Tree growth and recent climatic changes in the western Himalaya

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Cedrus deodara and *Pinus gerardiana* growing in the dry temperate forest of Uttarkashi and Kinnaur, Western Himalaya have large number of annual rings and are most suited to make long replicated chronology for dendroclimatic analysis. *Juniperus macropoda* and *Taxus baccata* are older than other conifer taxa. Dendroclimatic potential of these two taxa is yet to be ascertained. The study shows that low growth in *C.deodara* and *P.gerardiana* occurs during most of the low precipitation years. Low tree growth has also been recorded during low lake level periods in Ladakh and years of El-Nino events. The study envisages that tree ring data could be useful in understanding of long term variability in precipitation, lake level changes and also El-Nino events.

Key-words—Tree rings, *Cedrus deodara*, *Pinus gerardiana*, climate, western Himalaya.

INTRODUCTION

TREE ring records have now been recognised as important source of proxy data for climatic analysis (Fritts, 1976; Hughes *et al.*, 1982; Schweingruber, 1987). Extensive work in this field of research has been done in North America and Europe but meager information is available from Asian continent except some parts of the central Asian republics. Data have now been started emerging from India, China, Japan, Korea, etc. It is now realised that the study from the Asian regions would be of paramount significance in understanding the global perspective of climatic changes (Hughes, 1982). In this paper prospects of *Cedrus deodara* and *Pinus gerardiana* for long term climatic changes, especially precipitation have been discussed.

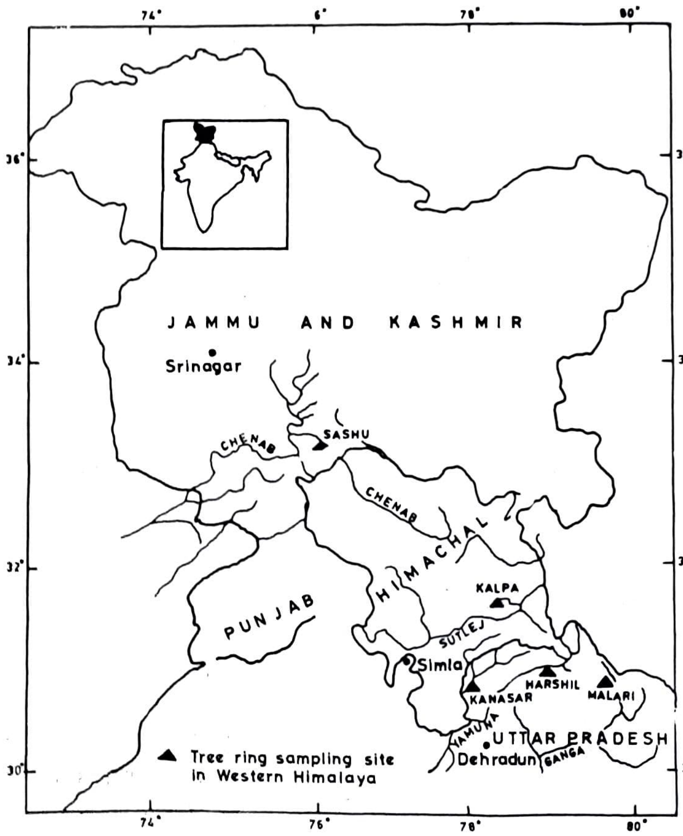
The western Himalaya comprises diverse vegetation due to diversity in physiography, altitude, climate and bedrock geology. Several conifer species, viz., *Abies pindrow*, *Picea smithiana*, *Cedrus deodara*, *Pinus gerardiana* and *Pinus roxburghii*, from these regions have been found suitable for tree ring analysis (Pant & Borgaonkar, 1984a; Ramesh *et al.., 1985; Hughes & Davies, 1987; Bhattacharayya et al. 1988; Bhattacharyya & Yadav, 1989, 1990). As each species responds differently against the seasonal climatic variability, the tree growth/climate relationship would be useful proxy data for reconstructing various aspects of climatic oscillation. For example, tree ring data from* *Abies pindrow* growing in the sub-alpine regime in Kashmir has been found suitable for reconstruction of temperature (Hughes & Davies, 1987). *Cedrus deodara* and *Pinus gerardiana* in the dry inner valleys in Kistwar, Jammu and Kashmir have been found to be drought sensitive (Bhattacharyya *et al.*, 1988).

