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RING WIDTH CHARACTERISTICS OF 4 PINE TREE SPECIES FROM HIGHLY DISTURBED AREAS AROUND MURREE, PAKISTAN

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Abstract

Observational and quantitative ring width characteristics of 4 pine species i.e., 1. *Abies pindrow*, 2. *Cedrus deodara*, 3. *Pinus wallichiana*, 4. *Pinus roxburghii* from highly disturbed sites of Murree Hills were studied. From each pine tree species wood (cores) samples were collected, prepared in the laboratory, studied under microscope and measured by Velmex measuring machine attached with the computer. Dendrochronological techniques were followed in the study. All four species showed clear ring boundaries, distinct rings without any missing or locally missing rings while double or false rings were recorded in *Pinus roxburghii* and *Pinus wallichiana* only. Wide or complacent rings were common in each species. Ring width pattern was cross dateable within species with some common narrow rings were also recorded among the species. Cores show poor correlation with master chronology of each species. Highest mean ring width (3.40mm) was recorded in *Cedrus deodara* while lowest (1.3mm) was observed in *Pinus roxburghii*. Unfiltered Autocorrelation was from 0.515 to 0.585 and mean sensitivity ranged from 0.37 (*Cedrus deodara*) to 0.433 (*Abies pindrow*). It was shown that observational characteristics were similar to undisturbed sites while correlation with master chronology was extremely poor if compared with trees of undisturbed site. It is concluded that besides poor correlation among the samples of a tree species and between species there is no difference between the trees of disturbed and non-disturbed areas.

Key words: Dendrochronology, Disturb forests, Ring-width, Sensitivity, Murree.

Introduction

Dendrochronology is a rapidly growing applied science in which pattern of ring width of trees are considered as a best, and reliable past proxy record (Ahmed, 2014; Ahmed & Zafar, 2014). Based on its technique, used in various science subjects, has many branches so does have applications i.e. climatology, hydrology, forestry, glaciers, archeology, seismology etc. Suitability of any tree species in tree ring studies depends upon its ring width characteristics i.e. sensitivity, cross match ability of narrow/wide rings and correlation among samples of a tree or between trees. The focus of this paper is to describe the ring width characteristics and chronology of pine trees preferably young trees, the range of age starts from juvenile stage up to recently mature trees. The previous work done in this area has covered the undisturbed or least disturbed locations to generate the forest community status, age and growth rates of pine tree species i.e., Wahab (2011); Khan (2011); Siddiqui (2011); Akber (2013); Akber *et al.*, (2014); Hussain (2013); Zafar (2013). The rings produced by trees show differences in their widths i.e. narrow or broad due to the impression of climatic and non-climatic effects on them (Fritts, 1976). These patterns of ring widths can be compared with each other within a tree and cross matched with the other trees of the same species as they face the similar environmental and climatic conditions in the same geographical location. Different species may show different ring width characteristics in similar environmental conditions while same species in different environmental conditions show different response through their ring width or growth (Ahmed, 1984). No work was done to describe ring width characteristics of pine species from highly disturbed areas. Therefore, present investigations were conducted in highly disturbed areas around Murree Hills, to see the possible difference in growth rate, ring pattern and quantitative ring width characteristics between undisturbed and disturbed situation.

Materials and Methods

Forested area with open canopy, wide gaps between trees, closed to human settlement, presence of domestic animals or presence of logged trees are considered disturbed forest sites. Following this categories four sites 1) Ayubia (*Abies pindrow*), 2) Koozah gali for *Cedrus deodara*, 3) Main Murree for *Pinus wallichiana* and 4) Ghora gali for *Pinus roxburghii* were sampled. Standard Dendrochronological procedures of Stokes & Smiley (1968), Fritts (1976), Speer (2010) and Ahmed & Zafar (2014) were followed in the field and laboratory. A Swedish increment borer (12") was used to obtain wood samples from four pine tree species. Cores were marked with all details and were kept in drinking straws to prevent damage in the field. Cores were air dried and mounted on wooden frames with glue and tied with tapes. Air-tighted again and polished using different grith of papers. Cross-dated under microscope using skeleton plot technique was used as described by Cropper (1979). The rings of each core were marked into a proper year of ring formation, first they were cross-dated within a species and measured using Velmex measuring machine attached with microscope and computer. Program COFECHA (Holmes *et al.*, 1992, Grissino-Mayer 2001) was used to obtain quantitative ring width characteristics.

Result

Photographic example of rings width of 4 Pine species of study area is shown in Fig. 1. Following is a description of each species separately.

