DENDROCHRONOLOGICAL POTENTIAL OF *JUNIPERUS EXCELSA* (M.BIEB) FROM DRY TEMPERATE FOREST OF BALOCHISTAN PROVINCE, PAKISTAN

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Abstract

Tree-rings are widely studied for determining tree ages, growth rates and reconstruction of thé past climate. Wood samples in the form of cross-sections and cores were obtained from 50 living *Juniperus excelsa* trees to determine their age, growth rates and ring-width characteristics from all sites of this dry temperate species. Age and growth rates varied greatly from tree to tree and site to site and even in the same sized trees. All the selected trees showed annual nature of growth rings with distinct and clear ring boundaries. Cross dating was not possible in all sample trees. Various problems were encountered during cross- dating. The presence of false rings, missing rings, wedge out, lack of ring pattern consistency and lobate growth around the tree was observed in *J. excelsa*. The results indicated that at least 4 cores, a suitable site-selection and samples of tree rings in the form of trunks sections may improve ring width characteristics and can successfully be used in Dendrochronological studies.

Introduction

Within the dry temperate forests of the Ziarat mountains, *Juniperus excelsa* usually forms pure forests between 2000 to 3000 m a.s.l. on calcareous sandy clay loams, with annual precipitation around 280 mm (Ali,1966; Atta, 2000). This tall (up to 50 m), evergreen forest tree is the only dry temperate Juniper and which is indigenous to the north-Eastern highlands of Balochistan Province, Pakistan. Its timber is strong highly valuable; After seasoning the wood is very durable, immune to fungal attacks, termites, wood borers, seed sucking insects (Pohjonen and Pakkala, 1992) and mistletoe infestation (Atta *et al.,* 2010). Therefore, juniper is the most preferred multi-purposes tree in Balochistan for construction, furniture, fencing and medicinal uses (Chaffey, 1982), and considered as a "living forest fossil" in this area. The juniper dominated woodlands once covered a large part of the country. However, as a consequence of human influence, the regeneration and growth of these forests have been adversely affected (Atta, 2000). These forests have been considerably depleted and majority of them stands look like disturbed, over matured, open, fragmented and less productive and are now reduced to some isolated patches (Ahmed *et al.,* 1990).

The tree ring analysis are widely applied in ecological studies for determining tree ages, growth rates and to study the relationship between tree growth and variable environmental factors by comparing annual variations in ring-width with annual variations in the climate parameter of interest and makes predictions of climate trends in future. Age measurements are usually used to determine the age class distribution of a tree population from which inferences on the dynamics of that population are drawn. The study of chronological sequences of growth rings in relation to past event has been termed as dendrochronology. The origin, methods principles and uses have been reviewed by (Fritts, 1976) as well as predictions of possible future change in climate, hydrology, forest dynamics *etc*. Hughes *et al*. 1982; Cook & Kairiukstis 1990). One of the central principles is 'Cross dating which allows missing or false rings to be identified by comparison of ring width sequences between trees. Recent applications of dendrochronological techniques in the world is used to know the reconstruction of the past climate and events like fires, flooding, droughts, river-flow changes, landslides and volcanic eruption can be traced in tree-ring sequences (Schweingruber, 1998). Dendrochronology is still a challenge in dry temperate regions, because tree rings are often irregular, narrow, may be missing or exhibit unclear boundaries and growth (Wils and Eshetu, 2007). Long term tree ring variations in *Juniperus excelsa* at the upper timber line in Hunza-Karakoum was used in reconstructing modes of regional climate over the past 500 years (Esper, 2002). Juniper from Ethopia highlands contains a large scale of precipitation signal (Klaassen *et al.,* 2008). The selection of suitable site and species play most important role in tree-ring research. Ahmed (1987, 1989) explained the scope of dendrochronology in Pakistan, and mentioned suitable sites and tree species, which could be used in tree-ring chronologies from Himalayan region of Pakistan. A dendrochronological approach to estimate age and growth pattern of various species and dendrochronological potential of few tree species from the Himalayan region of Pakistan was described by Ahmed & Sarangzai (1991a,b). Ahmed *et al* (2009) also investigated age and growth rates of some Gymnosperms of Pakistan. Population dynamics of *Juniper excelsa* has been described by Ahmed *et al.,* (1990) from Balochistan.

To support conservation, restoration and sustainable use of the remaining woodlands more information is needed on growth patterns and population dynamics of *Juniperus excelsa*. Moreover, in the context, of increasing concern about global climate change, this study was an opportunity to assess the dendrochronological potential of *Juniperus excelsa* in the poorly documented region of the dry temperate forests of Balochistan, Pakistan.

