited negative and positive significant correlation i.e., $p<0.05$ and $p<0.1$ respectively. Diameter and growth rate of *Cedrus deodara* from Kumrat valley (stand 1) showed negative significant correlation ($p<0.05$). *Picea smithiana* of stand 30 (Paye) showed a positive significant correlation ($p<0.02$).

Age/growth rate: Age and growth rate of conifer trees of study area usually showed negative correlations except for *Picea smithiana* which showed positive relationship (Table 3). Age and growth rate of *Pinus wallichiana* from Sudhan Gali-2 showed weak correlation ($p<0.1$). *Abies pindrow* from three locations viz., Malam Jabba-1, Sudhan Gali-2 and Nathia Gali-2 showed significant correlation at: $p<0.01$, $p<0.01$ and $p<0.05$ respectively. *Cedrus deodara* from Kumrat and Naran valley showed significant correlation $p<0.05$ and $p<0.02$ respectively. On the other hand, *Picea smithiana* showed a positive significant correlation ($p<0.05$) between age and growth rate for samples obtained from Paye forest (stand 30).

Table 3. Linear regression equation and correlation coefficient between diameter / age, diameter / growth rate and age / growth rate of conifer species in single stands of moist temperate area of Pakistan.

Stand No.	Species	Regression equation (Y value)	Correlation (r value)	Significance level
	1. dbh / age			
1.	*Cedrus deodara*	2.7428x - 68.915	0.91	p<0.001
3.	*Abies pindrow*	1.3292x - 26.768	0.88	p<0.01
6.	*Pinus wallichiana*	0.1581x + 96.544	0.332	ns
9.	*Pinus wallichiana*	0.2362x + 92.65	0.13	ns
9.	*Abies pindrow*	-0.7466x + 231.78	0.68	p<0.1
10.	*Pinus wallichiana*	0.1702x + 82.283	0.122	ns
27.	*Abies pindrow*	-0.1673x + 283.1	0.07	ns
30.	*Picea smithiana*	3.5089x - 162.28	0.8522	p<0.01
40.	*Cedrus deodara*	6.3562x - 357.81	0.8158	p<0.01
	2. dbh / growth rate			
1.	*Cedrus deodara*	-0.0079x + 0.8076	0.678	p<0.05
3.	*Abies pindrow*	-0.0093x + 1.0779	0.729	p<0.05
6.	*Pinus wallichiana*	0.0012x + 0.2033	0.463	ns
9.	*Pinus wallichiana*	0.0021x + 0.1368	0.26	ns
9.	*Abies pindrow*	0.0039x - 0.1035	0.482	ns
10.	*Pinus wallichiana*	0.0022x + 0.2078	0.555	ns
27.	*Abies pindrow*	0.0008x + 0.0643	0.605	p<0.1
30.	*Picea smithiana*	0.0101x - 0.6187	0.861	p<0.02
40.	*Cedrus deodara*	-0.0099x + 1.2166	0.573	ns
	3. age / growth rate			
1.	*Cedrus deodara*	-0.0029x + 0.6096	0.747	p<0.05
3.	*Abies pindrow*	-0.0093x + 1.0779	0.849	p<0.01
6.	*Pinus wallichiana*	-0.0021x + 0.5454	0.388	ns
9.	*Pinus wallichiana*	-0.0027x + 0.6356	0.653	p<0.1
9.	*Abies pindrow*	-0.0061x + 1.2458	0.839	p<0.01
10.	*Pinus wallichiana*	-0.0001x + 0.349	0.046	ns
27.	*Abies pindrow*	-0.0004x + 0.244	0.767	p<0.05
30.	*Picea smithiana*	0.0022x - 0.0392	0.741	p<0.05
40.	*Cedrus deodara*	-0.0018x + 0.6843	0.8198	p<0.02

Key to abbreviations: dbh = diameter at breast height.
Note: More than six sample sized stands were used to investigate the correlation