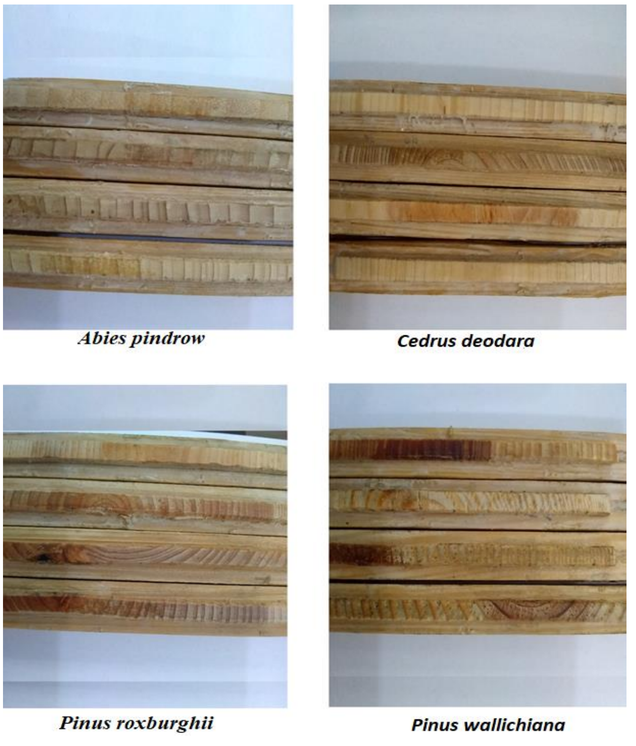

Fig. 1. Showing rings of 4 Pine species of study area.

Abies pindrow: Results of COFECHA analysis summarized and were shown in Table 1. Due to a large table of core sample in each species, it was not shown in this paper. 1 to 2 flags appeared in each ring series indicated cross matching error or problem in different areas or period of wood. Sample rings were annual in nature with clear ring boundaries. No double or missing ring was detected. Out of 25 cores all 25 cores were cross matched, while 12 cores showed negative correlation with master chronology. Minimum of -0.342 correlation (core. 15) and maximum of 0.442 (core.7 and 9) was detected while overall correlation with master chronology was 0.047. Mean ring width ranges from 1.18 (core. 17) to 3.223mm (core. 15). The range of mean sensitivity started from 0.186 (core. 20) to 0.538 (core. 7) and overall mean sensitivity was 0.433. Range of Autocorrelation lies between -0.141(core. 13) to 0.684 (core. 8). Total number of rings counted in the sample cores were 863. Fig. 2(a) showed the raw chronology of *Abies pindrow* with its age span and different growth rates before removing the flags from each core. Fig. 2(b) showed the sample size of these cross-dated cores indicating the old trees were taken by loggers. Area composed of many young trees. Fig. 2(a) also indicated different periods when this species show above average and under average growth. These period of below average growth (narrow rings) were from 1954-1957, 1959-1964, 1965-1971, 1981-1985, 1992-1996, 2010-2013 while periods of above average growth (wide rings) were from 1957-1959, 1964-1965, 1971-1980, 1986-1991, 1999-2009, 2014-2015. Fig. 2(b) indicated that the sample size was lower from 1954-1972 at an average of 10 while it increased from 1973-2001 up to 20 samples and from 2002-2015 it increased above 20 samples.

Narrow rings appeared in the years of 1956, 1957, 1963, 1968, 1969, 1970, 1973, 1074, 1982, 1983, 1984, 1985, 1993, 1994, 1995, 2010, 2011, 2012 while wide rings were in the years 1955, 1958, 1959, 1962, 1965, 1966, 1975, 1976, 1977, 1979, 1980, 1987, 1988, 1991, 1992, 2006, 2009, 2014, 2015. The overall mean narrow measurement of the rings shows 1.96 ± 0.11mm while maximum wide ring width measurement shows 7.83 ± 0.26mm (Table 1).

***Cedrus deodara*:** The results obtained from COFECHA (Table 1) clearly showed that 26 cores were cross dated out of which 14 cores showed negative correlation. The rings possess distinct boundaries. The oldest core of *Cedrus deodara* was of 89 years and the youngest core was of 6 years. No missing ring or double ring was seen in the results. The correlation with master chronology ranges from -0.002 (core. 4) to 0.359 (core. 20) while overall correlation with master chronology was 0.013. Mean measurement with master chronology ranges from 0.79mm (core. 24) to 14.98 (core. 26). Mean sensitivity of *Cedrus deodara* ranges from 0.133(core. 13) to 0.530 (core. 26) while overall mean sensitivity of 0.374. Autocorrelation was found to be in the range of -0.01 (core. 11) to 0.688 (core. 20). The overall master series correlation was 0.013 while Autocorrelation was 0.585. The total numbers of rings counted were 684. Fig. 3(a) revealed that below average growth appeared in 1969-1975, 1977-1987, 2009-2011periods while the ring widths reached above average in the period of 1976-1977, 1987-2002, 2006-2008, 2011-2015. The sample size of the species is given in Fig. 3(b) which showed that the sample of *Cedrus deodara* increased at the range of 5 in the years 1975-1985. It slightly increased but remained below 10 in the year 2000 and became constant at this level uptill 2015.