Materials and Methods

Field surveys were conducted during 2009-2010 in different valleys of the Ziarat district, Balochistan. Although many forest areas were fragmented, disturbed and look like over mature stands but during this study only healthy, sound and trees of different sizes with no sign of injury in each stands were selected over an area of approximately three hectares, especially located on steep slopes and crest ridges. Wood samples in the form of stem disks and cores were obtained at the level of breast height from various locations of Ziarat juniper forest (Fig. 1). Elevations and aspect of the sampling sites were recorded. Juniper species is known to be problematic for dendrorochronological studies (Esper, 2000). Therefore, we mainly worked with the whole sections from fallen trees or remains of recently cut trees However, increment cores were obtained from selective stands in the study area.

Dendrochronological methods of Fritts (1976) was followed for the determination of ages and growth rates. Sample collection and preparation were carried out according to the method outlined by Stockes and Smiley (1968) and Ahmed (1984). Wood samples (cores) were taken from those individual trees which were free from severe competition and situated on dry ground. The diameter at breast height (dbh) and the height of the cores 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 cores were kept in drinking straws to prevent possible damage and were air dried. Later, the cores were glued grooved mount so that tracheids were in a vertical position and were allowed to dry. These cores and cross sections were sanded with a sanding machine with progressively finer grades of sand papers until a suitable polished surface was achieved. Many cores do not pass through the center or pith. In these cores reliability, missing radius and its years were calculated according to the method described by Ogden (1980) and Ahmed (1984).The missing radius were calculated from the growth rate of inner most 20 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 idea how near the end of the core is to the presumed tree center and hence how reliable the age estimate. An attempt was made to establish cross-dating (in cores and cross sections) visually under the variable power binocular microscope. The radial uniformity of the trees and the ring width pattern of the site, was checked by cross-matching the cores from the same tree and with different trees. During this process missing rings and falls rings were identified in their correct sequence and each ring was properly dated in the year of its formation.

Results and Discussion

Location and details of study area are given in Table 1. In every juniper forests an attempt was made to describe the age, growth rates and ring-width- characteristics of the stand studied. Fig.1 shows the soil erosion and scattered trees while destruction (illegal cutting) was postulated in Fig.2 in Juniper forest. Age of the largest tree, diameter of the oldest tree and overall growth rates of trees from particular site is shown in Table 2. The oldest (860 yrs) *Juniperus excelsa* with132 cm dbh was recorded from Tore Sagran near the Koh Khalifat mountain of District Ziarat. A 52 dbh tree of *J. excelsa* was estimated 88 years old while from the same place another tree have 264 rings with 78 cm dbh. Similarly largest tree 86 cm dbh of another juniper tree with 210 years was recorded from Surghund Sray khazi, while oldest tree 329 years with smaller size of 75 cm dbh was recorded from the same valley. A largest tree 147 cm dbh of juniper tree with 170 years was recorded from Nishfa vally while oldest tree (510 years) with smaller size 92 cm dbh was recorded from the same location of the study area. It indicate that age are greatly varied from tree to tree, site to site and even two closely situated same sized trees of the same species. Like age, rate of the growth in juniper forests also varies greatly among the same sized tress even in the same area. Table 2 also shows growth rate in various juniper forests. Slowest growth rate (15 years/cm) was recorded from trees of stand 2, 10, 11 and 24 while fast growth (0.16 years/cm) rates was obtained from juniper trees of stand 14. However, juniper trees growing in Pila forest Chormul Gut area showed (0.16 years/cm) while slowest rate of growth (0.5 cm/yeas) was recorded from Nishfa valley (stand 10).

Only a few age/diameter estimates**,** using modern dendrochronological technique**,** have been published in Pakistan**.** Ahmed (1988) presented age of some planted tree species of Quetta and found significant relation between diameter and age. Ahmed *et al.* (1990) calculated age of 14 to 17 years for 2 to 3cm dbh *J. excelsa* saplings. Ahmed *et al.* (1990) estimated the average age of 16 *J. excelsa* trees (from 20 to 30cm dbh) was 160 years. A *Pinus gerardiana* tree of 66**.**5cm dbh had 600 rings**,** while another tree of 124cm dbh was only 361 year old (Ahmed *et al*; 1991). Dendrochronological approach was also used to estimate age and growth rate of various species from Himalayan range of Pakistan by Ahmed and Sarangzai (1991). Juniper trees of 21 cm dbh from Susnamana forest show age of 105 and 187, while trees of similar diameter from Ziarat range from 75 to 169 years. A tree of *Pinus wallichiana* with 20.5 Dbh from Zhob District attains age of 112 years, while same age is estimated from an individual of the same species having a dbh of 65 cm from Ayubia. Similarly *Abies pindrow* from Murree had 351 rings with diameter of only 11.3 cm (Ahmed, 1989) while 200 cm *Cedrus deodara* from Kalam was 346 years old. Relationship between diameter and age of *J. exelsa*, *Pinus wallichiana*, *Pinus gerardiana* and *Abies pindrow* (Ayubia) was highly significant.

