INT. J. BIOL. BIOTECH., 7 (3): 159-174, 2010.

DENDROCHRONOLOGICAL POTENTIAL OF GYMNOSPERMIC SPECIES OF PAKISTAN

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ABSTRACT

This paper encircles an extensive survey of wood sampling of different pine species from sub-alpine to moist, dry temperate and sub tropical region of Northern mountain system of Pakistan. Wood samples of *Abies pindrow* Royle, *Cedrus deodara* (Roxb. Ex Lamb), *Picea smithiana* (Wall) Boiss., *Pinus gerardiana* Wall Ex Lamb.G. Don *Pinus roxburghii* Sargent and *Pinus wallichiana* A.B Jackson were obtained from 52 different locations. The main purpose of this sampling was to locate suitable sites and sensitive tree species which could be used for applied Dendrochronological research in Pakistan. Age and growth rates of various species are presented. It is shown that despite some problems cross-dating is possible in all species. It is also presented that in many individual narrow rings are appeared in similar calendar years in different species, showing strong climate signals. On the basis of these studies it is suggested that except *Pinus roxburghii* Sargent all species show sensitive rings if sampled from extreme sites and could be used for applied Dendrochronological investigations.

Keywords: Dendrochronology, cross-matching, gymnosperms, sensitive rings.

INDRODUCTION

The Northern area of Pakistan covers an area of 72500Km^2 lies between latitude 30^{0}30'38N and longitude 72^0 30' – 78E. Topographically, Pakistan has 3 types of massive and continuous mountain system. 1-The Northern mountain system has Karakorum, the Himalaya and the Hindukush. Due to the collision of Indo-Pakistan and Asiatic plate, the geologically unstable area has some of the highest mountain peaks in the world (K2 8611m a.s.l. Nanga Parbat 8126m a.s.l. Masherbura 7821m a.s.l. and Rakhoposhi 7788m a.s.l.). Neighboring China is link via the famous Silk Road (Karakorum Highway) through the Khunjirab pass, the highest sealed highway (4700m a.s.l) in the world. The area adjoins the disputed Kashmir to the East while Afghanistan to the West. Depending upon the height and direction of mountain and topography various areas are characterized by subtropical, moist temperature, dry temperature and sub alpine zone. 2-The western mountain system includes Koh Sufed and the Sulaiman Range. 3-The South-Western mountain system form a Baluchistan plateau.

In Sulaiman Ranges thickly forested area lies between latitude 31^{0}20' and 31^{0}50N and longitude 69^{0}40 and 70^{0}E with highest Peak Takht-e-Sulaiman 3414M a.s.l, while in Juniper track it lies between Kuch to Chantair latitude 20^{0}9 and 30^{0}37N and longitude 67^{0}1 and 68^{0}3'E from 1200 to 2500M a.s.l. (Rafi 1965) Champion et al (1965) described this area as dry temperature. The mountainous topography was created in the Tertiary period when the area was subjected to prolonged orogeny caused the convergence of continental plates. Glaciation has played an important role in formatting the irregular, steep and rugged topography which reached its maximum during the Pleistocene period.

Influence on climate

The climate of Pakistan greatly influence by these mountain systems. Due to a cold wave spreads over Pakistan in winter and air pressure rise in January the land became colder than sea. Therefore, surface air flows from land to sea. However, in the higher troposphere, a compensating air flow must occur from sea to land, warming the high mountain peaks. (Continental anticyclone phenomena).

By the end of above phenomena in March, Western rain appears in spring on West of river Indus. Due to adiabatic decompression, western wind when flowing down from the Sulaiman Range, warm up. These rains have long duration but low intensity. They occur mainly in the higher mountains of the western part of Pakistan, Sulaiman Range and the Hindukush.

In summer the Himalaya stop the southward cold air from Central Asia. Hence an intense heat accumulate over the Indus plain. Further a monsoon trough starts over the gulf of Bengal. Due to the SW (South-West) Winds, monsoon rains move south of the trough, towards Kashmir. As the air pressures are high over Baluchistan and

NWFP, those areas have dry summer (Siddiqui 1977). Monthly temperature and rainfall of a few locations of moist and dry temperate areas are shown from Fig. 1 to 4.

Himalayan region and northern Baluchistan are highly potential for Dendroclimatological studies (Fritts, Lamarche, Ogden and Rothlisberger personal communications. Since climatic change/global warning effects nearly all aspects of our life, it is a big concern and challenge for scientists and policy makers. Reliable estimates of future climatic events would be of great value in planning of extension of tourism, predicting floods losses, hydrology, managing forestry, agriculture and coastal resources in a country like Pakistan. Therefore it is important to find out sensitive tree species and suitable sites in northern areas of Pakistan which could be useful for such types of investigations.