Correlation between diameter / age, diameter / growth rate and age / growth rate of four dominant conifer species on overall basis: The above mentioned correlations of conifer species of all forests (total stands) of moist temperate area are presented in Table 4. Diameter of *Pinus wallichiana* showed a positive highly significant correlation ($p<0.001$) with age while relationship between age/growth rate were also found to be negatively significant at $p<0.001$. A highly negative significant correlation ($p<0.001$) was observed between age and growth rate of *Abies pindrow* and dbh/growth rate at $p<0.05$. *Cedrus deodara* exhibited highly significant correlation (positive and negative) between diameter/age and age/growth rate ($p<0.001$). Another negative significant correlation ($p<0.01$) was observed between diameter and growth rate of same species. *Picea smithiana* was poorly correlated in all three parameters but a correlation between dbh/age ($p<0.01$) and between diameter/growth rate ($p<0.05$) was found.

Correlation of conifers growth rate with ecological factors (soil nutrients, edaphic and topographic factors): Relationship between conifers growth rate and ecological factors (Table 5) generally showed poor correlations. Growth rate of *Pinus wallichiana* did not show any significant correlation with ecological variables while *Cedrus deodara* exhibited weak correlation ($p<0.1$) with soil nitrogen. *Abies pindrow* also showed weak correlations ($p<0.1$) with salinity, total dissolved salts and water holding capacity. *Picea smithiana* and *Taxus fuana* excluded from this section due to small sample size.

Multiple regression analysis: The results of multiple regression analyses are presented in Table 6. The table of simple correlations between growth rate of *Pinus wallichiana* and the soil nutrients show that none of the independent variable is significantly correlated with the growth rate, consequently the overall regression for *P. wallichiana* is non-significant as depicted by ANOVA table (Table 6a). The results for *Abies pindrow*, given in Table 6b, showed that individual correlations of the nutrient variables with growth rate are not significant. The F-ratio for the regression is also non-significant. However some soil variables such as calcium and phosphorus have high weights in the regression equation. The overall multiple regressions are non-significant. The results outlined for *Cedrus deodara* (Table 6c) disclose that the individual variables are non-significant. However, R^2 value is high indicating some dependence of the growth of *C. deodara* on soil nutrients, particularly soil nitrogen content.

Table 4. Linear regression equation and correlation coefficient between diameter / age, diameter / growth rate and age / growth rate of conifer species in all stands of moist temperate area of Pakistan.

Parameters	n	Regression equation	Correlation (r)	Significance Level
			Pinus wallichiana	
dbh / age	70	y = 1.048x + 24.649	r = 0.5490	p<0.001
dbh / growth rate	70	y = -0.0012x + 0.4846	r = -0.0938	ns
age / growth rate	70	y = -0.0029x + 0.6824	r = -0.44	p<0.001
			Abies pindrow	
dbh / age	74	y = 0.2325x + 147.32	r = 0.0728	ns
dbh / growth rate	74	y = -0.0012x + 0.3161	r = -0.2522	p<0.05
age / growth rate	74	y = -0.0011x + 0.3879	r = -7006	p<0.001
			Cedrus deodara	
dbh / age	61	y = 2.042x - 46.447	r = 0.6067	p<0.001
dbh / growth rate	61	y = -0.0027x + 0.572	r = - 0.3707	p<0.01
age / growth rate	61	y = -0.0015x + 0.5289	r = -0.6859	p<0.001
			Picea smithiana	
dbh / age	14	y = 2.1895x - 51.655	r = 0.6976	p<0.01
dbh / growth rate	14	y = -0.0025x + 0.4497	r = -0.5759	p<0.05
age / growth rate	14	y = -0.0004x + 0.296	r = -0.2728	ns

Key to abbreviations: ns = Non significance

Table 5. Correlation between over all growth rates (cm / year) of dominant conifer species with ecological factors (soil nutrients, edaphic and topographic factors) of moist temperate area.