Narrow Rings were found in years: 1927, 1929, 1938, 1940, 1941, 1943, 1944, 1945, 1946, 1951, 1954, 1956, 1960, 1963, 1975, 1978, 1981, 1982, 1983, 1984, 1985, 2002 and 2012.

Wide Rings were shown in years: 1928, 1930, 1933, 1934, 1936, 1937, 1939, 1942, 1948, 1949, 1950, 1953, 1957, 1958, 1961, 1962, 1964, 1965, 1966, 1967, 1968, 1970, 1972, 1976, 1980, 1987, 1989, 1990, 1991, 1997, 2005, 2007, 2011, 2013, 2014. The total mean narrow ring width of chronology was 3.40 ± 0.53mm and the total of maximum wide ring width chronology was 19.66 ± 0.53mm.

Table 1. Summary of COFECHA: Mean Ring width characteristics of 4 Pine species.

Name of spp.	Un-filtered						Filtered			
	Min-Max Age	Master[1] Chron	Mean[2] msmt	Max[3] msmt	Std[4] Dev.	Auto[5] Corr.	Sens[6]	Value[7]	Std[4] Dev.	Auto[5] Corr.
A.P	9-62	0.047	1.96	7.83	1.042	0.515	0.433	2.64	0.514	0.013
C.D	6-80	0.013	3.40	19.66	1.790	0.585	0.374	27.15	0.731	0.028
P.W	12-112	0.076	1.65	12.37	0.973	0.576	0.411	5.84	0.480	0.014
P.R	16-98	0.020	1.30	6.74	0.869	0.572	0.426	1.50	0.463	0.004

Note: A.P = *Abies pindrow*; C.D = *Cedrus deodara*; P.W = *Pinus wallichiana*; P.R = *Pinus roxburghii* 1 = Correlation with master chronology; 2 = Mean ring width in mm; 3 = Maximum ring width in mm; 4= Standard deviation; 5 = Autocorrelation; 6 = Mean sensitivity; 7 = Value

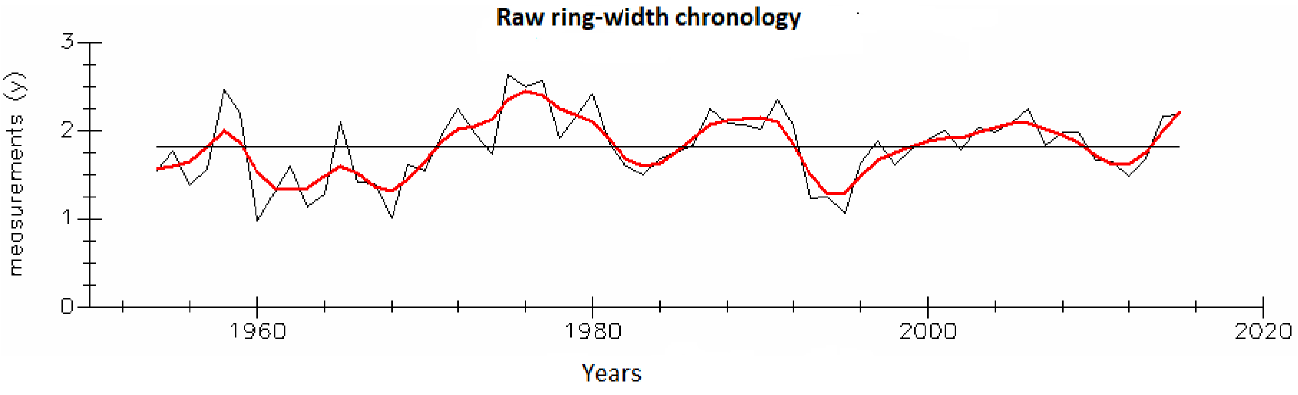

Fig. 2(a). Showing Raw ring-width chronology of *Abies pindrow* and growth rates from 1954 to 2015.