BACKGROUND

In Pakistan tree ring research started in 1986 when Ahmed (1987 – 1988) described Dendrochronology and its scope in Pakistan and problem encountered in age estimation of forest trees. Ahmed (1989) also presented first tree-ring chronologies of *Abies pindrow* from Himalayan moist temperature region of Pakistan. Ahmed et al (1990A, 1990B, 1991) used Dendrochronological techniques to described population dynamics of *Juniperus excelsa* and *Pinus gerardiana* from dry temperate areas of Pakistan. Ahmed and Saranzai (1991, 1992) applied Dendrochronological methods to estimate age and growth rates of various tree species of Himalayan region of Pakistan. They also presented a Dendrochronological potential of Himalayan trees. Ahmed and Naqvi (2005) presented tree-ring chronologies of *Picea smithiana* from various climatic zones of Himalayan areas of Pakistan. Ahmed et al (2006) also investigated Phytosociology and structure of Himalayan forests from different climatic zones of Pakistan. *Juniperus excelsa* was used to estimate climatic growth response from Himalayan zone of Pakistan (Treydte et al, 2006). Beside these studies, so far no investigations has been carried out in the field of Dendrochronology in Pakistan. However recent interest has developed to use these techniques in climatic reconstruction earthquake studies, river-flow reconstruction, glaciers and forests Population Dynamics. Tree-ring research laboratory with latest equipment has been founded in the Department of Botany, Federal Urdu University of Arts, Science and Technology Karachi, Pakistan. An extensive survey is carried out in northern and north western forests of Pakistan, to collect wood samples and to determine suitable sites where gymnospermic trees producing sensitive rings.

Suitability of gymnospermic tree species are determined under this paper. Now the data obtained from these investigations are being used for Dendroclimatic studies. Tree-rings are also being used to determine Population Dynamics of forest trees of Pakistan. Recently a research proposal "Drought Reconstruction of River Indus" has been approved by Pak/US Science and Technology collaborative program. It is hoped that these investigations will open a new era of applied research in Pakistan.