Serial No.	Variables	r-value	Significance level	r-value	Significance level	r-value	Significance level
		1. *Pinus wallichiana*		**2. *Abies pindrow***		**3. *Cedrus deodara***	
			1. Soil nutrients				
1.	N	-0.1582	ns	0.1095	ns	-0.4271	p<0.1
2.	P	-0.1452	ns	0.0089	ns	0.2286	ns
3.	K	-0.2482	ns	0.0284	ns	0.0095	ns
4.	Ca	-0.1747	ns	0.0387	ns	-0.0191	ns
5.	Mg	0.2718	ns	-0.2887	ns	0.1723	ns
6.	Na	-0.0099	ns	-0.2255	ns	0.2065	ns
			2. Edaphic factor				
7.	Organic matter	-0.0384	ns	-0.1568	ns	-0.0614	ns
8.	Salinity	0.0392	ns	-0.3746	P < 0.1	0.1213	ns
9.	Conductivity	0.2706	ns	-0.1291	ns	0.2227	ns
10.	TDS	0.0317	ns	-0.3901	P < 0.1	0.1310	ns
11.	pH	0.0399	ns	-0.1744	ns	-0.1219	ns
12.	WHC	0.1627	ns	-0.3490	P < 0.1	-0.1665	ns
13.	Soil compaction	0.1006	ns	0.1971	ns	0.0782	ns
			3. Topographic factors				
14.	Elevation	-0.186	ns	0.0682	ns	0.2774	ns
15.	Slope	0.1179	ns	0.1662	ns	-0.3175	ns

Note: Growth rates (mean) were calculated from the cores of 21 stands of *Pinus wallichiana* and *Abies pindrow* while 16 stands of *Cedrus deodara*

Key to abbreviations: TDS = Total dissolved salts and WHC = Water holding capacity

Discussion

In this study age and growth rate of dominant conifer species of moist temperate forest of Himalayan and Hindukush region of Pakistan is evaluated. Particular attention is given to investigate the relationship of age and growth rate with the diameter of trees. Correlations between the growth rate of dominant conifer species with the environmental variables (soil nutrients, edaphic factors and topographic factors) are also investigated to assess the role of environmental variables in the distribution of conifer species as suggested by Currie (1991). Multiple regression analysis was performed to evaluate the role of soil nutrients in the abundance and distribution of three dominant conifer species (*Pinus wallichiana*, *Cedrus deodara* and *Abies pindrow*) in the moist temperate areas. Because of inadequate data, the regression analysis of two species (*Picea amithiana* and *Taxus fauna*) was ignored.

Pederson *et al.*, (2007) evaluated the tree-ring studies and commented that this research has made significant contribution to our understanding of the environmental changes and forest stand dynamics. A variety of environmental factors are often associated with the altitudinal gradient of mountains, and the distribution of a plant species could indicate the adaptability of the plant to such environmental regimes along the gradient. On the limit of the distribution area of a tree population, i.e., timberline on a mountain, some environmental factors often become limiting factors restricting further extension of the population (Block & Treter 2001; Currie, 1991). Since environmental factors are important in governing the dominance of trees in terms of providing adequate nutrition, moisture and light to the tree species, correlations were sought between environmental factors and the growth rate of dominant conifer species. Some environmental factors showed significant correlations with the growth rate which provide evidence regarding the influence of these variables on growth, abundance (prominence) and distribution pattern of these species. Weak correlations between growth rate and environmental variables, in general, are observed for a number of reasons. The foremost is the disturbance factor which alters the dominance. Beside these factors, anthropogenic causes such as logging, fire, overgrazing and cutting of trees also play an important role. Another important factor is competition, both intra-specific and inter-specific, that influences the survival ability of different species to varying extent, thereby resulting in decreased abundance levels depending on the availability of resources, mainly water, nutrients, sunlight and space. Lastly, predation, herbivory and disease are also potential causes of changes in abundance. The combined impact of these factors is subjected to randomness of unknown and varied degree which tends to mask the expected relationship between abundance and nutrient or moisture availability. However in these forests the dominant factor is human disturbance which has a long history.

Table 6. SPSS results of multiple regression analysis of growth rate of three dominant conifer species (*Pinus wallichiana, Abies pindrow* and *Cedrus deodara*) with the soil nutrients.

