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TREE-RING CHRONOLOGIES OF *ABIES PINDROW* (ROYLE) SPACH, FROM HIMALAYAN REGION OF PAKISTAN

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Abstract

Dendrochronological methods were applied to three *Abies pindrow* stands in northern Pakistan, and dated chronologies with maximum period from 1750 to 1987 AD were obtained. Sample and chronology statistics are discussed. These chronologies show from 22 to 41% chronology variance ('Y' in ANOVA; due to climate). Despite stands being located on different aspects, they showed similar climatic signals. However, it is suggested that west facing steep slopes are the most suitable sites for tree-ring studies. It is concluded that *A. pindrow* could be used in dendroclimatological investigations.

Introduction

Tree-ring studies, in Pakistan, have been carried out and a lot of work has already been published by Pakistan Forest Institute. However, their studies are confined to the forest mensuration only. Champion *et al.*, (1965) estimated age of single *Pinus gerardiana* tree from Zhob District while ages and growth rates of a few *Juniperus excelsa* were given by Sheikh (1985).

Khan (1968) calculated ages and growth rates of *Pinus wallichiana* from Trarkhal Forest. Using dendrochronological techniques, Ahmed (1988) has presented ages and growth rates of some planted tree species of Quetta. Similar studies were also conducted by Ahmed & Saranzai (in preparation) in Himalayan region of Pakistan. A brief introduction to dendrochronology, its applications and its scope in Himalayan region of Pakistan has been discussed by Ahmed (1987). Ahmed also mentioned a few tree species which may be suitable for tree-ring investigations. Besides these studies no dendrochronological work has yet been published from Himalayan region of Pakistan and no chronology has yet been produced from any tree species from this area. However, isotopic coherence in trees from Kashmir Valley was described by Ramesh *et al.*, (1985), while Hughes & Davies (1986) made a dendrochronological survey and presented dendroclimatological study from western Himalaya but both studies were confined to Indian region.

The importance of suitable tree species and sites for tree-ring investigation is strongly recognised. The criteria for a good site have been determined in various countries of Northern and Southern Hemisphere, but they are still open for question in Himalayan regions. Since aspect may also play an important role in determining suitable sites for dendrochronological investigation (Ahmed & Ogden, 1985), a search was conducted in the Murree and Ayubia Hills for a site with *Abies pindrow*, where the dendrochronological techniques of cross-dating and chronology could be applied. The main purpose of present study was to assess dendroclimatogical potential and present tree ring chronologies of *A. pindrow* from moist temperate Himalayan region of Pakistan. This paper presents modern tree-ring chronologies from Himalayan region of Pakistan.

Materials and Methods

The genus *Abies* (Pinaceae) is distributed north temperate to arctic regions of the world, comprising 20 species. Two species *A. pindrow* (Royle) Spach, and *A. spectabilis* (D. Don.) are found in Afghanistan and Indo-Pak Himalayan region up to Kumaons, forming an upper conifer belt in moist and dry temperate zones. *A. pindrow* grows from 2000 to 3000m while latter species grow from 2400 to 3900m (Champion *et al.*, 1965; Beg & Samad 1974). In Pakistan *A. pindrow* is distributed in Murree Hills, Dir, Chitral, Gilgit Agency and Kashmir, as a pure forest or associated with *Pinus wallichiana* A.B. Jackson; *Cedrus deodara* (Rexb.) Lond., and *Picea smithiana* (Wall.) Boiss.

The study area falls in the Himalayan moist temperate region (Champion *et al.*, 1965). Three stands dominated by *A. pindrow* were sampled at Murree and Ayubia. Mainly sampling sites were selected where growth was expected to be limited by environmental factors, (i.e. steep slopes), with no obvious signs of recent human disturbance. However, in each stands a few trees growing on ridge tops were also sampled for comparison. Coring techniques and sample preparation were carried out according to the method outlined by Stokes & Smiley (1968). During the present study approximately 90 cores from 45 trees were obtained using a Swedish Increment Borer. These cores were air dried and glued in a grooved mount so that tracheids were in a vertical position. Later, the cores were sanded with a sanding machine and progressively finer grades of sandpaper until a suitable polished surface was obtained. Short cores were generally not included in the chronology but were retained for confirmation of cross-dating. Following Stokes & Smiley (1968), for each sampling site, an attempt was made to establish cross-dating and each core was examined under the variable power microscope. This technique allows missing or false rings to be identified by comparison of ring-width sequences between trees. In each site if good cross-dating was achieved among the cores of at least 60% of trees, the sites were considered cross-matched sites. Ring sequences from different sites were also cross-dated. Only cross-dated cores were measured to 0.01mm using a computer compatible Henson measuring stage and the programme PULSE COUNTER and an APPLE II computer (Robinson & Evans, 1980). Growth in *A. pindrow* starts in spring and covers one calendar year so that the outermost ring, which was formed in 1987 and samples were taken in November 1987, was designated by the 1987 ring.