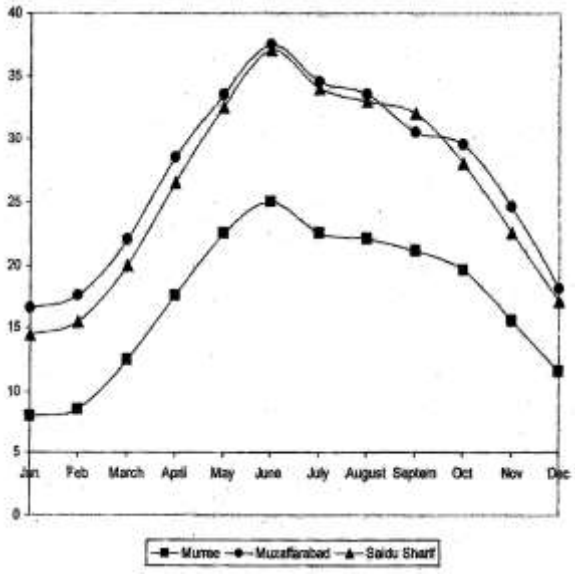

Fig. 1- Mean monthly temp (^{o}C) three stations
Moist temperate forest

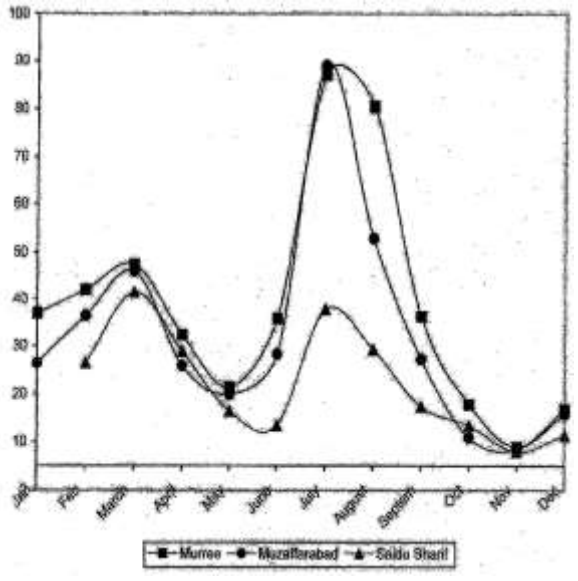

Fig. 2- Precipitation Rain fall in mm
Moist temperate forest

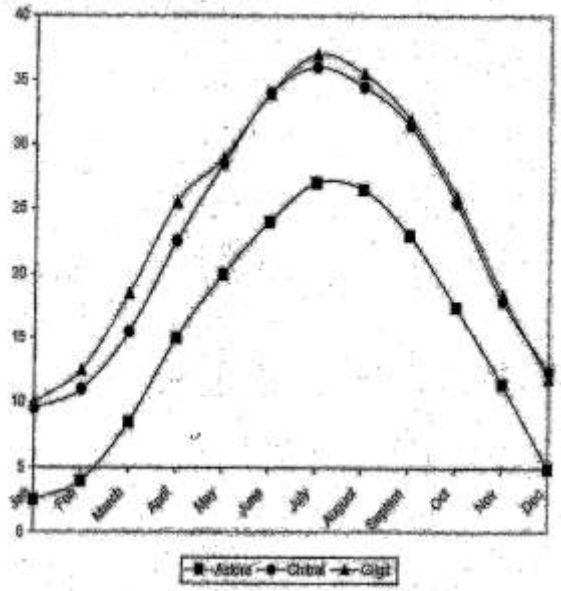

Fig. 3- Mean monthly max temperature three stations- Dry temperate forest

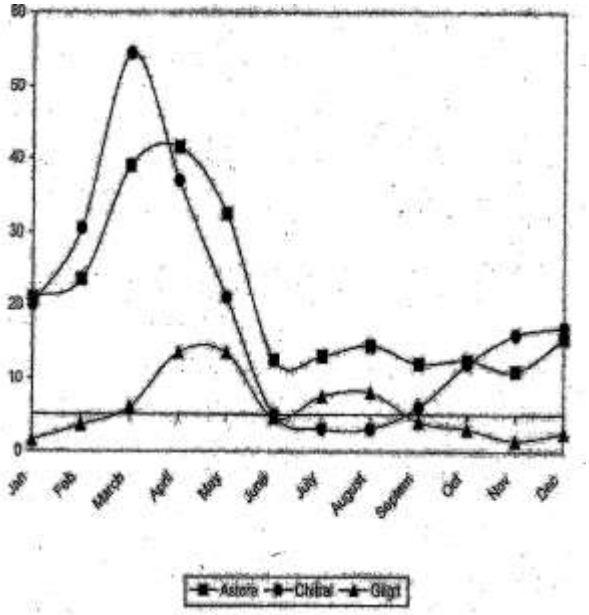

Fig. 4- Monthly amount of precipitation mm three stations- Dry temperate forest

MATERIALS AND METHODS

Wood sampling in the form of cores were collected from 52 different sites of Afghanistan, Abbottabad, Murree, Azad Kashmir, Dir, Chitral, Mansehra, Swat, Kaghan and northern areas of Pakistan.

Sampling collection, handling in field, transportation and sample preparation for the microscopic analysis, Stokes and Smiley (1968), Fritts (1976) and Ahmed's (1984), procedure were followed. Age and growth rates of all tree samples were calculated according to the standard methods described by Ogden (1981) and Ahmed (1984).

Visual cross-matching was done under the microscope and selected cores were subjected to measurement on Volmex measuring machine attached to the computer. After measurement of a species from a particular site is completed to nearest .001 mm, the ring width data was subjected to program COFECHA, presented by Holmes (1983). This program check the visual cross-matching and provide basic statistics ring-width series or part of it, which does not correlate or poorly correlated with other samples of the site are rejected at this stage.

RESULTS

From Dendrochronological point of view four climatic zones are important in Pakistan. Ahmed *et al*. (2006) described these zones and forests with their main tree species.

Sub Tropical Zone

The area received an annual rainfall of about 761mm with a maximum 161mm in August and a minimum 10mm in November. The coldest month is January (10^0C) while the hottest month (32^0C) is June. *Pinus Roxburghii* Roxb is the characteristic pine tree species of the zone. On lower elevation (830 – 1870) it is associated with *Olea ferrugirea* while on the higher elevation (1300 – 1870m), it is found with *Quercus incana* and rarely with *Pinus wallichiana*, on its upper limit.

Moist Temperature Zone

Climatic summary of Murree (2270 m) is presented here to represent this area. The area receives a maximum rainfall 351mm in the month of August and a minimum of 17.8mm in the month of November. The mean daily temperature peaks in June (12.5^0C) while drops to the minimum (3^0C) in January. The area receive about 1.8m to 6.7m snowfall from 1935m to 2440m elevation respectively.

Pinus wallichiana is widely distributed species in moist temperate areas from 1800 to 2450 m a.s.l. It is distributed either as a pure stands or associated with other pine or broad leaved species.

Table 1. Sampling Sites and Species.