SITE AND POTENTIAL TREE

Most of the trees used in earlier studies are not old enough to make long replicated chronologies. Our field surveys in the Himalayan regions and published records (Bilham *et al.*, 1983; Bhattacharyya *et al.*, 1988) have indicated that the old trees are generally confined to stressed conditions along steep slopes or on rocks with thin soil cover. Such old trees are often short in stature with heavy spreading upper branches. However, a few old trees of *C.deodara* with huge girth (over 10 m) and height have also been recorded from mesic sites in Kanasar and Tolma in Dhauli Valley near Joshimath (U.P.) and Kishtwar (Kashmir). A disc of such tree is lodged in F.R.I., Dehradun having 704 rings (Raizada & Sahni, 1960). Other conifer taxa having almost the same girth have also been reported from several sites in the Himalayan region. Thus old trees in the western Himalayan region have been found to be confined to sites

Photograph 1. Showing characteristics of old deodar tree growing in Harshil near Gangotri, western Himalaya.

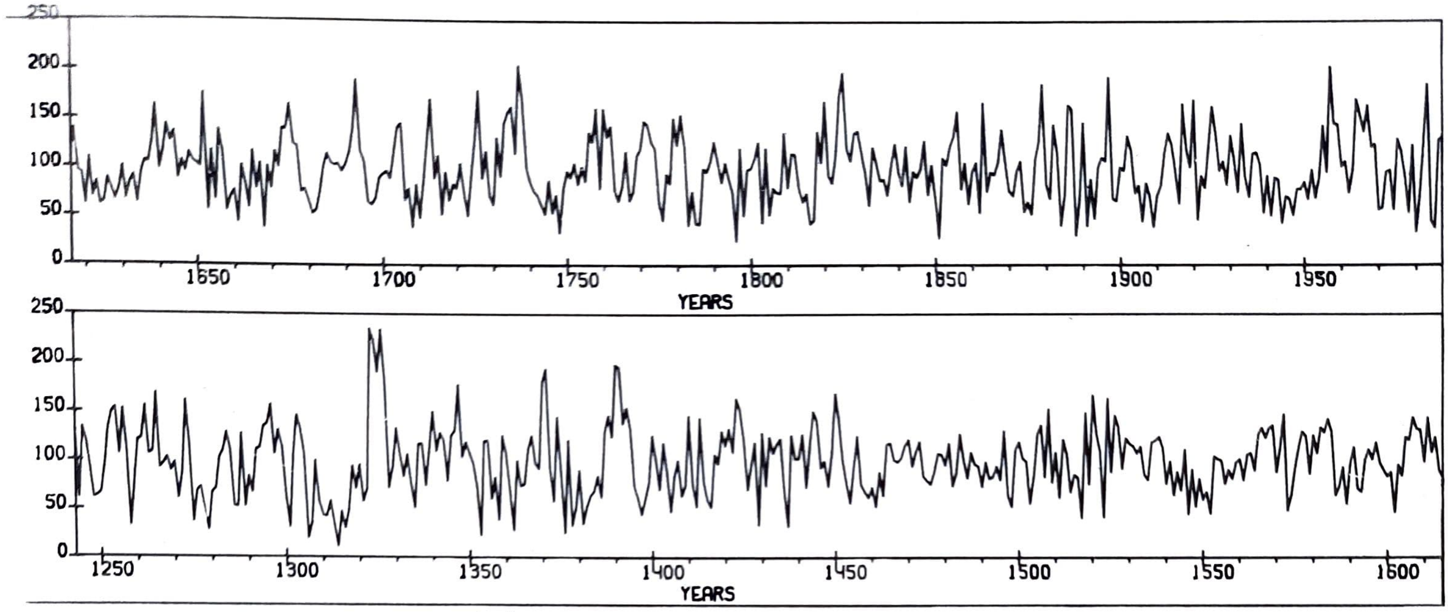
either inhospitable or optimal for tree growth. Based on global perspective, it was found that the old trees are



