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TREE-RING CHRONOLOGIES OF *PICEA SMITHIANA* (WALL.) BOISS., AND ITS QUANTITATIVE VEGETATIONAL DESCRIPTION FROM HIMALAYAN RANGE OF PAKISTAN

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Abstract

Modern Dendrochronological techniques were used in 5 stands of moist temperate and dry temperate areas in Pakistan. Out of 91 cores from 60 trees of *Picea smithiana* (Wall.) Boiss., sampled where cross dating was possible among 48 cores. Dated chronologies from 1422 to 1987 AD were obtained. However, common period of all chronologies 1770 to 1850 A.D. is presented. Chronologies and sample statistics are described. These chronologies show from 17% to 33% variance ("Y" in ANOVA) due to climate. Dry temperate sites show low autocorrelation as compared to moist temperate sites.

Due to small sample size, no statistical correlation was observed between community and dendrochronological attributes. However, community attributes gave some idea to select better sites for dendrochronological investigations.

It is suggested that despite difference in climatic zones and chronologies, trees show some similar pattern of ring-width. Hence, *Picea smithiana* (Wall.) Boiss., could be used for dendroclimatological investigations. It is also suggested that detailed sampling is required to present strong database.

Introduction

Ahmed (1987, 1989) explained the scope of dendrochronology in Pakistan, and mentioned suitable sites and tree species, which could be used in tree-ring analysis. He also presented modern tree-ring chronologies of *Abies pindrow* Royle from Himalayan region of Pakistan. A dendrochronological approach to estimate age and growth pattern of various species and dendrochronological potential of a few tree species from the Himalayan region of Pakistan was described by Ahmed & Sarangezai (1991, 1992). Beside these studies, which began so successfully, were not continued over a long period. However, tree-ring research has been extended to our neighbor countries like Iran, Turkey, China, Nepal, Russia and India.

Selection of suitable site and species play most important role in tree-ring research. According to Ahmed (1984) and Schweingruber (1986), species composition of site reflects habitat conditions, which in turn may reflect dendrochronological characteristics (sensitivity). Furthermore, non-climatic factor i.e., slopes, altitude, aspect and competition also influence the growth of tree (Fritts, 1974; Ahmed, 1984). Bearing these points in mind, a phytosociological and structural analysis of the sampling stands was also carried out. This paper presents modern tree-ring chronologies from *Picea smithiana* (Wall.) Boiss., and a quantitative description of the core sampling sites.

Material and Method

Stands of *Picea smithiana* (Wall.) Boiss., were sampled at Nalter, Astor (Gilgit), Kalam and Miandum (Swat). All sampling sites are composed of irregular, rugged and steep slopes. No meteorological data is available from these elevations, however, they received more rainfall and snow than lower height.

Vegetational sampling: At each of the five locations, stands containing *Picea smithiana* (Wall.) Boiss., were sampled with the point centered quarter method of Cottom & Curtis (1956). In each stand, 25 points were taken at 20 m intervals. For including lower vegetation, at each sampling point, 1.5 m in diameter circular plot was established and frequencies of different species were obtained. Phytosociological attributes are described following Mueller Dombois & Ellenberg (1974). The communities were named on the basis of highest importance value of the species.

Dendrochronological sampling: Within each sampling sites, *Picea smithiana* (Wall.) Boiss., trees were selected where growth of trees was expected to be limited by environmental factor i.e., usually on steep slopes. From each site at least 12 trees (2 cores per tree) were cored from sound, mature, healthy, undisturbed and free from severe competition from neighbor trees. Coring, sampling preparation and cross dating procedures were carried out according to the techniques described by Stockes & Smiley (1968). Each polished core was examined under the variable power microscope to locate any locally missing, false rings, and to date ring sequences of each tree sample. These tree samples were then cross-matched among other tree samples of a site.

After cross-dating was obtained between and among the trees of a sites, ring width series of each wood sample (core) was measured to the nearest 0.01 mm using computer program PULSE COUNTER of Robinson & Evans (1980). The following 2 types of statistical analysis were carried out using various computer program (RWLIST-INDEX SUMAC) presented by Fritts, (1976) and Graybill (1979):

1- Chronology statistic in which mean ring-width, mean sensitivity, standard deviation and first-order autocorrelation were calculated for the final summarized ring-width series.

2- Sample statistics, which were obtained using the previously calculated final summarized series in the form of analysis of variance and cross-correlation analysis. In all cases, polynomial curve-fitting techniques were used for standardization to remove low frequency variance.