Fig.1. Stand of *Juniperus excelsa*

Fig.2. A stump of *Juniperus excelsa*

Fig.3(a). Stem disc of *Juniperus excelsa* showing lack of ring pattern consistency of growth rings

Fig.3(b). Stem disc of *Juniperus excelsa* with ecentric growth and missing rings

Fig.3(c). Wood cores of *Juniperus excelsa* with distinct and wedging rings

Fig.3(d). Wood cores of *Juniperus excelsa* with distinct annual rings

Growth rates of various tree species from Himalayan regions of Pakistan was presented by Ahmed and Sarangzai (1991). According to them *Pinus gerardiana* from Zhob District show 6 to 24 years/cm, *Pinus wallichiana* from the same District 3 to 14 years/cm, *Abies pindrow* from Ayubia 3 to 20 years/cm, *Pinus roxburghii* from Swat 2 to 6 years/cm and *Cedrus deodara* from Kalam show 2 to 10 years/cm growth rate. They also reported that growth rate decreases with increasing altitude and negative significant relationship between these two variables.

Ahmed *et al.* (2009) presented age and growth rate data from 39 locations for various gymnospermic trees. A tree of *Picea smithiana* with 140 cm Dbh was 281 years old, while *Cedrus deodara* with 180cm dbh was 533 years old. An individual of *Taxus wallichiana* with 92cm dbh had 394 rings and 70cm dbh *Pinus wallichiana* was only 48 years old. Except *Pinus roxburghii* all species, under investigation, show no relation between diameter and age, indicating that prediction of age from diameter in unreliable.

Ahmed *et al* (2009) also presented growth rates of some gymnosperm trees of Pakistan, they found no relation between elevation and growth rates. In their studies, *Pinus wallichiana* showed fast growth (1.7 years/cm) from District Dir, while *Abies pindrow* from Murree produced narrow (7.0 year/cm) rings. Average growth rate of 6 year/cm was recorded from *Picea smithiana* from Nalter Valley, while the growth rate of *Cedrus deodara* was 4.0 year/cm from Kalam. Out of 23 stands, only six stands showed significant relation between diameter and growth rate. Therefore like age, the growth rate is also not predictable from the diameter. In general, growth rate is the product of the various factors (climatic and non climatic, genetic, competition, *etc*) and detailed investigations by which useful predictions and conclusions can be made, need to be undertaken.

Though previous data on the age and growth rate of dry temperate species is scanty present results are comparable in most cases. It is suggested that largest tree is not necessarily the oldest tree of the population; same is true for the oldest tree.

Table 1. Summary of topographic characteristics of sampling sites in Ziarat *Juniperus excelsa* Forests.

Main Location	Stand	Sites	Long(N)	Lat (E)	Elev(m)	Asp	Slope(°)	Canopy
Zizri Area	1	Tore Sagran	30° 20'	67° 42'	2948	W	45	Open*
	2	Khalifat Area	30° 20'	67° 42'	2948	NW	43	Open*
Baba Kharwari	3	Prospectus Point	30° 20'	67° 49'	2645	NW	36	Open*
	4	Zergut Area	30° 20'	67° 48'	2520	E	33	Open*
	5	Shaidan Area	30° 20'	67° 48'	2440	E	30	Open*
Kotal Sarri	6	Mulicut Area	30° 22'	67° 48'	2630	NE	29	Open
	7	Sarri Area	30° 22'	67° 47'	2795	N	26	Open
Cautair	8	Karbikach Area	30° 25'	67° 47'	2600	S	37	Open
	9	Khumuk	30° 25'	67° 43'	2570	SW	41	Open
Nishfa Valley	10	Along Road	30° 17'	67° 59'	2639	W	46	Open
	11	Ghuza Area	30° 18'	67° 59'	2660	W	41`	Open
	12	Prang Shella	30° 24'	67° 50'	2666	N	40	Open
Pila Forest	13	Markhazai	30° 25'	67° 37'	2740	NE	30	Open
	14	Bian Takari	30° 25'	67° 37'	2680	N	24	Open
	15	Chormul Gut	30° 20'	67° 37'	2600	ES	21	Open
Sasnamana state forest	16	Sarru Narri	30° 24'	67° 49'	3116	NE	38	Open
	17	Khawas Neikh	30° 24'	67° 49'	3000	NE	40	Open
	18	Basharat Shella	30° 24'	67° 49'	2800	E	32	Open
	19	School Area	30° 24'	67° 49'	2790	SW	36	Open
	20	Mir Ahmed Sakhobi	30° 24'	67° 48'	2775	S	31	Open
	21	Tangi Top	30° 24'	67° 48'	2620	S	30	Open
Chasnak Aghburg	22	Arzani	30° 27'	67° 41'	2880	SE	30	Open
	23	Bailza	30° 27'	67° 41'	2775	SE	21	Open
	24	Surri Mana	30° 20'	67° 20'	2690	ES	28	Open
	25	Speena Sakher	30° 20'	67° 20'	2865	ES	33	Open
Surghund	26	Saraghara Area	30° 20'	67° 50'	2510	W	29	Open
	27	Surghund Srag Khazi	30° 33'	67° 14'	2470	W	32	Open
Spera-Ragha	28	Tore Sokhar	30° 31'	67° 14'	2695	N	42	Open
	29	Spara Oza	30° 30'	67° 19'	2680	N	31	Open
	30	Prang Shella	30° 25'	67° 16'	2775	E	39	Open