Map 1. Location of sampled tree ring sites in the Western Himalaya.

growing either under optimum condition in mesic, closed canopy forest or stressed condition in the sub-alpine and arid regions (LaMarche, 1982). However, owing to intensive deforestation in western Himalaya such old trees growing in their optimal conditions are few, which are, however, survived due to conservation plan by Forest Department either due to their paucity or sanctity. Such protected trees from a specific site might be inadequate in number for the dendroclimatic analysis. Besides, frequent heart rot, hollows in the trunk made by fire or through chopping by axe for extraction of fire wood and short length of increment corer to extract samples, make it difficult to get long cores from such trees.

Some conifer taxa, viz., *Cedrus deodara*, *Pinus gerardiana*, *Juniperus macropoda* and *Taxus baccata* have been recorded to have potential for making long tree ring chronologies from the western Himalayan region. These grow either in pure formations or in association with other taxa. Other conifers growing in this region, viz., *Abies*, *Picea*, *Pinus* (other than *P. gerardiana*) are found to be less than 400 years old. They may also withstand aridity and exposure to extreme temperature and high wind speed. *Cedrus deodara* is distributed at 1200-3300 m altitude from Afghanisthan to entire Western Himalaya and extends sporadically upto Karnally valley, Nepal, but does not grow further east in the eastern Himalaya (Collier, 1924). Natural habitats of this taxon in Himalayan region imply that this tree can also thrive



Text-figure 1. Tree ring chronology of *Cedrus deodara* extending from 1243-1987AD from Harshil, western Himalaya.

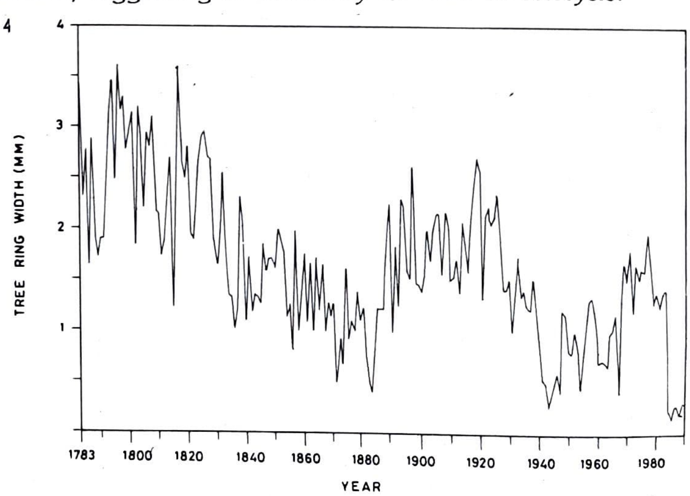
on sites under a wide range of monsoon precipitation, but snowfall in winter is common feature to all these sites. Thus, precipitation during winter seems to be essential for its growth. *Pinus gerardiana* owing to its restricted distribution, grows in areas beyond the reach of monsoon in dry Sutlej Valley in Kinnaur, Chenab valley in Chamba, Himachal Pradesh and Kishtwar in Jammu and Kashmir extending in adjoining regions of Pakistan to Afganisthan. *Juniperus macropoda* has a wide range of distribution and found in Baluchistan, Chitral, etc. in Pakistan and extends eastwards to Nepal, in an altitude between 1524 to 4627 m above mean sea level.

Taxus baccata, another conifer taxon has been found to attain age over one thousand years (Raizada & Sahni, 1960). Tree ring analysis in connection to dendroclimatic studies of this taxon is yet to be determined.

Tree ring sampling sites of *Cedrus deodara* ranging from moist temperate forest in Kanasar and Tolma to dry arid sites of Malari near Niti Pass and in Harshil near Gangotri have been shown in Map 1.