Main Location	Sites	[1]Lati	[2]Long	[3]Ele	[4]Asp	Slope [(0)]	[5]Sp.Sm
A-Afghanistan	Dangam	35 ^{o} 02 `	71 ^{o} 32 `	2429	N	30	P. s – C. d
B-Abbottabad Murree	Naran	34 ^{o} 53 `	73 ^{o} 39 `	2500	NW	R-top	P. w- A. p
	Thandyani	34 ^{o} 14 `	73 ^{o} 22 `	2320	S	31	C. d
	Nathiagali	34 ^{o} 04 `	73 ^{o} 24 `	2640	S	25	A. p
	New Murree	34 ^{o} 54 `	73 ^{o} 24 `	2300	SE	40	A. p – P. w
	Murree-Hills	33 ^{o} 54`	73 ^{o} 22 `	2300	SW	25	A. p – C. d
	Kuza Gali	34 ^{o} 02 `	73 ^{o} 24 `	2560	Plain	R-top	C. d
	Changla Gali	33 ^{o} 59 `	73 ^{o} 23 `	2660	W	47	A. p
	Karee Gali	33 ^{o} 57 `	73 ^{o} 23 `	2280	N	42	C. d
	Ayubia	34 ^{o} 49 `	73 ^{o} 24 `	2500	NE	36	A. p
C-Azad Kashmir Muzzafarabad	Sundhan Gali	34 ^{o} 22 `	73 ^{o} 28 `	2450	E	22	P. w – A. p
		34 ^{o} 20 `	73 ^{o} 22 `	2500	N	32	P. w – A. p
		34 ^{o} 19 `	73 ^{o} 25 `	2420	W	38	P. s
	Batrasi	34 ^{o} 24 `	73 ^{o} 21 `	1500	W	34	P. r
	Chikar Forest	34 ^{o} 54 `	34 ^{o} 54 `	1930	NW	28	P. w
	Shogran	34 ^{o} 37 `	73 ^{o} 28 `	2400	S	23	P. s
D-Chitral	Ziarat	35 ^{o} 23 `	73 ^{o} 23 `	1928	W	23	C. d
E- Dir Upper	Janas Valley	35 ^{o} 29 `	72 ^{o} 03 `	2160	S	30	T. b
		35 ^{o} 29 `	72 ^{o} 02 `	2160	E	50	P. w – A. p
	Satto Khwar	35 ^{o} 26 `	72 ^{o} 04 `	2570	N	48	P. w
		35 ^{o} 24 `	72 ^{o} 05 `	2515	E	50	P. w – C. d
		35 ^{o} 24 `	72 ^{o} 07 `	2515	ES	54	C. d
	Shahoor	35 ^{o} 28 `	72 ^{o} 00 `	2150	N	48	P. w
	Batkalae	35 ^{o} 23 `	72 ^{o} 06 `	2527	NW	47	P. w – P .s
	Bailo Barkan	35 ^{o} 22 `	72 ^{o} 10 `	2380	E	44	P. w – P. s
	Sore Kamar	35 ^{o} 30 `	72 ^{o} 09 `	2210	S	35	P. w
		35 ^{o} 30 `	71 ^{o} 89 `	2250	S	35	P. s
		35 ^{o} 30 `	71 ^{o} 95 `	2325	ES	34	P .s
	Shahi Awar	35 ^{o} 00 `	71 ^{o} 37 `	2150	W	40	C. d
	Souray Barken	35 ^{o} 21 `	72 ^{o} 08 `	2322	N	35	P .s

	Shahikot	35 ° 10 `	71 ° 80 `	1920	W	34	C. d
	Barawal	35 ° 11 `	71 ° 69 `	1800	E	38	C. d
	Shalthalo Bala	35 ° 09 `	71 ° 57 `	1950	E	42	C. d – P. w
	Shahi Khwar	35 ° 09 `	71 ° 32 `	2080	N	37	C. d
	Panerako Awar	35 ° 29 `	71 ° 95 `	2240	N	45	P. s
	Danair	35 ° 25 `	72 ° 03 `	2460	W	43	P. s
F—Dir Lower	Bagh Dushkhel	34 ° 43 `	71 ° 50 `	1610	SW	27	P. r
	Anbarzie	34 ° 47 `	71 ° 51 `	1400	N	38	P. r
	Kattan Bala	34 ° 42 `	71 ° 48 `	1820	N	32	P. r
G—Northern area	Naltar	36 ° 07 `	71 ° 14 `	3380	N	27	P. s –P. w
	Chera	36 ° 01`	74 ° 35`	3100	NW	36	P.s
	Astore	35 ° 44`	73 ° 55`	3280	W	31	A.p
		35 ° 54`	73 ° 34`	3160	E	26	P.w
H—Kaghan Valley	Sheno	34 ° 38 `	73 ° 26 `	2650	W	43	C. d – P. w
	Naran	34 ° 47 `	73 ° 36 `	2500	NW	R-top	C. d – P. s – P. w
	Malakundi	34 ° 54 `	73 ° 52 `	1600	NE	20	C. d
	Khairan	34 ° 47 `	73 ° 32 `	2000	E	35	C. d
	Shogran	34 ° 54 `	73 ° 28 `	2400	S	23	C. d
	Sri Paya	34 ° 47 `	73 ° 28 `	2900	N	39	A. p – P. s
I—Mansehra	Dadar	34 ° 41 `	73 ° 25 `	2340	N	28	P. r
J—Swat	Malamjaba	35 ° 12 `	72 ° 81 `	2600	W	34	C. d – P. w
	Marghazar	34 ° 73 `	72 ° 53 `	1600	W	37	P. r
	Kalam Ausho	35 ° 31 `	72 ° 35 `	2700	E	plain	C. d

Note: P. s = *Picea smithiana* , C.d = *Cedrus deodara*, P.w = *Pinus wallichiana;* A. p = *Abies pindrow*, P. r = *Pinus roxburghii*, T. w = *Taxus wallichiana;* 1= Latitude, 2= Longitude, 3= Elevation (m), 4= Aspect, 5= Species Sampled

Table 2. Overall growth rate range year / cm of tree species in different climatic zones.