Results

Vegetative description: The diameter size class distribution of main associated species in each sampling site is shown in Fig. 1. Characteristics of sampling sites, their phytosociological characteristics and site summary are given in Tables 1, 2 and 3 respectively. Most of the stands dominated by 2 tree species only, third tree species is either completely absent or present with low I.V.

Nalter is located on the 33 miles north of the Gilgit city. The highest peak is about 2440 m and the whole area comprised of irregular, rugged and steep terrain. Nearest meteorological station was located at Gilgit on 1482 m height. Records of this station indicates that July is the hottest month with the mean monthly temperature of 36°C, while the coldest month is January with mean monthly temperature of 9.4°C. The annual rainfall is about 152 mm; however, higher elevation received more precipitation in the form of snowfall. Champion *et al*., (1965) described the vegetation of this area but so far, no quantitative work has been published. Two sampling sites were laid on different elevations on the same slope.

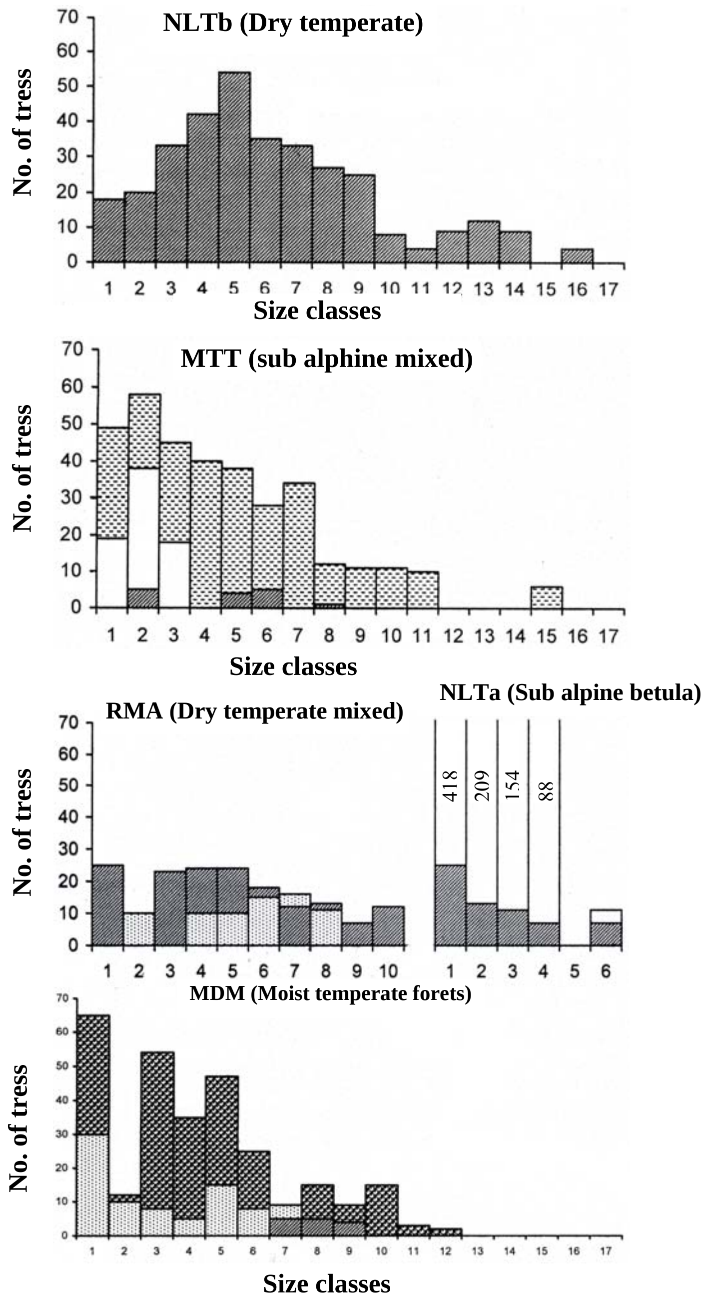

Fig. 1. Diameter size class distribution of tree species from different sampling sites.

Picea smithiana *Abies pindrow* *Pinus wallichiana* *Pinus wallichiana* *Betula utilis*

NLTa: 418, 209, 154 and 88 are the number of Betula trees in different diameter size classes.

Table 1. Characteristics of sampling sites.