(6a) *Pinus wallichiana*

Model summary

Model	R	R^2	Adjusted R^2	Std. Error of the estimate	Change statistics					Durbin-Watson
					R^2 Change	F Change	df1	df2	Sig. F Change	
1	0.569(a)	0.323	-0.041	0.18640	0.323	0.888	7	13	0.543	1.778

a Predictors: (Constant), Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, Sodium, Organic matter,
b Dependent variable: Growth rate of *Pinus wallichiana*

ANOVA

Model		Sum of squares	df	Mean square	F	Sig.
	Regression	0.216	7	0.031	0.888	0.543(a)
1	Residual	0.452	13	0.035		
	Total	**0.668**	**20**			

Coefficients

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.	95% Confidence interval for B		Co linearity statistics	
		B	Std. Error	Beta			Lower Bound	Upper bound	Tolerance	VIF
1	(Constant)	0.589	0.345		1.705	0.112	-0.157	1.334		
	Nitrogen	-0.199	0.184	-0.365	-1.081	0.300	-0.598	0.199	0.457	2.189
	Phosphorus	-0.245	0.513	-0.145	-0.477	0.641	-1.353	0.864	0.561	1.782
	Potassium	-0.146	0.085	-0.504	-1.720	0.109	-0.330	0.038	0.605	1.652
	Calcium	-0.164	0.149	-0.272	-1.107	0.288	-0.485	0.156	0.865	1.156
	Magnesium	0.315	0.310	0.280	1.019	0.327	-0.354	0.985	0.689	1.450
	Organic matter	0.001	0.031	0.014	0.045	0.965	-0.065	0.067	0.547	1.827
	Sodium	0.165	0.162	0.355	1.020	0.326	-0.184	0.514	0.429	2.332

Regression equation

$Y = a + b_1 N + b_2 P + b_3 K + b_4 Ca + b_5 Mg + b_6 OM + b_7 Na.$

$Y = 0.589 – 0.199N – 0.245P – 0.146K – 0.164Ca + 0.315Mg + 0.001OM + 0.165Na; R^2 = 0.323$

(6b) *Abies pindrow*

Model summary

Model	R	R square	Adjusted R^2 square	Std. Error of the estimate	Change statistics					Durbin-Watson
					R square Change	F Change	df1	df2	Sig. F Change	
1	0.557(a)	0.310	-0.062	0.07431	0.310	0.834	7	13	0.578	2.482

a Predictors: (Constant), Sodium, Phosphorus, Calcium, Organic matter, Magnesium, Potassium, Nitrogen
b Dependent Variable: Growth rate *Abies pindrow*

ANOVA

Model		Sum of squares	df	Mean square	F	Sig.
	Regression	0.032	7	0.005	0.834	0.578(a)
1	Residual	0.072	13	0.006		
	Total	0.104	20			

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Co linearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	Const.	0.254	0.138		1.842	0.088					
	N	-0.010	0.073	-0.046	-0.134	0.895	0.152	-0.037	-0.031	0.457	2.189
	P	-0.113	0.204	-0.170	-0.554	0.589	-0.256	-0.152	-0.128	0.561	1.782
	K	-0.046	0.034	-0.405	-1.368	0.195	-0.020	-0.355	-0.315	0.605	1.652
	Ca	-0.090	0.059	-0.375	-1.515	0.154	-0.350	-0.387	-0.349	0.865	1.156
	Mg	0.064	0.123	0.143	0.515	0.615	0.178	0.141	0.119	0.689	1.450
	OM	0.008	0.012	0.203	0.651	0.527	0.155	0.178	0.150	0.547	1.827
	Na	0.058	0.064	0.317	0.902	0.384	0.244	0.243	0.208	0.429	2.332

Regression equation

$Y = a + b_1 N + b_2 P + b_3 K + b_4 Ca + b_5 Mg + b_6 OM + b_7 Na.$

$Y = 0.254 – 0.10N – 0.113P – 0.046K – 0.09Ca + 0.64Mg + 0.008OM + 0.058Na; R^2 = 0.310$

(6c) *Cedrus deodara*

Model summary

Model	R	R square	Adjusted square R	Std. Error of the estimate	Change statistics					Durbin-Watson
					R square Change	F Change	df1	df2	Sig. F Change	
1	0.813(a)	0.662	0.366	0.06957	0.662	2.235	7	8	0.141	1.667

a Predictors: (Constant), Sodium, Phosphorus, Calcium, Magnesium, Organic matter, Nitrogen, Potassium

b Dependent Variable: Growth rate *Cedrus deodara*

ANOVA

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	0.076	7	0.011	2.235	0.141(a)
	Residual	0.039	8	0.005		
	Total	0.114	15			