Sr #	Name of the species	Altitude Limit m a.s.l.	Moist Temp. Years / cm	Dry temp. Year / cm	Sub Alpine Year / cm	Sub Tropical Year / cm
01	*Abies pindrow*	2000 – 3450	3 – 5	4 – 9	6 – 9	ND
02	*Cedrus deodara*	1930 – 3000	2 – 4	3 – 5	3 – 7	ND.
03	*Juniperus excelsa*	1800 – 3500	ND	8 – 16	Not taken	ND.
04	*Pieca smithiana*	2000 – 3250	3 – 6	4 – 8	6 – 10	ND.
05	*Pinus gerardiana*	1800 – 3100	ND	ND	11 – 24	ND
06	*Pinus roxburghii*	900 – 1800	ND	ND	ND	3 – 4
07	*Pinus Wallichiana*	1800 – 3300	2 – 7	5 – 14	Not taken	ND

Temp = Temperate m a.s.l. = meter above sea level.ND = Not distributed.Data based on 20 to 25 tress of each species from each climatic zones. It is shown that slowest growth rates, 11-24 year/cm was calculated from *Pinus gerardiana* from subalpine site. Juniperus excelsa from dry temperate region was also show growing (8-16 year/cm) tree.

Table 3. Narrow rings distribution in samples of different species of different sites.

Code	Psaf	Cdzi	Psch	Psna	Apas	Pwas	Apay
No,of samples	*21*	*18*	*23*	*35*	*48*	*48*	*13*
Years							
2006							
2005							
2004	**13**	**9**		**14**	**25**	**2**	**7**
2003							
2002	14			10	15	1	8
2001		15	12		11		
2000	**17**		**18**	**8**	**19**	**1**	**7**
1999	9				19	1	7
1998				7			
1997					8	2	
1996				12			
1995	**19**		**15**	**15**	**25**	**3**	**13**
1994							
1993				10	5		
1992			10	1	12	3	
1991	16		15	13	12		8
1990						2	
1989	**17**		**14**	**15**	**27**	**2**	**9**
1988							8
1987	10			13	26	6	
1986							
1985	**18**	**17**	**16**	**27**	**26**	**6**	**11**
1984	13					8	12
1983		10		3	7	3	
1982				24	43	15	10
1981				8			
1980	9			9		10	
1979	15			11	41		10
1978			18	23	12		
1977	6					8	
1976	18		13	9			11
Code	**Psaf**	**Cdzi**	**Psch**	**Psna**	**Apas**	**Pwas**	**Apay**
1975					29	9	
1974	**13**		**18**	**31**	**34**	**12**	**11**
1973							
1972				23	10	6	
1971	**10**	**16**	**15**	**6**	**18**	**5**	
1970	20			13	3	8	11
1969		12	9	5	9		
1968	17			10	21	13	
1967				22		8	12
1966	13			9	13	11	
1965	11		7				

1964				20	19	15	
1963							
1962				31	24	10	10
1961			14	5		8	
1960	**20**	**17**		**16**	**29**	**11**	**10**
1959			15	24			
1958	5			9	24	15	
1957				7	23	9	
1956	18	16	8	7			13
1955				7	12	10	
1954		**11**	**10**	**31**	**31**	**12**	**7**
1953	13			11	35		11
1952							
1951	**17**	**12**	**7**	**32**	**29**	**15**	
1950		12					9
1949				13	18	10	
1948	18			4		7	
1947		8		22	38	14	11
1946	**16**	**16**	**10**	**21**	**37**	**14**	
1945				14			6
1944			14	6	43	11	11
1943				19	16		
1942	17						
1941		13		15		9	12
1940			12	8	40	8	
1939	19						
1938			11	32	44	12	
Code	**Psaf**	**Cdzi**	**Psch**	**Psna**	**Apas**	**Pwas**	**Apay**
1937	13						
1936				10	24	8	
1935	14	12		13	22	9	12
1934			8	11	38	13	
1933	15	15		8	12	6	
1932				6		6	11
1931	11		11	31	42	14	
1930							
1929	**18**	**10**	**5**	**15**	**38**	**15**	**13**
1928				12			
1927	**17**	**17**	**11**	**19**	**42**	**11**	
1926				19	18	10	
1925	15		7	9	25		
1924							
1923			7	28	29	7	10
1922					15		
1921	**17**	**14**	**14**	**32**	**31**	**12**	**13**
1920	16			22	18		
1919					12		12
1918	10	14			30	10	

1917			16	31	36	7	
1916							
1915	**14**		**18**	**33**	**46**	**14**	**7**
1914							
1913		16		13	6	6	
1912	**20**	**12**	**16**	**17**	**33**	**11**	**9**
1911				20	42	12	9
1910							
1909	13		16	31	40	5	
1908							12
1907	12		18	20	27	15	
1906					14		
1905		17				5	6
1904	7			4			10
1903			14	29	35	13	
1902	16	12					
1901				30	43	15	9
1900							
Code	**Psaf**	**Cdzi**	**Psch**	**Psna**	**Apas**	**Pwas**	**Apay**
1899	**15**	**17**	**15**	**13**	**29**	**4**	**10**
1898				5		13	10
1897	13		16	26	30	15	
1896							
1895	**21**	**18**	**18**	**26**	**43**	**15**	**7**
1894				11			
1893							
1892		12		17	41	13	11
1891	7			23	35	13	
1890	**18**		**17**	**27**	**21**	**6**	**11**
1889				6	27	3	
1888	**10**	**11**	**10**	**15**	**22**	**14**	
1887				32	30	4	13
1886		17		6	12	5	
1885	17			11	20	8	
1884			17	27	43	11	
1883				10		9	7
1882	13			4	11		
1881			11			2	
1880		**18**	**15**	**24**	**38**	**8**	**4**
1879	19			26	11	13	
1878							
1877			16	31	46	15	
1876					23		8
1875			18	31	31	11	
1874							
1873				20	31	14	9
1872				8			
1871	**14**	**15**	**16**	**7**	**17**	**11**	