Locations	Abbreviations	Latitude S	Longitude E	Altitude m	Slopes (Degree)	Aspect
Nalter	NLT	36°20	74°13	3350 3500	32-38	N
Rama	RMA	35°22	74°51	3100	35	S
Mitiltan	MTT	35°36	72°73	2350	32	W,N
Maindum	MDM	33°34	73°74	2300	18-21	N,S

Table 2. Site summary of vegetation sampling. Relative phytosociological attributes and importance values of first two leading dominant species of 5 *Picea smithiana* forests.

Locations	Name of species	RF[1]	RD[2]	RBA[3]	IV[4]
NLTa	Betula	91	93	85	269
	Picea	8	6	15	29
NLTb	Picea	100	100	100	300
RMA	Picea	53	67	78	198
	P. wallichiana	47	33	18	98
MTT*	Cedrus	56	70	73	199
	Betula	31	21	24	76
MDM*	Abies	72	75	80	227
	P. wallichiana	21	23	18	62

Note: 1=Relative frequency, 2=Relative density, 3=Relative basal area, 4=Importance value. (Percentages have been rounded to nearest whole number).
* The area was represented by a few *Picea smithiana* trees.

Table 3. Site summery of vegetation sampling. Absolute values of 5 *Picea smithiana* forests.

Locations	Density ha^{-1}		Basal area m^2 ha^{-1}	
	SD[1]	PD[2]	SB[3]	PB[4]
NLTa	945	65	39	9
NLTb	333	333	167	167
RMA	227	153	93	72
MTT	408	11*	107	-
MDM	360	10*	76	-

Note: 1. Stand density (SD), **2.** Picea density (PD), **3.** Stand basal area (SD), **4.** Picea basal density (PB).
*Adjusted when sampled for ring-width analysis. Due to small number of Picea in this sites, not fall in sampling point.

***Betula-Picea* community (NLTa):** At higher elevation from 3350 to 3500 m broad leaved *Betula utilis* D.Don., was dominating with a density of 880 stem ha^{-1} and 30 m^2 ha^{-1}basal area. *Picea smithiana* (Wall.) Boiss., was the only other tree species with low density, basal area and importance value. Its many individuals were found to be swollen, rotten, badly damaged and miss shaped near the base. Champion *et al*., (1965) described this area as a sub alpine Betula forest. Above 3500 m, *Betula utilis* D.Don., occupied 100% of the stand density while below 3350 m its density decreased rapidly with increasing number of *Picea smithiana* (Wall.) Boiss., Diameter size class distribution of this stand showed (Fig. 1) skewed unimodel structure with modes in the small (10-20cm) diameter class for *Picea smithiana* (Wall.) Boiss.

Picea smithiana **community (NLTb):** At elevation of 3100 m on the same slope *Betula utilis* D.Don., was completely replaced by *Picea smithiana* (Wall.) Boiss. No other tree species was recorded in this area and the sampling site is described as dry temperate monospecific conifer forest (Champion *et al*., 1965). The areas showed sound, healthy and large sized trees. *Picea smithiana* (Wall.) Boiss., occupied 333 individual ha^{-1} with a basal area of 167 m^2ha^{-1}. Its canopy was closed with tall and huge trees. Twelve percent of trees were found in 10 to 30 cm dbh classes while 24 present in the 50 to 70 cm dbh classes. Below this sampling site, the lower elevation was dominated by mixed conifer species i.e., *Pinus wallichiana* A.B. Jackson and *Abies pindrow* Royle. Ground flora was comprised of 14 species but due to anthropogenic disturbance *Geranium* sp., *Mentha longifolia* (L.) Huds., and *Viola sylvestris* Lam. were recorded in 70% of the sampling plots while *Leotopodium* sp., *Gagia elegans* Wall.ex Royle, *Artemisia bervifolia* Wall.ex DC.and *Juniperus squamata* Buch.Ham.ex Lambert were found from 40 to 50% of the circular plots.

Picea-Pinus **community (RMA):** Astor (RMA), sampling site was located 75 miles from Gilgit around Rama Rest House, closed to Astor city and one of the highest peak Nangaparbat (8128 m). The area lies within the dry temperate zone and characterized as a dry temperate mixed conifer forest (Champion *et al*., 1965). Nearest weather station, Astor (2440 m) showed that July is the hottest (27.2°C monthly maximum) while January is the coldest month (1.7°C mean monthly maximum). Highest relative humidity (80%) occurs in the month of January and lowest (50%) in the month of June. The mean annual rainfall is about 479 mm and most of which is received during the month of February to May.

