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Long-living Neoza pine in western Himalaya: the natural archive of climate

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ABSTRACT

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1546-year (AD 466-2011) long ring-width chronology of Neoza pine has been developed here from Kinnaur district of Himachal Pradesh. So far, this chronology is the longest record for this species. The chronology shows significant relationship with weather data of pre-monsoon season. The study establishes that there is immense potential of Neoza pine dendroclimatology in data scarce western Himalaya.

Key-words: *Pinus gerardiana* Wall. ex Lamb., Neoza pine, natural archive of climate, western Himalaya.

INTRODUCTION

Neoza (chilgoza) pine (*Pinus gerardiana* Wall. ex Lamb.), a native to the north-western Himalaya, is usually found growing over elevations between 1800 and 3350 m a.s.l. in north-west India, Pakistan, and eastern Afghanistan (Raizada & Sahni 1960). Its forests, disjunctly growing on arid sites in Kinnaur and Pangi, Himachal Pradesh and Ravi and Chenab valleys in Kashmir, are open type very occasionally forming moderate to dense pole crops. The three needle pine (Neoza), often growing in association with blue pine (*Pinus wallichiana*) and Himalayan cedar (*Cedrus deodara*), could be easily identified in field by its thin, grey, smooth bark exfoliating in irregular thin flakes. During the last few years, the area under Neoza pine forests has shrunk markedly as each and every cone over the tree is lopped even before maturity to collect nuts, leaving very little for natural regeneration (Singh et al. 1973). In view of such heavy exploitation, the species is facing extinction and has been listed in Red Data Book and categorized as an endangered species (Sehgal & Sharma 1989). Though the tree is rarely felled because of its valuable nuts, old trees of Neoza pine are hard to get in the western Himalayan region. In order to establish the longevity of this species, several authors in India and Pakistan (Bhattacharyya et al. 1988, Ahmed & Sarangzai 1991, Singh & Yadav 2007, Ahmed et al. 2011) have made extensive efforts. The longest record of Neoza pine chronology prior to this study was of 1087 years from Purbani, Satluj Valley in Kinnaur, Himachal Pradesh (Singh & Yadav 2007).

The western Himalayan region, from where weather records are very limited, is bestowed with variety of high-resolution climate proxies such as annual growth ring forming trees, layered ice/snow and lake deposits, and speleothems (Yadav 2009, Kotlia et al. 2012). The ring-width chronologies prepared from trees growing over stressed sites provide one of the best annually resolved natural archive of environment as these could be precisely dated to calendar years and also calibrated with the weather records available from areas close to the specific forest stands. The tree-ring chronologies prepared from different climate stressed sites in the western Himalaya have been widely used to develop long-term precipitation (Yadav & Park 2000, Singh & Yadav 2005, Singh et al. 2006, Yadav 2011a, b) and temperature reconstructions (Yadav et al. 2004, 2011). In view of the ecological preferences of Neoza pine, it has been recently noted that the growth dynamics of trees over arid sites could be taken as a sensitive ombrometer (Yadav 2011a). Old trees of such species offer valuable proxy to develop long-term high-resolution climate records needed to understand natural variability and anthropogenic impact on climate change. During extensive field survey in summer 2012, the authors discovered a very old grove of Neoza pine near Barang in Kinnaur, Satluj Valley, Himachal Pradesh (31°30′N, 78°17′E, 3017 m a.s.l.) (Figure 1). The Barang area is very close to Purbani in Kinnaur from where over millennium old tree of Neoza was first discovered in 2007 (Singh & Yadav 2007). The findings reported here show that Neoza pine forests growing over different sites in Kinnaur, Himachal Pradesh could be one of the oldest in the Himalayan region. However, to ascertain this extensive sampling of Neoza pine growing in other pristine natural environments in the western Himalaya is required. Here, tree-ring chronology of Neoza pine is reported from Barang, Kinnaur, which is the longest so far for this species. Dendroclimatic potential of the chronology is also explored using instrumental and gridded climate data.