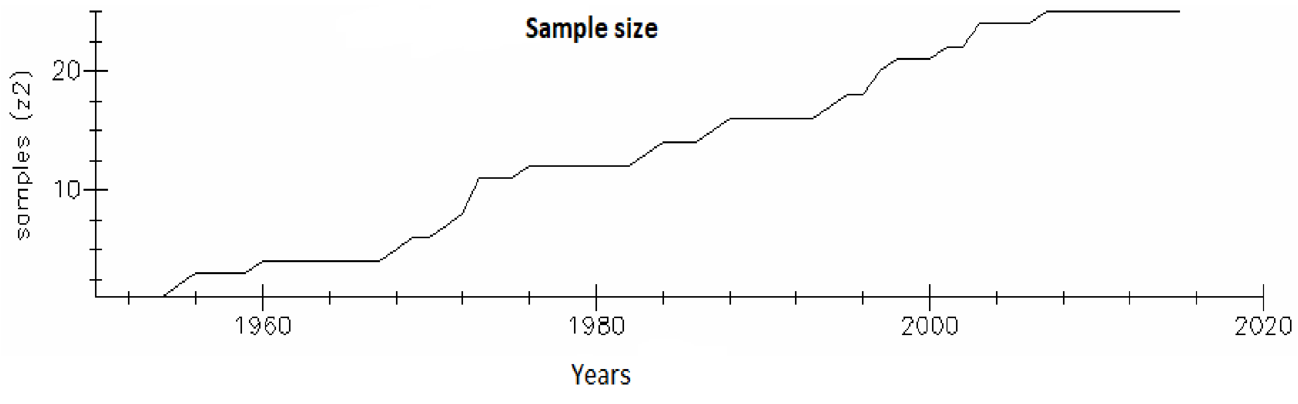

Fig. 2(b). Showing Sample size of *Abies pindrow*.

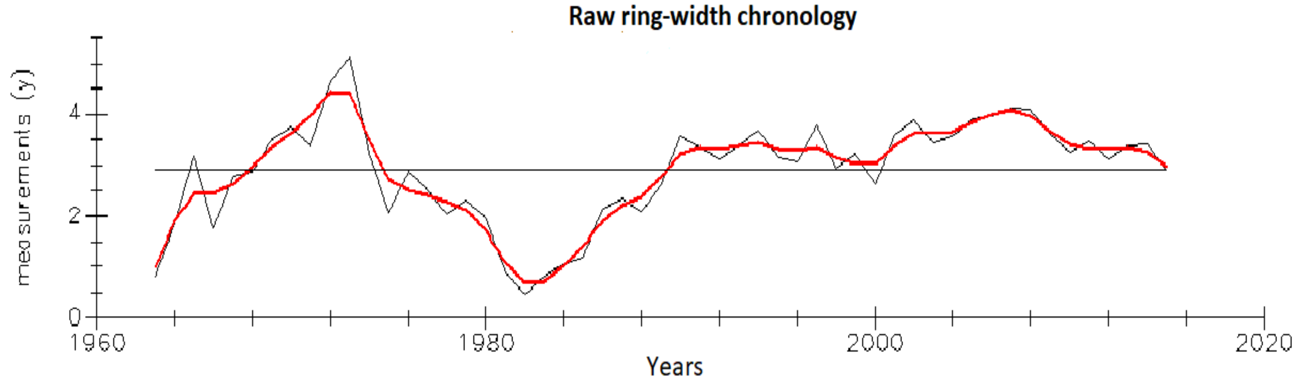

Fig. 3(a). Showing Raw ring-width chronology of *Cedrus deodara* and growth rates from 1964 to 2015.

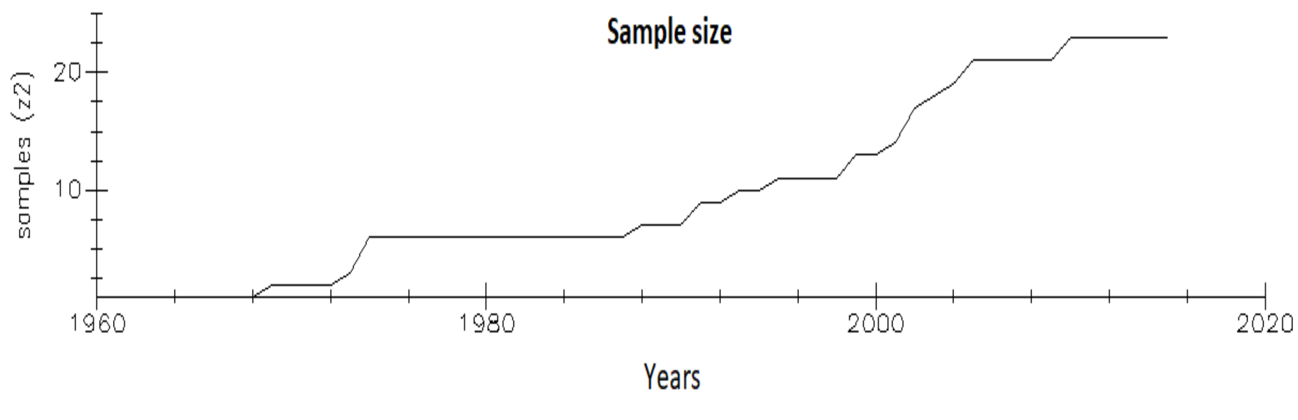

Fig. 3(b). Showing Sample size of *Cedrus deodara*.