The community stands on the southern slopes on 3100 m elevation. *Picea smithiana* (Wall.) Boiss., attained a density of 153 stem ha^{-1} and 78% of the relative basal area (Tables 2 and 3). *Pinus wallichiana* A.B. Jackson a co-dominant species occupied less density and basal area. Both species showed gaps in diameter size classes with flattened structure. About 46% of the *Picea smithiana* (Wall.) Boiss., stems were found in 30 to 60 cm dbh classes. Its trees were scattered and canopy was open. The ground flora consisted of 11 species but only 3 species were widely distributed and recorded 70 to 80% of the sampling plots i.e., *Viola sylvestris* Lam., *Fagonia bruguieri* DC., and *Ranunculus molkioides* DC.

Cedrus-Betula **community (MTT):** Matiltan (MTT) glacier is located 10 km north to the Kalam valley in Swat. The sampling sites are located on 2350 m to 2400 m elevation on west and north facing slopes. Meteorological records of this area is not available. The area was dominated by the largest *Cedrus deodara* (Roxb.ex Lamb.) G.Don., trees with a basal area of 82 m^2 ha^{-1}. The size class structure of this species showed large number of individual in small size class (10–20 cm dbh) with a gradual decrease in large size classes. It also indicates big gaps in structure, probably due to cutting. Co-dominant species was *Betula* with 75 stem ha^{-1} and a basal area of 24 m^2 ha^{-1}., broad leaved species *Quercus incana* Roxb., attained low importance value. The area may be characterized as a sub alpine mixed forest. In this community *Picea smithiana* (Wall.) Boiss., were distributed either as a solitary or in a group of a few individual on steep slopes, therefore, it could not be included during vegetational sampling. However, 11 trees were sampled (cored) in this area. Ground flora was poor, scattered and consisted of a species in which

Alliaria petiolata L., *Rosa macrophylla* Lindl., and *Fragania nubicola* Lindle. ex Lacaita were recorded in 50 to 60% of the circular plots.

***Abies-Pinus* community (MDM):** Miandum (MDM) is located (2300 m elevation) near Mazam kareen (Swat) on north and south facing slopes. Sampling area fall under moist temperate conifer forest of Champion *et al*., (1965). Meteorological data from (Miandum) is not available.

In this community, broad-leaved species are extremely rare due to anthropogenic disturbance. Canopy was closed with a thick and dense ground flora. *Abies pindrow* Royle was the dominant species. Its 274 individual ha^{-1} occupied 62 m^2 ha^{-1} basal area. *Pinus wallichiana* A.B. Jackson a co-dominant species was represented by 96 individual ha^{-1} with 18% of relative basal area. A few individual of *Picea smithiana* (Wall.) Boiss., were also observed in a group on steep slopes, therefore, was not possible to include in the vegetation sampling. However, wood samples (cores) were obtained from these trees. Diameter size class distribution of this stand showed that both dominant species have higher number of individual in small size class. Ground vegetation consisted 14 species in which *Adiantumcapillus-veneris* L., and *Ranunculus muricatus* L., were recorded in 90 to 100% of the plots. *Adiantum incisum* Forssk*., Geum vibernum* L.*, Bellis perennis* L.*, Galium elegans* DC.*, Hedera nepalensis* K. Koch., and *Chrysanthemum leucanthemun* L. were distributed in 50-60% of the circular plots.

Dendrochronological description

Ring-width characteristics: Site characteristics, phytosociological attributes and structure of sampling forests are described earlier. Wood samples collected from highest elevation (3350-3500 m) from *Betula* community produced extremely narrow rings. Radial uniformity was good but locally missing rings and apparently frost-damaged rings were encountered during investigation. In these samples cross matching was poor and in most case uncertain. Consequently, these samples were not included in further analysis.

Samples collected from the lower elevation (3100 m) from the same area (NLTb), gave distinct ring-width sequence, with no missing or double rings. Most trees were large, sound and healthy. The circuit and radial uniformity of these wood samples were excellent. Trees growing at this location produced sensitive rings and cross-matched among other trees. There 14 trees were selected for measurement.