Certain statistics provided a quantitative base for evaluating the dendrochronological potential of a tree-ring chronology. These statistics were obtained by running programme

RWLIST, INDEX and SUMAC (Fritts, 1976; Graybill, 1979). RWLIST was used to check the raw data, sort out unsuitable cores and select the proper cores for next analysis. At this stage only those cores were eliminated which showed unusual mean ring-widths in comparison to others. Programme INDEX is designed primarily to remove non-climatic trends in the data. Selected ring-width series were converted into a new and standardised time series. Hughes *et al.*, (1978) and Norton (1983) found only small differences in their results using different curve fitting techniques. Since the polynomial curve is the most convenient method for data standardisation (Fritts, 1976) the data was standarised by a polynomial curve. The output of INDEX was used in the next programme SUMAC. The programme SUMAC allows some final checks and prepares the data for dendroclimatological investigations. Two types of statistics were obtained using this programme. 1. Chronology statistics (i.e. mean ring-width, mean sensitivity, standard deviation and first-order autocorrelation) for the final summarised series. The values of this final series were used in further analyses. 2. Sample statistics in the form of analysis of variance and cross-correlation analysis. Details are given in Fritts (1976) and Graybill (1979).

Results

Ring characteristics: Locations and characteristics of study areas are shown in Table 1. In all sites most of the large and apparently sound trees were found to be rotten in the centre. Trees growing on steep slopes were found to be slow growing with sensitive (greater ring-width variability) rings, while trees from ridge tops had many broad rings. Fast growing trees with complacent (lack of ring-width variability) rings and non cross-dated cores were not measured and excluded from further analyses. Although most trees were relatively young, a few date back to 1750AD. Absent rings were rare. A few double rings (false rings) could be easily detected and properly dated. Rings were distinct and clear and trees had good radial and circuit uniformity.

Chronology and sample characteristics: Chronology statistics from cross-matched sites are given in Table 2 while summary of ANOVA and cross-correlation analyses

Table 1. Characteristics of *Abies pindrow* sites.

Location	Abbreviation	Code	Latitude S	Longitude E	Altitude M	Slope (degrees)	Aspect	Remarks
1. Murree	APMN	002	33° 34	73° 74	2166	21	N	Mixed Open stand.
2. Ayubia	APAW	004	- do -	- do -	2616	38	W	Pure closed stand.
3. Ayubia	APAS	003	- do -	- do -	2436	31	S	Mixed open stand.

APMN = *Abies pindrow*, Murree, North facing slope;
APAW = *Abies pindrow*, Ayubia, West facing slope;
APAS = *Abies pindrow*, Ayubia, South facing slope.

Table 2. Chronology statistics for three sites.

Abbreviations	No. of trees	No. of cores	Period AD	No. of years	AC[1]	MS[2]	MRW[3]	SD[4]	%AR[5]
1. APMN	5	10	1840-1987	148	.53	.24	1.00	.34	0
2. APAW	6	10	1750-1987	238	.72	.25	1.00	.42	0
3. APAS	6	11	1870-1987	119	.58	.24	1.01	.31	0

1. First order auto correlation;
2. Mean sensitivity,
3. Mean ring-width (mm);
4. Standard deviation.
5. % missing rings.

(sample statistics) are presented in Table 3. All sites show similar values of mean sensitivity and mean ring-width, while autocorrelation ranges from .53 to .72.

The longest chronology (238 years) was obtained from the west facing slope of Ayubia. This site also had highest percentage of common variance (Y=41%) and the highest average correlation between trees. It is located on highest elevation and west facing steep slope (Table 1). The lowest value of common variance was from less steep north facing slope at Murree Hills.