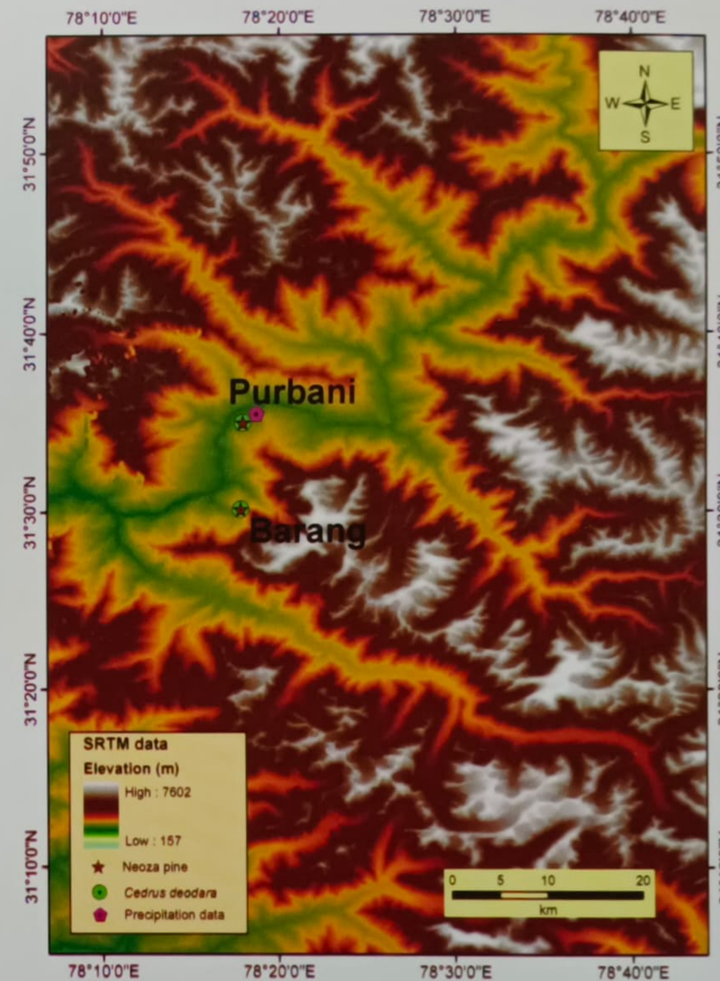

Figure 1. Map showing the location of tree-ring sites (Purbani and Barang) and precipitation observational station Purbani in Kinnaur, Satluj valley, Himachal Pradesh.

DATA AND METHOD

The increment core samples were collected from old Neoza pine trees growing in Kinnaur, Himachal Pradesh (Figure 1). The increment cores, collected using Swedish increment borer of 5 mm diameter were air dried and fixed on grooved wooden supports. The ring-widths in individual core samples, after polishing with different grades of abrasives to make the cellular details clear under the binocular microscope, were measured to 0.01 mm accuracy and precisely dated using TSAP (Rinn 1991) and verified using COFECHA, a dating quality check program (Holmes 1983). Significant correlation noted in ring-width measurement series from a network of sites indicated common forcing, i.e. climate, affecting tree growth. Ring-width measurement series >500 years and longer were taken to develop mean chronology using ARSTAN (Cook 1985). In the first step of chronology preparation, a data adaptive power transformation was applied to all tree-ring measurements to reduce the influence of outliers (Cook & Peters 1997). The power transformed measurement series were then standardized using cubic smoothing spline with a 50% frequency response cut-off width equal to 2/3 of the individual series length. The low-order autocorrelation from detrended