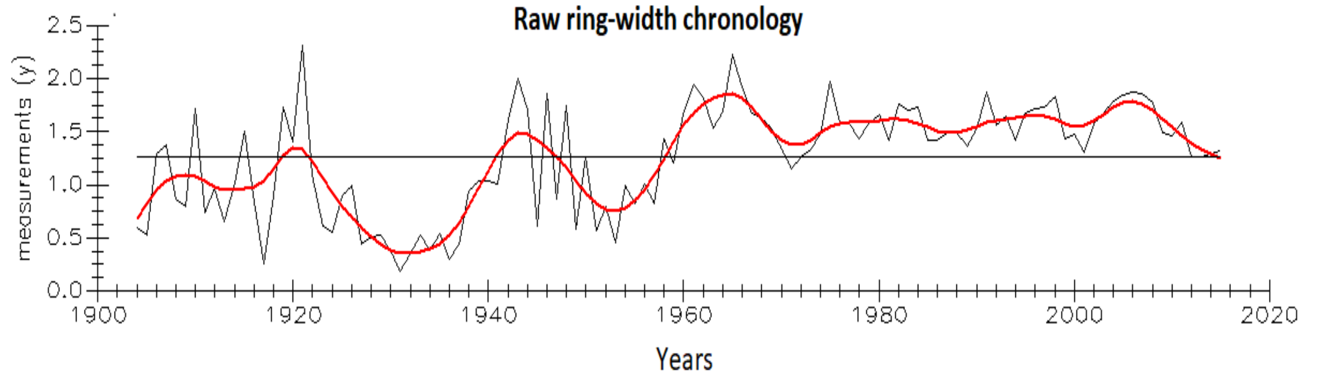

Fig. 4(a). Showing Raw ring-width chronology of *Pinus wallichiana* and growth rates from 1904 to 2015.