Inter-chronology characteristics: Cross-dated chronologies are plotted in Fig. 1. Though APAW chronology covers a period from 1750 to 1987 AD, for comparison, only the period from 1840 to 1987 AD is shown. All chronologies show distinct narrow and wide rings and the pattern of these rings was found to be similar among all sites (Fig. 1). In each chronology the period common to all cores was shorter than the total chronology length. However, with the exception of APAS site, both ring-width series used in cross-correlation analysis covered most of the 1910 to 1986 period. The average correlation between cores on each site, based on 20 year intervals is shown in Fig. 2. It is evident that trees on all sites show high and low correlation during the same periods.

Table 3. Sample statistics for three sites.

	Analysis of variance					Cross-correlation analysis		
Abbreviation	Period[1]	No. of trees[2]	%Y[3]	%YxTG[4]	%Other	No. of trees	No. of cores	r[5]
1. APMN	1900-1986	5	21.69	10.89	67.42	5	10	.24
2. APAW	1880-1986	5	15.26	43.49	5	10	.46	
3. APAS	1926-1986	4	34.27	25.54	40.19	4	8	.36

1. Common period (AD) in all cores;
2. Subset of main chronology with two cores per tree for the common period;
3. Percentage common variance;
4. Percentage variance due to differences between trees;
5. Average correlation coefficient.

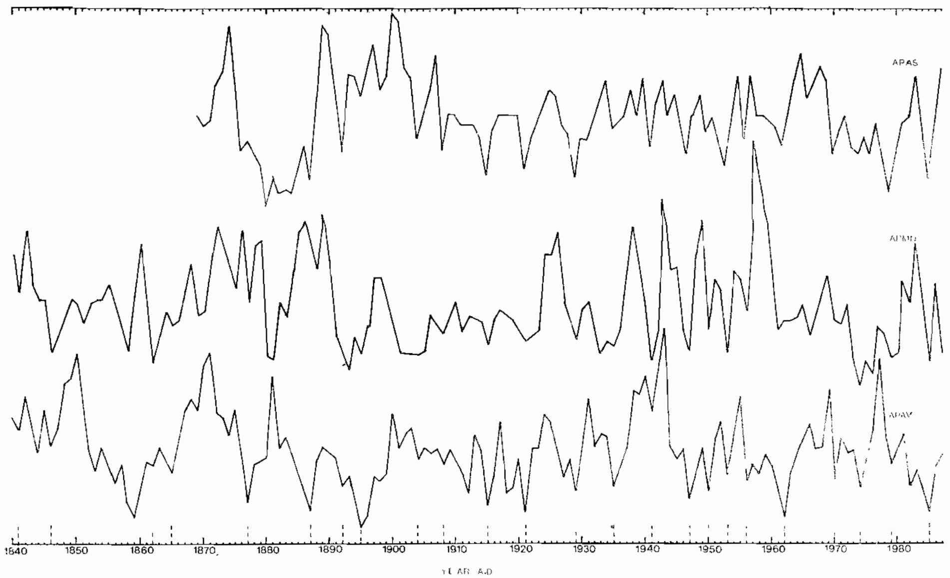

Fig. 1. Ring width chronologies from three sites. Dashed line show narrow rings present in most individuals of all chronologies. For abbreviations see Table 1.

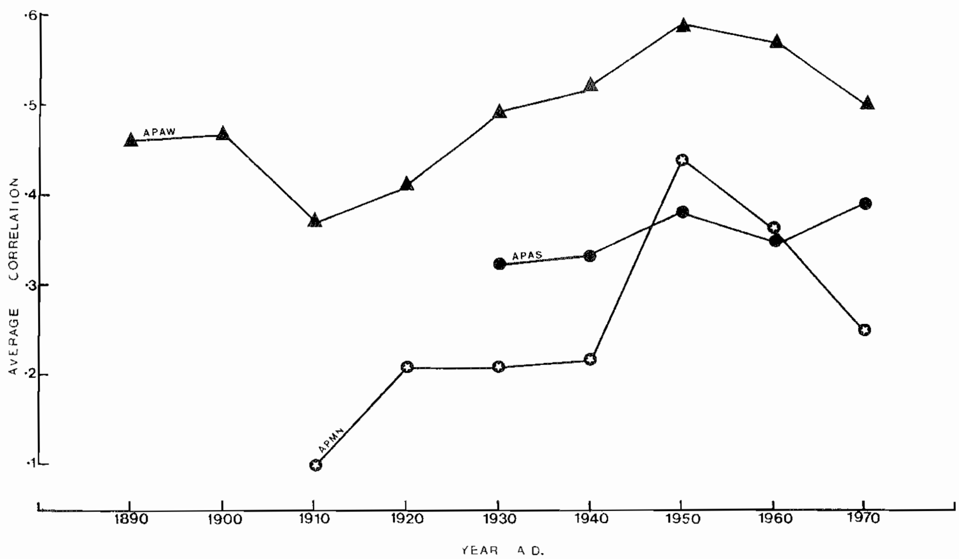

Fig. 2. Average correlation of indices between trees within each site for 20 year period (with 10 year overlap). All chronologies show same pattern of correlation in different period. For abbreviations see Table 1.