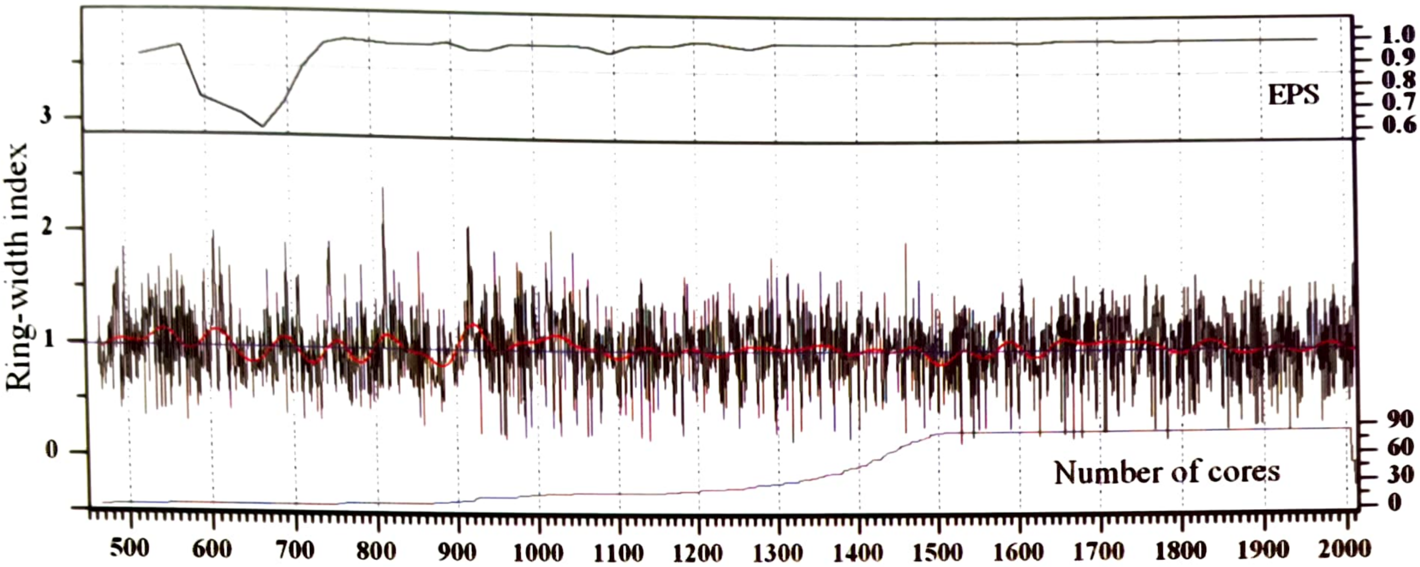

Figure 2. Ring-width chronology of Neoza pine (*Pinus gerardiana*) (AD 466-2011). Thick red line is 50-year low pass filter. The number of samples used in the preparation of chronology and EPS (expressed population signal) calculated for 50 years with overlap of 25 years are also indicated.

series was removed using autoregressive moving average (ARMA) modelling and the resulting residual series averaged to a mean site chronology by computing the biweight robust mean (Cook 1985).

RESULT AND DISCUSSION

The ring-width chronology of Neoza pine prepared in this study spans from AD 466-2011 (1546 years). The ring-width chronology (standard version) showing annual-to-decadal and longer scale variations along with the number of samples used is shown in figure 2. The threshold value of expressed population signal taken as a measure of population signal in the chronology (Wigley et al. 1984) reached to 0.85 and above