Coefficients (a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Correlations			Co linearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	Const.	0.237	0.171		1.380	0.205	-0.159	0.632					
	N	-0.264	0.082	-0.807	-3.218	0.012	-0.453	-0.075	-0.389	-0.751	-0.662	0.672	1.49
	P	0.164	0.132	0.275	1.245	0.248	-0.140	0.468	0.261	0.403	0.256	0.868	1.15
	K	0.008	0.059	0.037	0.142	0.891	-0.128	0.145	0.025	0.050	0.029	0.614	1.63
	Ca	-0.006	0.026	-0.048	-0.222	0.830	-0.066	0.055	0.037	-0.078	-0.046	0.895	1.12
	Mg	0.176	0.112	0.353	1.569	0.155	-0.083	0.436	0.169	0.485	0.323	0.838	1.19
	OM	-0.020	0.013	-0.425	-1.561	0.157	-0.049	0.010	-0.094	-0.483	-0.321	0.570	1.76
	Na	0.162	0.057	0.716	2.864	0.021	0.032	0.293	0.248	0.712	0.589	0.677	1.48

Regression equation

$Y = a + b_1 N + b_2 P + b_3 K + b_4 Ca + b_5 Mg + b_6 OM + b_7 Na$

$Y = 0.237 – 0.264N + 0.164P + 0.008K – 0.006Ca + 0.176Mg - 0.020OM + 0.162Na; R^2 = 0.662$

Key to abbreviation: VIF = Variance inflated factor and OM = Organic matter of soil

Age estimation: Age of *Pinus gerardiana* trees was estimated by Champion *et al.*, (1965) while Sheikh (1985) recorded the age of *Juniperus excelsa* from Ziarat, Baluchistan but no dendrochronological methods were employed. It is apparent that tree age varies from site to site, species to species, within a species and even in similar sized trees of the same species or different species in an area (Ahmed *et al.*, 2011). Tree ages with their respective diameters as described in the results section agree with the findings of Ahmed *et al.*, (2011). The ages of conifer species with their respective diameter estimated in the present study are similar to those evaluated by the other workers in Pakistan like Ahmed *et al.*, (1991b) reported age of 112 years of *Pinus wallichiana* with 20.5 cm dbh from Takht-e-Sulaiman (dry temperate area) and same age is estimated from an individual of this species having a dbh of 65 cm from Ayubia and 58 cm from Khanspur indicating the fast growth rate in moist temperate conifer forests. Another tree of *Pinus wallichiana* from Murree Hill was 71 years old with 58 cm dbh. Other species of similar diameter also show great variation in their ages at different sites and also different individuals occurring at the same site. *Abies pindrow* showed great variation between age and diameter from Murree area in such a way that 103 years and 150 years old trees attained the diameter of 71.2 and 92 cm respectively while a tree of 11.3 cm dbh achieved the age of 351 years. Maximum age (277 years) of *Abies pindrow* with 89 cm dbh recorded from Ayubia. Ahmed *et al.*, (2009) reported the oldest tree of *Cedrus deodara* (533 years) with 180 cm dbh cored from Ziarat (Drosh) District of Chitral while 319 years old tree of same species had 74 cm dbh that was recorded from the same locality. Largest tree (148 cm dbh) of *Picea smithiana* with 177 years old was recorded from Nalter Valley, while oldest tree (347 years) with smaller size (91 cm dbh) was recorded from the same Valley. In present study fast growing species *Pinus* *wallichiana* attained 164 cm dbh in 85 years at Sudhan Gali of Azad Kashmir, while the same species from same location took 136 years to attain the size of 112 cm dbh. An age of 108 years was calculated for *Abies pindrow* tree of 137 cm dbh, while the oldest tree (228 years) had considerably small diameter (74 cm dbh) from Ayubia, District Abbottabad.