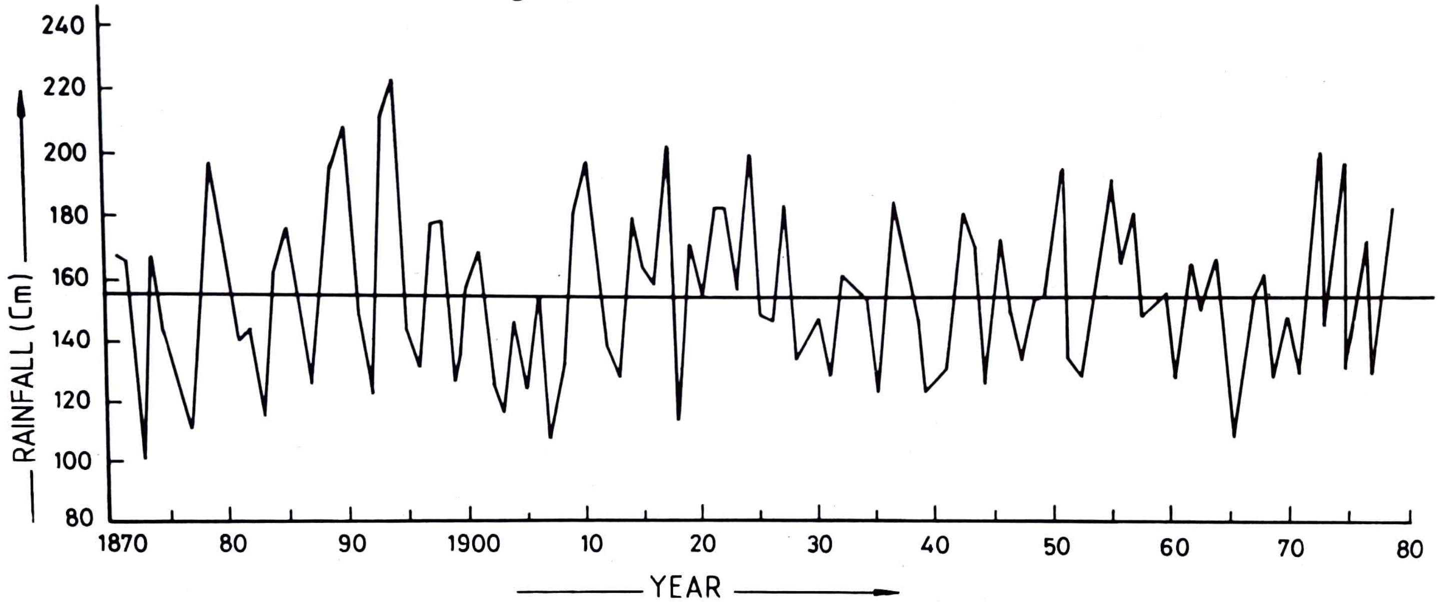
Growth rings of many of these samples were dated through cross-matching (Stokes & Smiley, 1968) and their ring widths measured by using increment measuring machine with 0.01mm accuracy at the Indian Institute of Tropical Meteorology, Pune. Tree ring data from Tolma about 20 km south of Malari extended from 1360 AD to 1986 AD and from Kanasar 1736 AD to 1988 AD. Other typical sites for making long tree ring chronologies of deodar are Malari and its surrounding sites near Niti Pass. Recently with collaboration of IITM, Pune, a large number of tree cores of deodar have been collected from these sites. Most of the trees have more than 600 rings. Detailed analysis of these cores is in progress. So far, trees growing at Harshil have yielded the longest dated deodar tree ring records from the Indian sub-continent. This site is characterised by dry temperate forest represented mainly by Cedrus *deodara* at lower elevations and *Pinus wallichiana*, *Betula utilis* at the upper level forming tree line. Tree ring samples from Harshil were collected from trees growing on rocky slope with thin soil cover and are exposed to high wind speed. These trees are of short stature, highly branched and most of them with prominent crown die back (Photograph 1). The branches of many of these trees are seen lopped heavily for fire wood. A chronology of 745 years (1243-1987 AD) of this taxon (Text-fig. 1) has been prepared from this site (Yadav & Bhattacharyya, in press). The chronology shows high mean sensitivity (0.344), low first order autocorrelation (0.150) and high signal-noise ratio (20.52) suggesting its suitability for climatic analysis.