Picea smithiana (Wall.) Boiss., growing with *Pinus wallichiana* A.B. Jackson on further lower elevation grow fast with complacement rings, were not suitable for cross dating. At Astor around Rama Rest House (3100 m), individuals of *Picea smithiana* (Wall.) Boiss., were smaller and shorter than in Nalter area. Sensitive ring sequence occurred in trees growing on NW facing slopes. Ring boundaries were distinct and clear. Trees had good radial and circuit uniformity. A few trees were rejected on the basis of frost damaged rings, however, 10 tree samples were included for further analysis.

Kalam and Miandum sampling sites were located on same elevation and aspect. Mean ring-width of these trees were also similar to the other sampling site (Table 4). Tree growing on moist site showed complacent and wide rings. Sample size in this area was small. In cross-matched tree samples, dating before 1800A.D. was uncertain due to the bands of narrow and uncountable rings. Therefore, the period before 1800 A.D was not included in further studies.

Table 4. Chronology statistics for 4 sites. 1. Autocorrelation, MS[2] = Mean sensitivity SD[3] = Standard deviation AbS[4] = Percentage missing rings MRW[5] = Mean width in mm.

Abbreviation	No. of Trees	No. of Cores	Period A.D	AC[1]	MS[2]	SD[3]	AbS[4]	MRW[5]
NLTb	14	24	1422-1987	0.31	0.18	0.19	Zero	1.008
RMA	6	10	1780-1987	0.14	0.14	0.14	Zero	0.998
MTT	5	8	1800-1987	0.47	0.18	0.22	Zero	1.001
MDM	3	6	1770-1987	0.54	0.20	0.25	Zero	1.009

Table 5. Sample statistics for 4 sites.

Analysis of variance						Cross-correlation analysis		
Abbreviation	**Period**	**No. of trees[1]**	**% Y^2**	**% Y x T/G[3]**	**% Other**	**No. of trees**	**No. of cores**	**r^4**
NLTb	1872-1987	14	17.30	28.55	54.15	14	24	34.8
RMA	1851-1987	6	26.02	26.62	47.36	6	10	36.16
MTT	1861-1987	5	14.76	42.94	42.30	5	8	23.21
MDM	1800-1987	3	33.27	35.87	30.87	3	6	36.76

Note: 1, Subset of main chronology with two cores per tree for the common period given in the previous column; 2, Percentage common variance; 3, Percent variance due to different between trees; 4, Average correlation coefficient.

Chronology and sample characteristics: A summary of chronology statistics is given in Table 4 while sample statistics is presented in Table 5. A few cores from NLTb site give the largest (1422-1987 A.D) ring-width sequence. Overall, mean ring-width was same in all sites (Table 4). Highest values of first order autocorrelation (0.54), percentage of common variance (Y=33%) and correlation coefficient (r = 37) was recorded from MDM. *Picea smithiana* (Wall.) Boiss., growing at MTT site showed higher value of first order auto-correlation with lowest values of percentage of common variance and correlation coefficient (Table 5). The lowest value of autocorrelation (0.14) and higher correlation coefficient was recorded from RMA chronology.

Inter chronology characteristics: Tree-ring chronologies from 4 different sites are plotted in Fig. 2. Longest ring-width sequences (1422-1987 A.D) were obtained from NLTb site, but for comparison, the sequence from 1770 to 1987 A.D is presented. The tree-width sequences of all four sites, cross-matches each other and pattern of wide and narrow rings was found to be similar. Each chronology indicates some distinct narrow and wide rings. In each site different wood samples come from various aged tree, consequently indicating different number of rings. Therefore, the period (number of rings) common to all wood sample from one site was shorter than the total chronology length.

Similarities among chronologies were provided by cross-correlation analysis (Table 5). The analysis covered from 1880 to 1970 A.D, a common period of all tree samples (cores) of the whole study area. An average correlation between tree samples on each sites, based on 20-year intervals is presented in Fig. 3. It is also indicated that from 1880 to 1970 A.D, trees from all four location show high or low correlation during the same period.