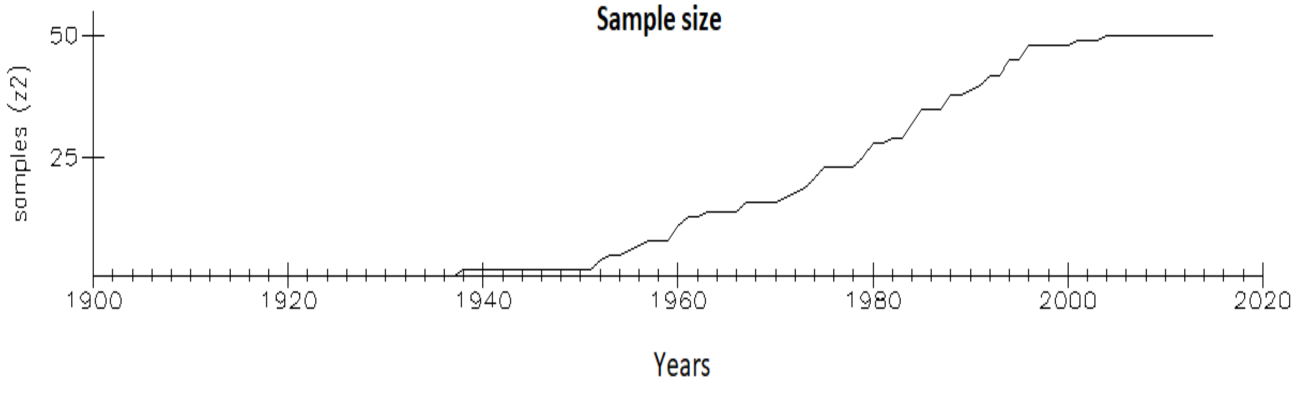

Fig. 4(b). Showing Sample size of *Pinus wallichiana.*

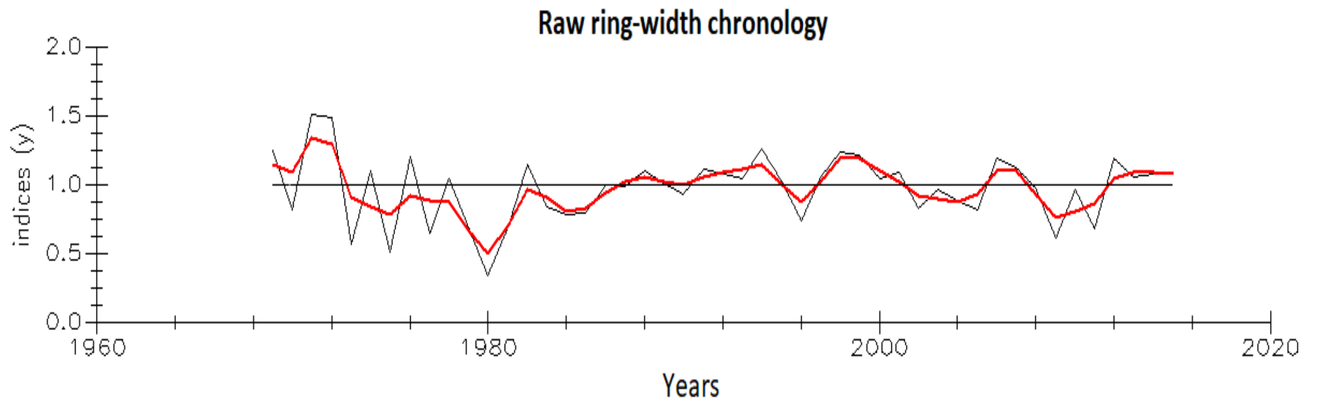

Fig. 5(a). Showing Raw ring-width chronology of *Pinus roxburghii* and growth rates from 1940 to 2015.

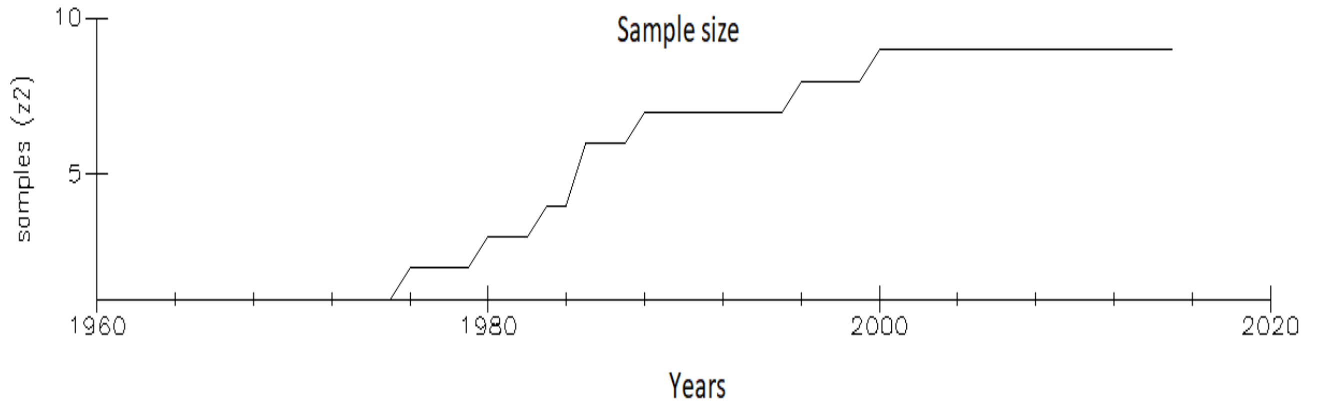

Fig. 5(b). Showing Sample size of *Pinus roxburghii*.

Pinus wallichiana: Out of 119 cores, 54 were cross dated only. The oldest tree of this species was of 112 years (core. 4) and the youngest tree was of 12 years (core. 19). Flags appeared in the cores with a minimum number of 1 and maximum number of 3. Correlation with master chronology was found in the range between -0.002 (core. 22) and 0.386 (core. 16) while overall mean was 0.076. Mean measurement range was found from 0.79mm (core. 37) to 0.323mm (core. 26). Total rings counted were 2134. Overall autocorrelation was 0.576. Fig. 4(a) showed the raw ring width chronology in which various growth transitions appeared in the rings. They showed very instant change in the above average and below average changes in their ring widths. The rings count starts from 1904 which is at below average (slow growth) and this condition remains in periods of 1904-1906, 1907-1909, 1912-1915, 1916 and 1918. While the rings occurred at above average (fast growth) in the periods of 1906-1907, 1909-1911, 1915-1916, 1918-1922, 1942-1944, 1946-1947, 1948-1949, 1958-1971, 1972-2015. The sample size of *Pinus wallichiana* was very low from 1937 up to 1951 at the range of 4 (Fig. 4b). The size increases upto 10 while reaching 1960 and slightly increased to 25 in 1985; from here it gradually increased upto 25 in the year 1999. From 1999 the sample size becomes constant at 25 up till 2015.