The ages of conifers with respect to their diameter have also been estimated by some workers elsewhere showed good agreement with the current study. Kelly & Larson (1997) reported the age of *Thuja occidentalis* (red-cedar) 701 years from cliff-faces of the Niagara Escarpment, Canada. McCarthy & Weetman (2006) reported the ages of balsam fir *Abies balsamea* (264 years), black spruce (264 years), white spruce (247 years) and white birch (286 years) from Newfoundland's great Northern Peninsula, Canada. They further reported that the live tree size-age relationship, for example that of balsam fir took an average age of 125 years to reach 5 cm in diameter. A further 125 years, however, enabled the trees to grow from 5 to about 28 cm diameter. Youngblood *et al.*, (2004) recorded the maximum age of ponderosa pine from three different locations of California i.e., 618 years at Metolius, 613 years at Pringle Butte and 330 years from Black Mountain. They recorded the mean diameter of live old-growth ponderosa pine of 60.0 ± 1.55 cm, and stated that diameter of old-growth trees did not differ among three different localities.

Growth rate estimation: Fast growth rates and large size of trees seem to be a fitness criterion because of increased competitiveness, attainment of reproductive size earlier, reduction of generation time, and increased short-term survival probability (Bigler & Veblen, 2009). Growth rates of conifer species from the study area disclosed that it varies greatly from species to species, site to site and even among the individuals of the same species from similar site. It depends on the availability of adequate nutrients, suitable environmental conditions and prevention from natural or man made disaster or other disturbances.

Slow and fast growth rates of conifer trees were estimated and compared with earlier studies. Among selected conifers *Abies pindrow* exhibited slowest growth rate which is similar to the results obtained by Ahmed & Sarangzai (1991). They stated that *Abies pindrow* is a slow growing tree of moist temperate areas as confirm in the present study. Ahmed *et al.*, (2009) suggested that *Abies pindrow* and *Taxus fuana* are slow growing trees but in the present study *Taxus fuana* did not show wide variation in growth rate. *Cedrus deodara* occupied second position in the present study followed by *Pinus wallichiana* and then *Picea smithiana* with regard to slow growth rate.

In the current study fastest growth rate of *Pinus wallichiana* was recorded from Patriata-1 while Ahmed & Sarangzai (1992) reported the radial growth of *Pinus wallichiana* (2.5 year / cm) from Murree. Ahmed *et al.*, (2009) also reported highest growth rate of *Pinus wallichiana* (1.7 years/cm) from Shalthalo Bala, (District Dir), they concluded that *Pinus wallichiana* is the fastest growing tree. *Abies pindrow* from Malam Jabba-1 showed the fast growth rate. Fast growth rate of *Cedrus deodara* was recorded from two forests Shinu and Naran while Ahmed & Sarangzai (1991) recorded its fastest growth rate from Swat. Fast growth rate (2.4 years/cm) of *Picea smithiana* was recorded from a tree at Shogran 3.

Correlations of conifer dbh / age; age / growth rate and dbh / growth rate: Trees of equal height and diameter differed in age by as much as 120 years (McCarthy & Weetman, 2006); they concluded that tree size provided minimum indication of the actual chronological age of trees in the old-growth stands. In general, poor relationship was observed between tree age and size.

Tree growth is best understood on an individual tree basis, as trees respond to the stochastic release of growing space, or by simply growing slowly upward into the canopy. This wide variability in the tree size-age-size relationship found in old-growth stands comprised of shade-tolerant tree species is well known (Gates & Nichols 1930; Parish *et al.*, 1999). This general lack of relationship between tree age and size in old stands confirm the established notion that size is generally more important than actual chronological age in assessing reproductive development and stand dynamics (Harper & White 1974; White, 1980). A weak age-dbh relationship in multi-aged communities was observed by Harper (1977).