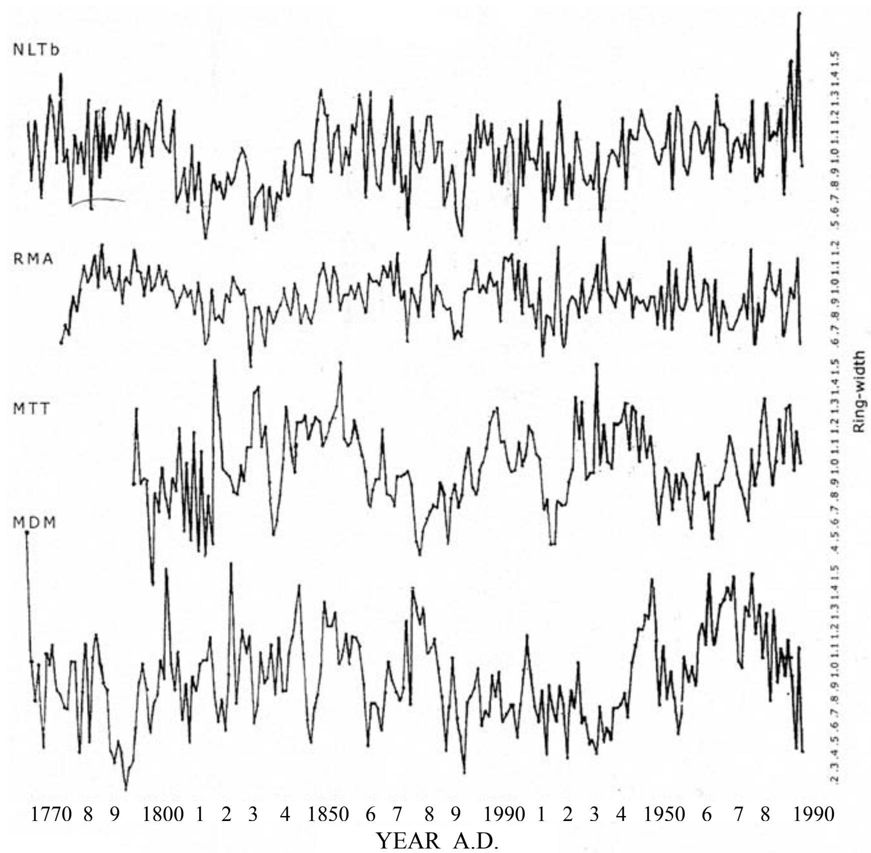

Fig. 2. Ring-width chronologies of 4 *Picea smithiana* sampling sites. Narrow and wide ring among all site showing similarities.

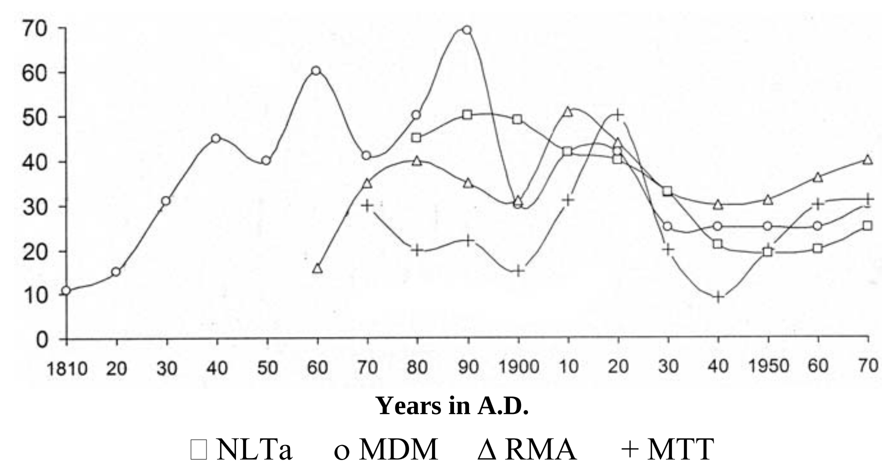

Fig. 3. Average correlation of indices between trees within each site for 20 year periods (with 10 year overlap) common to all tree samples on the site.

Discussion

Picea smithiana (Wall.) Boiss., grows mixed, pure, open or in dense stand with or without any stratification of associated species. It has wide ecological amplitude, distributed to sub-alpine, dry temperate and moist temperate areas in Himalayan range of Pakistan. Soil moisture in dry area must be adequate to develop a forest in distinguishable in from that associated with the moist temperate zone (Champion *et al*., 1965). Due to the presence of isolated, scattered individuals and low I.V. of *Picea smithiana* (Wall.) Boiss., MTT and MDM sites are not considered as a *Picea* stand, though these sites were sampled for dendrochronological investigations.