Fig 4



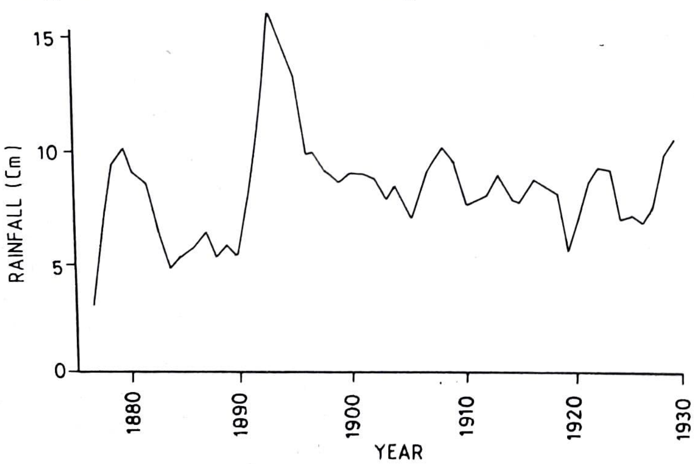
Text-figure 2. Tree-ring width series of *Pinus gerardiana* extending from 1783 to 1990 AD from Kinnaur, western Himalaya.

Pinus gerardiana has been considered another promising species for getting long tree ring record for the analysis of droughts (Bhattacharyya *et.al.*, 1988). A large number of tree cores of this pine species were collected from Rekong Peo, Kalpa, Pooh and other forest sites at Kinnaur. Some of these cores collected from Rekong Peo have been dated and ring width of these dated cores measured at IITM, Pune. The oldest core from this site extends from 1783 to 1990 (Text-fig. 2). Earlier a chronology of this taxon extending back from 1550 AD to 1984 AD was made from Kishtwar, Jammu and Kashmir (Bhattacharyya *et al.*, 1988). Trees growing at Kalpa have also been found to have a large number of rings but dating of these samples is yet to be done.



Text-figure 3. Average annual rainfall data from the U.P. Himalaya extending from 1870 to 1980 AD (After Pant & Bargaonkar, 1984 b)

Juniperus macropoda is another potential tree for making long tree ring chronology. Earlier Bilham *et al.*, (1984) reported a disc of very old tree with over 1200 rings from the Karakoram range but lobate nature of growth rings has impeded the crossdating of tree ring sequences even in radii of the same disc.



Text-figure 4. Average annual rainfall data from Leh, Ladakh, Jammu and Kashmir (After De Terra & Hutchinson, 1934).

TREE GROWTH AND RECENT CLIMATIC CHANGES

A good cross dating has been observed in ring width patterns of *C. deodara* and *P. gerardiana* growing under diverse environmental conditions in the western Himalaya. This suggests that a common set of climate related limiting factors are controlling the growth. Both *C.deodara* and *P. gerardiana* growing in Harshil and Rekong Peo, respectively are confined to water stressed environment, growing on steep slopes with thin soil cover along rocky out crops in dry-arid sites. They also experience high rate of evapotranspiration due to their exposer to high speed winds and extreme summer temperature. All these features testify that precipitation might be one of the significant limiting factor for tree growth in these sites. To understand the role of precipitation on growth of *C.deodara* and *P.gerardiana*, a direct relationship was studied between growth and available annual precipitation plots in the Western Himalaya. For deodar, since climate data from adjacent to the sampling site is not available, the rainfall series (Text fig. 3) computed earlier from the U.P. Himalaya (Pant & Borgaonkar, 1984b) has been used. This rainfall series could be considered a regional one as it is based on average annual rainfall data of six meteorological stations located in distant geographical sites in the U.P. Himalaya with a significant correlation at 1% level.

Similarly, due to the non availability of meteorological data from tree ring sampling sites of *P. gerardiana* at Kinnaur, rainfall of Leh quoted from published records

(De Terra & Hutchinson, 1934, Text–fig. 4) has been used in the present study. The choice of using this data in the present study is based on the criterion as both the regions, Kinnaur, and Leh are situated in close proximity and receive precipitation brought by the western disturbances.