Discussion

Fast growing trees with complacent ring sequences were frequently found on ridge tops. Trees are probably more easily blown over on ridge tops than elsewhere, consequently, the survivors may grow faster than those on steep slopes due to more space being available for them. Their photosynthetic area is more exposed than tree growing on slopes with intermixed branches. In addition, due to fast run off of water from steep slopes trees growing on these steep slopes get less moisture than those on crests except during heavy rains (Jackson, 1967). Therefore, it seems feasible that on ridge top *A. pindrow* have more opportunity to grow faster than on steep slope. Hence less important for dendrochronological investigations. Ahmed & Ogden (1985) and Norton (1983) found same with *Agathis australis* and *Nothofagus* species of New Zealand.

The present study agrees with Hughes & Davies (1986) and no clear relationship was observed between mean ring width and increasing altitude. Norton (1983) reported reduced auto correlation, higher mean sensitivity and standard deviation with increasing altitude in *Nothofagus* in New Zealand. However, as far as the auto correlation is concerned reverse was the case in this study.

Though mean ring-width and mean sensitivity do not show any variation among the chronologies, they show considerable variation among cores of the same site. All sites show low mean sensitivity. However, low mean sensitivity does not necessarily mean that a strong climatic signal is absent (LaMarche, 1983).

Norton (1983) assumed that in *Nothofagus*, wide rings with high autocorrelation indicated better condition for growth. This was not obviously so in *Abies*. Variability in autocorrelation reflects the degree of growth 'flushing' along individual radii and may not be related to other site or chronology statistics. Ahmed & Ogden (1985) concluded that the amount of auto-correlation may increase as the trees get larger and/or in dense stands where competition is more severe. The highest amount of auto-correlation in *Abies* was also recorded from the larger trees in dense stands. The present study showed high autocorrelation in the chronologies, as shown by Hughes & Davies (1986) in the same species from Indian areas. According to LaMarche (1974) higher value of auto-correlation may be associated with retention of foliage for several years. *Abies* also retains its leaves for several years. However, the origin of auto-correlation in *Abies* (like some other forest tree) is still in question and needs further investigation. At present, it may merely be described as a persistence which may or may not be of climatic origin.

Fritts (1976) found a positive correlation between the amount of autocorrelation and percent common variance (%Y). In the present study these attributes were also associated with increasing altitude while Hughes & Davies (1986) found no correlation with *A. pindrow* in Indian areas.

Although it is assumed that the common chronology variance (%Y) is due to climate, other factors such as fire, storms and human disturbance may influence all trees in a site, and more rarely, influence even widely separated areas. Periodic seed production is also likely to have a marked effect on ring width. However, no autecological or phenological work has yet been published on *Abies* in Pakistan.

Variation in %Y and average correlation among chronologies reflect the importance of site and sample selection and also the cross-dating in tree-ring investigations. Hughes & Davies (1986) obtained highest per cent of common variance (%Y) from western sites in *A. pindrow*. A similar situation was observed in the present study. It implies that west facing steep slopes may be the most suitable sites for dendrochronological studies.

The average common variance (Y=32%) in the chronologies is higher than *Abies* of western Himalaya (Hughes & Davies 1986) and slightly higher than several species of Australasia (Odgen, 1982: Ahmed & Ogden, 1985). In addition, though the similarities among chronologies were sufficient to allow cross-dating, a quantitative measure of the agreement between the chronologies was achieved by higher t-values (t=>3.6=; P>0.001). This gives evidence that despite different aspects all chronologies showed a similar climatic signal. Existence of strong regional pattern in the year to year variation in *A. pindrow* chronologies are also mentioned by Hughes & Davies (1986) and Ramesh *et al.*, (1985). Consequently, above results give additional strength to the opinion that *A. pindrow* could be used for further dendroclimatological investigations.

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