1870				3	11		
1869	11		9	19		4	7
1868			17	24	36	9	
1867	16			19	29	9	
1866							
1865		16	12	29	36	13	
1864	14			19	14		
1863					26	9	
1862	9		13	21	31		
Code	**Psaf**	**Cdzi**	**Psch**	**Psna**	**Apas**	**Pwas**	**Apay**
1861		18				10	
1860	12		9	13	11		
1859				12	8	11	10
1858				25	38	14	
1857				3			
1856	**10**	**18**		**6**	**22**	**11**	**11**
1855				26	30	8	
1854		15		5		5	
1853	10			22	25	9	12
1852			8			5	
1851						5	
1850	14			21	15	9	7
1849				7	15	4	
1848	**14**	**16**		**18**	**10**	**5**	**6**
1847			18	27	26	13	
1846				8			
1845	13				10	4	
1844			16	11	22	2	9
1843				28		9	
1842		15			18	11	6
1841	14		14	17	22	3	
1840						8	
1839			16	24	11	7	
1838							
1837	9			28	32	14	
1836				9			
1835			18	13		5	
1834				4			
1833			13	25	28	14	5
1832	4			22	28	10	
1831			15	25	32	14	4
1830				7			
1829		**18**	**15**	**3**	**17**	**10**	**8**
1828				7	21	7	
1827				20	25	9	
1826							
1825		17		14	16	11	8
1824				6	22	11	

Code	Psaf	Cdzi	Psch	Psna	Apas	Pwas	Apay
1823	6			13			
1822		13		4	7		
1821				7	9	5	
1820	**7**	**18**	**13**	**29**	**28**	**13**	**7**
1819				21	16	9	
1818			14				3
1817		14	12	30	31	14	
1816					5		
1815	**6**	**17**	**9**	**18**	**27**	**7**	**8**
1814				4		9	
1813				7		6	
1812		11	17	32	19	9	
1811		18				6	
1810			18	25		4	5
1809		16		19	20	11	
1808				23	28	15	
1807				7			5
1806	5		14	6	17	4	
1805				25	2	6	
1804				6	11	5	7
1803				11			
1802		17	18	28	20	14	
1801							
1800		16		17	8	11	
1799				16	3		
1798		15		6			
1797			15	23	21	14	7
1796							
1795							
1794			7	13	15	9	4
1793		11		10		5	
1792				23	10	10	
1791							
1790			12	26	18	12	4
1789							
1788			11	29	19	13	
1787		15					
1786				21	5		
Code	**Psaf**	**Cdzi**	**Psch**	**Psna**	**Apas**	**Pwas**	**Apay**
1785		**17**	**11**	**8**	**7**	**2**	**4**
1784				19	13	13	
1783							
1782		**14**	**9**	**25**	**19**	**11**	**4**
1781				9	12	8	
1780		14		27	10	12	
1779						5	4
1778		15	11	26	13	12	

1777					7	11	
1776		7					
1775				5	4		
1774		**14**	**11**	**26**	**18**	**13**	**5**
1773					3	8	
1772		11					
1771				26	15	12	
1770							
1769							5
1768		9		23	17	13	
1767			11	20			
1766							
1765				8		9	
1764				18	13	13	5
1763			11				
1762		13		20	18	14	
1761			11	17			
1760				13	16	14	
1759							
1758		13	13	25	16	14	
1757				12			
1756				4	9	11	
1755			12	25	5	4	5
1754		10		6	5	10	
1753				7	13	10	
1752							
1751				13	7	10	
1750			11	13	8	5	
1749			13	13	12		
1748						11	
Code	**Psaf**	**Cdzi**	**Psch**	**Psna**	**Apas**	**Pwas**	**Apay**
1747				10			
1746			11				
1745				22	17	14	
1744			7				
1743				12			
1742			11	11	14	14	
1741				13			
1740				12			
1739			9		8	6	
1738		6		22		8	
1737						10	3
1736				7	9		
1735					2	7	
1734			10	9	8	6	
1733				23	2	7	3
1732					6		
1731			7	24	15	14	

1730			8	13			
1729				9		6	
1728				4			
1727			8	18	10	5	
1726		7	9	4			
1725			11	19	7	8	
1724							
1723				19	10	11	
1722							
1721				19	12	10	
1720				22	8	8	
1719		6	6	8	7	5	
1718				6	9		
1717		6	8	21	13	7	
1716			9	5	5		
1715			11	9			
1714				11	10	7	
1713							
1712		5	7	18	14	8	
1711							
1710			7	13			
Code	**Psaf**	**Cdzi**	**Psch**	**Psna**	**Apas**	**Pwas**	**Apay**
1709			7	3		6	
1708							
1707			11	17	14		
1706				5	3	3	
1705				13	11	4	
1704		6	9	9	11	6	
1703					9	4	
1702				5		5	
1701			10	22			
1700				12	2		

Note: Psaf = *Picea smithiana* of Afghanistan, Cdzi = *Cedrus deodara* of Ziarat Chitral,
Psch = *Picea smithiana* of Chera Gilgit, Psna = *Picea smithiana* of Nalthar Gilgit,
Apas = *Abies pindrow* of Astore Gilgit, Pwas = *Pinus wallichiana* of Astore Gilgit,
Apas = *Abies pindrow* of Ayubia National Park.