The basal area and density values for other monospecific conifer forests in Pakistan are available, which range from 25 to 43 m^2 ha^{-1} and 174 ha^{-1} to 387 ha^{-1} respectively. *Picea smithiana* (Wall.) Boiss., value exceeding 167 m^2 ha^{-1}, the highest among all types of forests in Pakistan (Ahmed *et al*., in preparation). These values are similar to the *Agathis australis* Salisb., forests in NewZealand (Ahmed & Ogden, 1987) and higher than that recorded (60 m^2 ha^{-1}) for tropical rain forests (Brunig, 1983). Except NLT sites size class structure of *Picea smithiana* (Wall.) Boiss., showed that this species is deteriorated without any regeneration. High-density stand NLTb have low number of individual both sides of the middle indicating recent disturbance. Therefore, prompt action should be taken to save the only monospecific *Picea smithiana* (Wall.) Boiss., stand of Pakistan. According to Daubenmire (1968), if the diameter is a good indicator of age, the past history of the particular stand is predictable. Gaps in size class mean that the particular size class is absent from the stand due to a failure of regeneration at sometime in the past. However, in the present state of *Picea smithiana* (Wall.) Boiss., forest it may be due to the either small sample size or anthropogenic disturbances.

Due to small sample size, no statistical correlation was postulated between the vegetation composition, slope, elevation, community attributes and dendrochronological attributes; it is nevertheless possible to predict suitable sites where dendrochronological studies may be carried out. On the basis of the field experience gained in the study area and detailed consideration of the tree samples, it is suggested that *Betula utilis* D.Don., as a dominant species with *Picea smithiana* (Wall.) Boiss., on higher elevation (3500 m) are not likely to be a good indicator of ideal dendrochronological site. The climatic factors are too extreme to produce ring-width variability in this area. Extremely depressed, narrow and indistinct ring boundaries made cross-matching impossible, so large number of samples were discarded from this location. However, *Betula utilis* D.Don., as a co-dominant on low elevation (MTT site on 2350 m) may be considered good site, but more tree samples are required due to the above-mentioned problem, hence considerable tree samples were rejected. Therefore, it may be suggested that for sensitive ring the site with a moderate climate should be selected. Mean ring-width do not show any correlation with increasing altitude. Therefore, the present study agrees with Hughes & Davies (1986) and Ahmed (1989).

The statistics with not only measure association between two different time series, but also measure association between items lagged in time is referred autocorrelation (Fritts, 1976). Higher autocorrelation and mean sensitivity with increasing altitude was reported by Norton (1983), however, no such correlation was observed by Ahmed (1989) and in the present study. However, highest amount of autocorrelation was recorded in moist temperate sites. Higher autocorrelation were reported from dense stands of *Agathis* sp. (Ahmed & Ogden, 1985), Nothofagus (Norton, 1983) and Abies (Hughes & Davies, 1986; Ahmed, 1989). In the present study, higher amount of (.54) autocorrelation was also recorded from dense stand of MDM location. This value may be depending upon site condition, tree age and retention of foliage for several years and competitions in dense forests. *Picea* also retain its foliage for several years. However, Ahmed (1989) stated that origin of autocorrelation is unknown and it may or may not be due to climate.

Mean sensitivity is a relative difference in width from one ring to the next. Higher mean sensitivity and reduced autocorrelation with increasing altitude was suggested by Norton (1983), but it was not the case with *Abies pindrow* Royle (Ahmed 1989) and in present study with *Picea smithiana* (Wall.)Boiss. Sampling sites show low values of mean sensitivity as described by Ahmed (1989) from *Abies* forests of Pakistan. However, according to La Marche (1974), low mean sensitivity does not necessarily indicate the absence of strong climatic signals. Like Hughes & Davies (1986), present studies do not show any correlation between mean ring width and increasing altitude.

Fritts (1976) and Ahmed (1989) reported higher degree of autocorrelation with low percentage of common variance (%Y), but no correlation was observed between these variables during the present study. In addition, sample size was too small to calculate these types of relationships, same with the case between percentage of common variance (%Y) and aspects.

The highest common variance (Y=33%) was recorded from MDM location. This value is higher than *Abies pindrow* Royle of Pakistan and India (Ahmed, 1989; Hughes & Davies 1986) and Australasia (Ogden, 1982; Ahmed & Ogden, 1986).

All chronologies produce similar ring width pattern in their time sequences, on which cross dating between and among sites was possible. This indicates that despite some difference, all chronologies produced similar climatic signal. Therefore, it was suggested that *Picea smithiana* (Wall.) Boiss., might be used for further dendroclimatological analysis with increased sample size.

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