Table 1. Probable relationship among EL NINO years and tree ring indices of *Cedrus deodara*

El Nino years (E) (after Rasmusson and Carpenter, 1982; Quin *et al.*, 1988) * (E-1) preceding year ** (E+1) subsequent year of El Nino	Tree ring indices (L = low, M = medium, W = wide
1876*	L
1877	M
1880	L
1884	L
1887	W
1888**	L
1891	L
1896	M
1899	L
1902	W
1905	M
1906**	L
1911	L
1914	W
1915**	L
1918	M
1919**	L
1923	L
1925	M
1929*	M
1930	L
1932	L
1939	L
1941	L
1951	L
1953	L
1956*	L
1957	W
1965	W
1969	W
1970**	L
1972	L
1976	M
1977**	L

It has been noticed that growth was reduced in both the species, viz., *C.deodara* and *P.gerardiana* during most of the low rainfall years. The low annual precipitation in the U.P. Himalayan region during the years 1870-1877, 1904-1910, 1927-1929, 1934-1935, 1939-1941, 1944-1947, 1951-1953, 1960-1963 correspond to years having low growth in deodar (Text-fig. 1). In contrary, it has been noted that the high precipitation years do not necessarily always correlate with the years with good growth in these trees. Low moisture condition in such stressed environment are vital factor for the maintenance of tree growth affecting directly the various physiological activities in trees. However, during good rainfall years other factors might have become limiting for the growth.

It is difficult to explain the normal growth in deodar during 1964-1969 when rainfall is recorded low and low growth during 1970 to 1978 in spite of good regional rainfall. This might be due to some local climatic effect. The increased human pressure since the last two decades might have also played a significant role leading to abnormal behaviour of tree growth. Extensive lopping of branches for fuel and timber might have affected tree growth by losing a large number of needles which reduce productive photosynthates. This simple correlation recorded between most of the low tree ring width indices of deodar and low rain fall in the U.P. Himalaya indicates potentiality of this species growing in Harshil for the analysis of past precipitation. Furthermore, failure of summer monsoon in India is related with the occurrence of Equatorial Pacific Warm Episodes (El-Nino). Thus low tree growth is expected during these events because of the deficient precipitation. It is noted that out of 25 El-Nino events occurred in the time span of 1875 to 1979 (Rasmusson & Carpenter, 1983), tree growths were found to be low during 13 of these El - Nino years (E), 6 ensuing El-Nino years (E+1) and 3 preceding El-Nino years (E-1) (Table 1).

Similarly, reduced growth have been noted in *P. gerardiana* during most of the low precipitation years in Leh (Text–fig.4) which indicates the potentiality of this tree for the analysis of variability in winter precipitation. The changes in lake levels reported in several lakes of Ladakh (De Terra & Hutchinson, 1934) has been found to correspond with the fluctuation in growth of this species. For example low lake levels in Pangong Tso during 1875 to 1885 (Hutington, 1905) has been found to be linked with the periods of low tree growth in *P.gerardiana*. Similarly high lake levels recorded in Ladakh during the recent past believed to be resulted from the increase in rainfall between 1890-1900 in this region (De Terra & Hutchinson, 1934), also correspond with the periods of good growth in *P.gerardiana*. Thus, tree ring data would also be helpful to understand the past lake level changes in this region.

CONCLUSION

The present study envisages the potentiality of tree ring data of *P.gerardiana* and *C.deodara* in understanding the changes in precipitation during the recent past in the western Himalaya. This study, however, is not substantial as it is based on simple correlation between tree ring width data of *C. deodara* and *P. gerardiana* with the published rainfall plots of the western Himalayan region. To understand the important climatic variables affecting the tree growth, response function analysis would be carried out later depending on the availability of the meteorological data from adjacent to the sampling sites. The significant variables could be reconstructed through transfer function. A good correlation of low tree growth of *C.deodara* and *P.gerardiana* with low precipitation and El-Nino events suggests that climatically sensitive long tree ring chronology of these taxa would provide data for long term climatic reconstruction. This would be of immense value in understanding the correlation between summer monsoon and precipitation brought by western disturbances during winter and their link with E1-Nino events.

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