Long = Longitude, Lat = Latitude, Elev = Elevation, Asp = Aspect, *****= Core samples, otherwise Cross section

Most of the cross sections showed poor radial and circuit uniformity and abrupt change in ring width characteristics. Asymeteric trees were common. However, cross dating was possible in some trees. Outer margins of the samples were light where ring boundaries in some cases were not distinct, while inner portion of the wood samples characterized by distinct and clear ring boundaries. Staining treatment (for outer margins) may be useful to obtain fine anatomical features of the samples. In some cross-sections lobate growth rate was also observed (Fig. 3a,b). Absent rings were common in the slow growing trees while false rings were common in fast growing individuals. Some trees showed lack of ring pattern consistency around the stem. Growth rate and mean ring-width was highly variable between the trees. Juniper is also distributed in the form of pure and mixed stands at various higher elevated dry temperate valleys of northern area of Pakistan. More than 1000 years old trees have been successfully used for climatic reconstruction by Esper (2000) and Esper *et al.*, (2002).

Table 2. Estimated age and growth rates of Juniper trees in various locations. From each sampling sites age of largest tree, dbh of oldest tree and overall growth rates are shown.

Main Location	Stand	Sampling Sites	dbh (cm)	Age in years	Oldest tree age in years	dbh (cm)	Growth Years/ cm	Rate Cm/ Years
Zizri Area	1	Tore Sagran	44.4	138	528	124	11.89	0.08
	2	Khalifat Area	55.5	185	860	132	15.59	0.06
Baba Kharwari	3	Prospectus Point	26.7	255	608	106	14.20	0.07
	4	Zergut Area	27.5	375	720	110	11.70	0.08
	5	Shaidan Area	38.5	310	512	154	9.39	0.10
Kotal Sarri	6	Mulicut Area	22.3	290	452	89	9.14	0.10
	7	Sarri Area	46.5	488	795	186	13.56	0.07
Chautair Area	8	Karbikach	43.2	674	680	174	12.9	0.08
	9	Khumuk	34.2	335	864	136	14.59	0.06
	10	Along Road	35.5	248	648	142	15.61	0.05
Nishfa Valley	11	Ghuza Area	47.6	170	510	92	15.69	0.06
	12	Prang Shella	64.8	283	348	84	12.16	0.05
Pila Forest	13	Markhazai	52	88	264	78	10.07	0.09
	14	Bian Takari	65.5	240	408	189	12.67	0.16
	15	Chormul Gut	55.5	195	248	110	11.6	0.08
	16	Sarru Narri	23.6	131	518	128	14.8	0.13
Sasnamana	17	Khawas Neikh	32.2	277	536	132	15.5	0.14
	18	Basharat Shella	24.4	197	439	98	12.8	0.12
	19	School Area	28.4	165	330	126	15.5	0.10
	20	Mir Ahmed Sakhobi	24.4	131	280	52	11.4	0.09
	21	Tangi Top	29.7	264	330	45	13.6	0.08
Chasnak Aghburg	22	Arzani	37.8	157	288	41	12.8	0.06
	23	Bailza	46.4	341	598	80.6	15.5	0.14
	24	Surri Mana	30.6	312	471	41.5	13.5	0.12
	25	Speena Sakher	42.5	353	210	60.3	10.5	0.14
	26	Saraghara Area	68.2	288	427	99.9	15.3	0.11
Surghund	27	Sray Khazi	86.5	210	329	75.5	10.8	0.07
	28	Tore Sokhar	56.8	157	244	38.8	8.9	0.10
Spera-Ragha	29	Spara Oza	60.7	92	283	92.5	12.3	0.13
	30	Prang Shella	92.5	30.4	495	112	13.3	0.15

dbh = diameter at breast height

According to Ahmed (1989) at least 4 cores, a suitable site or trunks cross sections may improve ring width characteristics and can successfully be used for better cross-dating. It is concluded that *J. excelsa* a long-lived dry temperate species may offers an excellent opportunity for large scale Dendrochronological investigation, however more work is required.

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