Number in column indicated number of samples show narrow ring in that particular year and species. Bold numbers indicate narrow rings in maximum species and sites.

Cedrus deodara, widely distributed in dry temperate areas found in this zone from 1930 m to 2420 m a.s.l, associated with other tree species. At few places it forms small pure stands. Pure stands of *Abies pindrow* occupies higher elevation (2245 to 2550 m a.s.l) then *Pinus wallichiana*. However, it also associated with other tree species in many areas. At many places individuals of *Picea smithiana* and *Texas bacatus* are also present, with above mentioned tree species.

Dry Temperature Zone

Climatic record of Ziarat (2451 m) shows that the average annual rainfall is 269mm with a maximum of 74mm in July. The hottest month is July (27.4^0C) while the coldest month is January (7.9^0C). However, precipitation and temperature changes with increasing elevation.

Species listed in moist temperature areas are also reported in this zone. These species are distributed as a mixed or pure stands in moist sites of dry temperate areas.

Juniperus excelsa distributed from 1200 to 3000 m a.s.l and *Pinus gerardiana* from 1800 to 2700 m a.s.l are the most widely spread and characteristics species confined to dry temperate areas of northern Pakistan. First species also extended into the sub-alpine zone up to 3500m a.s.l at near Gilgit. It is also distributed in many glaciated valleys of northern area as a pure stand or associated with other tree species. *Cedrus deodara* is also one of the widely distributed species of dry temperate area forming pure forests in many locations. *Picea smithiana* forms pure forests in glaciated valley of Nalter only from 3100 to 3250 m a.s.l, while it associated with *Pinus wallichiana* on slightly lower elevation. A moist temperate species, *Abies pindrow* grows as a pure or mixed stand on 3200 m a.s.l at dry temperate valley of Astor.

Table 4. Summary of COFECHA: Statistics of cross-matched species from suitable sites.

	//---------- Unfiltered ----------\\					//------ Filtered ------\\			
Species and Sampling Sites	[1]Corr With master	[2]Mean msmt	[3]Max smt	[4]Std dev	[5]Auto corr	[6]Mean sens	[7]Max value	[8]Std dev	[9]Auto corr
Picea smithiana Afghanistan	0.538	2.15	9.53	0.990	0.817	0.188	1.43	0.265	-0.005
*Cedrus deodar*a Ziarat (Chitral)	0.548	1.60	8.34	0.775	0.825	0.214	1.49	0.284	0.005
Picea smithiana Chera (Gilgit)	0.727	0.96	7.32	0.505	0.789	0.278	1.59	0.318	0.2
Picea smithiana Nalthar (Gilgit)	0.653	0.82	4.28	0.400	0.840	0.217	1.13	0.250	-0.001
Abies pindrow Astore (Gilgit)	0.593	0.99	8.25	0.384	0.771	0.184	1.37	0.227	0.003
Pinus wallichiana Astore (Gilgit)	0.636	0.95	6.85	0.594	0.893	0.173	1.33	0.215	0.001
Abies pindrow Ayubia National park	0.549	1.59	11.36	0.934	0.778	0.262	2.22	0.355	0.004

Note: 1= correlation with master chronology, 2= Mean ring width, 3= Maximum ring width 4,8= Standard deviation, 5,9= Autocorrelation,
6= Mean sensitivity, 7= Maximum value.

Sub Alpine Zone

No meteorological record is available from this area however according to Champion et al (1965) maximum temperature do not exceed from 15.5^{0}C and snowfall from 1.5m. Nearest weather station Astor (2166 m) indicates that July is the hottest (27.2^{0}C) while January is the coldest (1.7^{0}C) month. Mean monthly rainfall is about 479mm which is from Feb to May. A broad leaved tree *Betula utilis* is the characteristics species of this zone. Pine or Juniper species distributed in this zone are smaller in size than other zones.

Cedrus deodara reported from Matiltan glacier and various subalpine area of Dir. *Pinus wallichiana* associated with other pine species from Astore and Matiltan. *Abies pindrow* also occupies subalpine zone around Rama Lake (Astore) and some areas of Dir.

It is *Juniperus excelsa* which confined to dry temperate areas is extended in to some subalpine northern area (near Gilgit). *Picea smithiana* also grow in subalpine zone at Nalter (Gilgit).

Age and growth rates

Table 2 shows age and growth rates of largest and oldest trees of various species belong to different sites. It is evident from the table that largest tree is not necessarily the oldest tree of the site and vise versa…

Age and growth rate varies considerably not only among the individuals of same species but also in trees of same size and site. Therefore, no significant relation was obtained between Dbh and age/growth rate. However, overall growth rates year/cm of tree species in different climate zones are presented here.