Narrow Rings (or slow growth) were found in the years: 1904, 1905, 1908, 1909, 1911, 1913, 1916, 1917, 1923, 1924, 1927, 1928, 1929, 1930, 1931, 1932, 1934, 1936, 1940, 1941, 1945, 1949, 1951, 1953, 1955, 1957, 1985, 1999, 2000, 2001, 2002, 2012 and 2013.

Wide Rings (or fast growth) were recorded in the years: 1906, 1907, 1910, 1915, 1919, 1920, 1921, 1922, 1926, 1939, 1942, 1943, 1944, 1946, 1948, 1950, 1956, 1958, 1960, 1961, 1965, 1966, 1967, 1975, 1976, 1981, 1982, 1983, 1991, 1997, 2005, 2006, 2007, 2008, 2009. Table 1 postulated that overall mean narrow ring width measurement was found to be 1.65 ± 2.94mm and maximum wide ring width was 12.37 ± 0.25mm.

Pinus roxburghii: Clear ring boundaries of *Pinus roxburghii* showed difference between early and late wood. Sixty six cores were taken from the trees, only 10 cores were cross dated in which the oldest core was 98 years old (core. 4) and the youngest core was of 16 years (core. 5). Result also showed flags with a maximum number of 3 and minimum number of 1 flag. Three cores exhibited negative correlation with master chronology ranged from -0.005 (core. 5) to 0.089 (core. 2). Mean measurement range starts from 0.69 (core. 3) to 2.31mm (core. 7). The range of autocorrelation started from 0.163 (core. 3) to 0.725 (core. 2) while overall mean autocorrelation was 0.572. Mean sensitivity occurred in between 0.269 (core. 9) and 0.652 (core. 7) with mean of 0.426. Total rings counted from all cores were 380. The overall master series chronology correlation appeared to be 0.020.

The ring-width chronology of *Pinus roxburghii* consisted of a variety of sudden changes in the whole life span Fig. 5(a). The chronology started from 1969. The ring widths showed below average growth in the periods of 1969-1975, 1977-1987, 1995-1997, 2004-2005, 2009-2011 while the above average growth appeared in 1976-1977, 1987-1995, 1997-2002, 2005-2007 and 2011-2015 period. The sample size of *Pinus roxburghii* is given in Fig. 5(b). The starting year is 1975; the Fig. 5(b) shows that the sample size increases up to 2 in the year 1975-1979, it has reached above 5 in 1985and finally at 9 or below 10 in the year 2000 where it became constant up till 2015.

Narrow rings were recorded in the year: 1918, 1919, 1920, 1926, 1935, 1937, 1938, 1939, 1940, 1941, 1948, 1949, 1950, 1951, 1955, 1956, 1958, 1970, 1973, 1975, 1981, 1996, 2004, 2005, 2009.

Wide rings were in the year: 1922, 1923, 1928, 1929, 1930, 1933, 1942, 1943, 1945, 1946, 1947, 1952, 1954, 1959, 1961, 1962, 1966, 1967, 1968, 1969, 1972, 1974, 1976, 1978, 1982, 1987, 1988, 1991, 1992, 1994, 1998, 1999, 2001, 2003, 2006, 2007, 2008, 2012, 2014 and 2015. The overall mean narrow ring width measurement was 1.30 ± 0.14mm and maximum wide ring width chronology was 6.74 ± 0.49mm (Table 1).

Discussion

Present study showed that disturbed Pine species i.e. *Abies pindrow, Cedrus deodara, Pinus wallichiana, Pinus roxburghii* bore clear ring boundaries and year wise distinct rings which were cross-dateable with minor problems i.e. double rings were common but easy to detect while no missing ring or partially missing rings were recorded. Due to cutting of trees only small sized and young trees were dominated with wide open canopy with large gaps in the area.