Despite such observations, some significant correlations were obtained between diameter and age of some conifer species within a single stand as well as on an overall basis. Based on overall data, diameter of *Pinus wallichiana* and *Cedrus deodara* showed highly significant correlation ($p<0.001$) with age while *Picea smithiana* also showed significant correlation ($p<0.01$) in this respect. Our results are in agreement with those of some other workers, e.g., Khan (1968) also found significant correlation between diameter and age of *Pinus wallichiana.* Ahmed (1988b) found significant relationship between diameter and age of some planted tree species in Quetta, Baluchstan. Platt *et al.,* (1988) found positive correlation between diameter and age of *Pinus palustris*. Ahmed & Ogden (1987) obtained significant correlation, but wide variance between these two variables. However, Ahmed *et al.*, (1990b) did not find significant correlation between diameter/age of *Juniperus excelsa* from the forest of Baluchistan, Pakistan. Ahmed and Sarangzai (1991) also obtained significant correlation between diameter and age in nearly all investigated species and sites. However, they also observed wide variance in this respect and concluded that at least in natural forest, diameter is not a good indicator of age. Wahab *et al.*, (2008) did not observe any significant correlation between dbh/age of *Picea smithiana* from the conifer forests of Afghanistan. Ahmed *et al.*, (2009) did not find significant correlation between diameter and age in four conifer species (*Pinus wallichiana, Abies pindrow, Picea smithiana* and *Cedrus deodara*) but they observed significant correlation ($p<0.001$) in *Pinus roxburghii*. Knowles & Grant (1983) estimated the age and diameter of ponderosa pine, lodgepole pine, limber pine and Engelmann spruce from Colorado Front Range of the Rocky Mountains, USA, and found that the diameter distribution curves exhibited patterns markedly different from those of age pattern.

Growth rates in normal condition increase the diameter of conifer trees. In the present study, a few significant correlations were obtained between diameter and growth rate in individual stands as well as on overall basis but most of the correlations were non significant. This observation corresponds with that of Ahmed *et al.,* (1990a) who did not find significant correlation between diameter/growth rate of *Juniperus excelsa* from the forest of Baluchistan, Pakistan. Likewise, Wahab *et al.,* (2008) also did not observe any significant correlation between dbh and growth rate of *Picea smithiana* from the conifer forests of Afghanistan.

Pinus wallichiana, Abies pindrow and *Cedrus deodara* showed highly significant negative correlation between the age and growth rate. This seems to support the view that the growth rate tends to decline with age, particularly when the tree is old. The growth rate of the tree presumably decreases owing mainly to physiological conditions related to old age namely senescence. *Picea smithiana* did not show significant relation in this respect. No significant correlation between age and growth rate of *Picea smithiana* from the conifer forests of Afghanistan (Wahab *et al.,* 2008). However in individual stands many significant relationships were observed between age and growth rate of selected conifer species presumably because of restricted age range and absence of old individuals.

Correlations between conifer growth rate with environmental factors (soil nutrients, edaphic and topographic factors): Soil nutrients, edaphic variables and topographic factors are known to govern the growth rate of conifer species, adequate supply or range of these factors normally increases the growth rates of conifer trees. In contrast to the above statement, poor relationship has been observed between the growth rates of conifer species with the environmental factors. This may be the result of long history of disturbance in these forests. Correlations were sought between the growth rate of three dominant conifer species (*Pinus wallichiana, Abies pindrow* and *Cedrus deodara*) with the measured environmental variables. Correlations for *Picea smithiana* and *Taxus fuana* were not investigated due to small sample size. Though *Pinus wallichiana* is a dominant species in many forests of this study and flourished successfully but could not exhibit any significant relationship with soil nutrients, edaphic and topographic factors. As suggested earlier this could be attributed to a long history of disturbance in these forests. *Cedrus deodara* showed a weak correlation with total nitrogen of soil out of 15 pairs of correlations while Sheriff *et al.,* (1986) observed that nitrogen and phosphorus together increase the stem volume of *Pinus radiata* by 130%. *Abies pindrow* showed weak correlation with edaphic variables of soil (salinity, total dissolved salts and water holding capacity). Presumably these are spurious correlations that do not reflect any particular pattern of conifer vegetation distribution and population dynamics. Only scanty work has been carried out along these lines not only in Pakistan but also elsewhere. Ahmed & Sarangzai (1991) found a negative significant correlation between altitude and growth rate, taking all growth rate values into account but no significant correlation between elevation and growth rate for five conifer species was detected (Ahmed *et al.,* 2009).

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