Cross matching

Cross dating or cross-matching is the most important principle of Dendrochronology. Its application provides a type of "experimental" control because it assures the proper placement in time of each growth ring. The yearly ring widths of a species must be cross-dated among all radius with in a stem and among different trees of similar species in a given stand as well as ring-width pattern of neighboring stands of the same species. If there is sufficient covariation among rings in different trees and the sample is large enough, the year in which each rings formed can be correctly ascertained. If there is low cross-matching or correlation of ring width variation among trees, the dating may be uncertain and the sample must be discarded for Dendrochronological work.

A comparative visual assessment of narrow rings appeared in different gymnospermic tree species belongs to different areas is presented in table 3. It is evident from this table that in some years, narrow ring appears in most of the samples of a site. For example out of 21 trees 17 samples of *Picea smithiana* collected from Afghanistan show distinct narrow rings in year 2000, 1995, 1989, 1985, 1976, 1970, 1968, 1950, 1956, 1951, 1948, 1942, 1939, 1927, 1921, 1912, 1895, 1888, and in year 1879. A large number of samples from *Cedrus deodara*, *Picea smithiana* from Chera, *Picea smithiana* from Nalter, *Abies pindrow*, *Pinus wallichiana* from Astore and *Abies pindrow* from Ayubia also show narrow rings in particular years. It is suggested that these species have cross-matchable sensitive rings and strong climatic factor may be influced on most of the individual of many species in that some particular year, reducing growth.

Once a regional cross-dating of one species and site is established the yearly ring width sequence should be cross dated with the yearly ring width sequence of same species of other sites, neighboring stands or different species of the same or different site.

Cross dating is possible because the similar extreme climate factor have limited the ring widths in large numbers of trees and the year to year fluctuation is limiting climatic factors that are similar throughout a region produce synchronous variation in ring structure. The fact that cross-dating can be obtained itself in evidence that there is same common climatic information common to the samples trees.

It may also be observed from the table that some narrow rings not only found in many samples of species, but in the other species too. For example in year 1985, 1927, 1929, 1899, 1820, 1921, 1912, 1899, 1915, narrow rings appear in all sites and species. These rings are called pointer or signature rings, showing strong and wide spread climatic influence on growth. It gives additional support to the previous conclusion that species under investigations are not only produce sensitive and cross-matchable rings but also contain similar climatic singles, hence may be used for applied Dendrochronological investigations.

Statistical summary of cross-matched species from suitable sites is given in Table 4. It is shown that higher autocorrelation values are minimized by using filter technique. Mean sensitivity ranged from 0.173 to 0.278, seems low, however with in the range of other studies of overseas. *Picea smithiana* from Gilgit, showed narrowest (0.96 mm) rings while same species from Afghanistan produced wide rings. It is also evident from the table that higher correlation is related to narrow rings. These statistics also indicate that these species are suitable for tree-ring investigation.

DISCUSSION

Selection of suitable species and site are the basic requirement and first step in Dendrochronological Research. Criteria of suitable site and species has been determined in developed countries but now initiated and established, through deep investigations in Pakistan. Suitable Dendrochronological sites are those where at least one climate factor temperature or rainfall controls the tree growth, developing narrow and sensitive rings.

Characteristics of suitable species from Dendrochronological point of view are …

1. Should be providing annual rings.
2. Main trunk should be concertric and asymmetric.
3. No lobate or abrupt growth pattern.

4. Having clear and distinct ring boundaries.
5. Should have clear circuit uniformity.
6. Year to year variation in rings width (sensitivity) and low auto-correlation.
7. Should be cross-matchable among tree of a same species.
8. Too depressed or wide rings should be minimum.
9. Missing/ absent, partially absent, double or false rings should be minimum.
10. Deformed damaged tree should be avoided.
11. Trees with competitive species should be avoided.

On the basis of visual cross-matching and COFECHA program it is suggested that following are the suitable species and Dendrochronological potential areas in Pakistan.

1. In moist temperate areas, *Abies pindrow* produced sensitive rings if growing on steep slopes with stony bedrock underneath the soil surface.
2. *Cedrus deodara* a widespread dry temperate tree also produces sensitive rings in the same situation but close to its distribution margin.
3. *Pinus wallichiana* a wide spread moist temperate species produced narrow ring only if growing on subalpine regions.
4. Picea smithiana a dry temperate species show sensitive rings only on higher elevation close to timberline.
5. *Pinus gerardiana* a restricted dry temperate species produced sensitive ring-width sequence at drier site of the dry temperate region.
6. *Pinus roxburghii* a sub-tropical tree species is not suitable for Dendroclimatic studies at least in Pakistan.

It is concluded that the chronology network described in this paper will provide a useful proxy ring-width data base which will be used in future applied Dendrochronological research.

ACKNOWLEDEGMENT

Higher Education Commission of Pakistan is gratefully acknowledged for providing financial grant No. 20-441 to our research project.

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(*Accepted for publication June 2010*)