Ring width characteristics of Pine trees belonged to least disturbed sites of subtropical, moist temperate, dry temperate, timber line as shown by various workers in Pakistan. In Pakistan, ring width characteristics were reported by Ahmed (1989) using *Abies pindrow* from Nathia gali showing 0.262 mean sensitivity, 1.59 mm mean ring width and 0.778 autocorrelation. Siddiqui *et al.*, (2013) recorded the most narrow rings from *Abies pindrow* from Kuzah Gali while the highest growth rate recorded by *Pinus wallichiana* from Patriata, Murree Hills during their survey on moist temperate areas around all over Pakistan. Ahmed *et al.,* (2012) also collected core samples of *Abies pindrow* from Astore and obtained quite similar results i.e. mean ring width was 0.99 mm, mean sensitivity was 0.184 and autocorrelation was 0.771. The species showed 1.96 mm mean ring width, 0.433 mean sensitivity and 0.515 autocorrelation which was more or less similar to the previous observations. According to Ahmed & Ogden (1985), the increase in autocorrelation of trees is an indication of gain in growth of trees due to climatic, non-climatic and biological factors or it may also be greater in the presence of severe competition. In the previous and current studies the degree of correlation gradually decreased which was a clear indication of decline or abrupt growth in *Abies pindrow*. In present study after 1700AD the trees showed greater growth rate while after 1980 to 2000 AD declines in growth of Ayubia forests was observed and might be due to thinning practices in the forest.

Bokhari *et al.*, (2013) collected wood samples for dendroseismology studies from 4 different sites of Azad Kashmir and investigated about growth trends in Pine species (*Abies pindrow* and *Cedrus deodara*). Our

COFECHA results showed 1977, 1953 years as common period for the development of narrow ring width in *Abies pindrow* while in *Cedrus deodara* the common periods in 2 different sites were 1997-1979, 1975, 1973, 1971, 1967-1966, 1957-1955, 1946-1945, 1919-1918 and marked as the pointer years. The mean measurement of *Abies pindrow* rings was estimated as 1.89 mm and 3.58mm from Sudhan gali and Pir Chinasi respectively while mean sensitivity was measured as 0.299 mm and 0.249 mm. Khan *et al*., (2018) described tree-ring chronology of *Abies pindrow* from Indus Kohistan, Pakistan. The mean sensitivity of their study was 0.186 with mean ring width of 1.42 mm. Mean measurement of *Cedrus deodara* rings was 2.00mm and 2.53mm from Kail and Keran areas respectively. *Cedrus deodara* showed clear indications of disturbance by showing high values of sensitivity and pointer years of narrow rings that confirmed the stress condition in the forest. In our analysis, 1977, 1978, 1975 also showed narrow rings showing similar growth response.

Akbar *et al.,* (2014) explored ring-width of *Pinus wallichiana* from Skardu. Their chronology length was 211 years whereas the mean sensitivity was 0.16. Similar to our study Ahmed *et al*., (2009) conducted tree-ring study of *Pinus roxburghii*. They suggested *Pinus roxburghii* growing on north facing slopes shows complacent ring. But contrast to their study, present finding shows narrow rings at similar locations. The difference in ring-width characteristic in the same location may be due to receiving of sunlight in the open canopy forest. Species growing on open canopy received high sunlight. Thus evapotranspiration rate at that particular area increases which affect the growth rings comparable to those species which are located on closed canopy or shaded areas. Since present study was conducted in high disturbed forests therefore, the ring-width showed narrow rings.

In our study, the COFECHA output file showed close correlation in the ring width growth of the 4 Pine species observed in the forest. Year 1938, 1940, 1941, 1951, 1970 and 1973 are the common years for the occurrence of narrow rings in *Cedrus deodara, Pinus wallichiana, Pinus roxburghii.* In year 1963, 1984, 1985, 2012, *Abies pindrow* and *Cedrus deodara* had narrow rings since both species occupied higher elevation. In 1956 all 4 species produced narrow rings showing similar strong climatic or non-climatic effects. It seems that 1982 was important for *Abies pindrow*, *Pinus roxburghii* and *Cedrus deodara* while in 1983 *Pinus wallichiana* and *Cedrus deodara* showed narrow rings. In 2004, *Pinus roxburghii* and *Pinus wallichiana* possessed narrow rings. Hence the cross correlation in pointer years is confirming the presence of environmental or biological stress which is responsible for limiting tree growth. The narrowest rings were found to be common in the year 1951 in *Cedrus deodara*, *Pinus wallichiana* and *Pinus roxburghii.* In 1927, *Cedrus deodara* and *Pinus wallichiana* showed another very narrow ring. In 1955, *Pinus roxburghii* and *Cedrus deodara* possessed another common narrowest ring. *Cedrus deodara* was the most sensitive and highly correlated with other species as shown in the results while *Abies pindrow* showed weak correlation with other species might be due to the occurrence of higher elevation than the other 3 species. According to the overall results obtained the most sensitive condition to be predicted was in 1951, as three species commonly showed narrowest growth rings in this year. It was shown that ring width characteristics of disturbed pine species were within the range of other studies in Pakistan and no obvious differences (except poor correlation with master chronology and mean ring width) were recorded between disturbed and non-disturbed pine tree species.

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