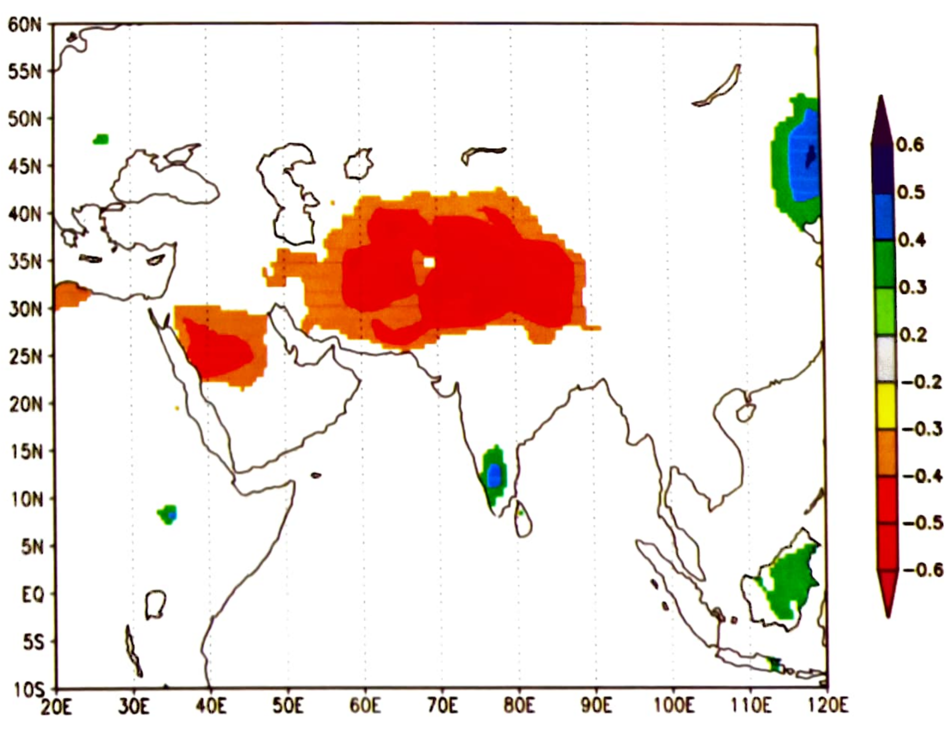

Figure 3. Spatial field correlation analysis between mean ring-width chronology of Neoza pine (residual version) and mean monthly surface temperature (March-June) (1970-2000) (CRU TS 3.10 surface temperature data were used in the analyses using climate explorer software, http://climexp.knmi.nl). The correlations were computed after detrending the respective series.

back to AD 720 with the replication of 3 core samples. The chronology statistics such as mean sensitivity, standard deviation, and autocorrelation are very similar to the chronologies of this species published earlier from different geographical regions (Bhattacharyya et al. 1988, Singh & Yadav 2007, Ahmed et al. 2011).

The spatial field correlation analyses using gridded temperature and precipitation data (CRU TS 3.1 available on http://climexp.knmi.nl) (Oldenborgh & Burgers 2005) and tree-ring chronology was performed to understand spatial linkages between climate and Neoza pine chronology. The field correlation analysis revealed strong negative relationship with March-June temperature over wide area in central southwest Asia (Figure 3). However, again the relationship was very weak with the gridded precipitation data (figure not shown). To understand the climatic signal, the chronology was further correlated with monthly precipitation of Purbani (31°35′N, 78°18′E, 2964 m a.s.l., 1941-1995) and mean monthly temperature of Srinagar, Jammu and Kashmir (34°05′N, 74°50′E, 1588 m a.s.l., 1891-2011), the nearest weather station data available with us. The tree-growth climate relationship study using correlations calculated for the common period 1941-1995 showed that growth of Neoza pine is favoured by cool and moist conditions (Figure 4). However, the correlations between mean monthly temperature and tree-ring indices were stronger as compared to precipitation. The correlation between tree-ring chronology and mean monthly temperature data from Srinagar, Jammu and Kashmir were noted to be stronger as compared to precipitation data even from station close to tree-ring sampling sites. The geodesic distance between Srinagar and a tree-ring sampling site is ~400 km. The existence of higher correlations between tree-ring chronology and Srinagar temperature data revealed that, due to strong coherence in temperature, data from distant locations could be utilized in calibrations. The weaker correlations between tree-ring indices and monthly precipitation showed that the single station precipitation data do not reflect regional precipitation pattern in the mountainous regions due to high spatial variability under dominant orographic forcing (Yadav et al. 2004, Bhutiyani et al. 2010). In view of the above findings, it is emphasized that the Neoza pine chronologies developed from climate stressed sites could be taken as a sensitive measure of temperature change over wide regions of central southwest Asia as well. The climate records developed from such long-term chronologies from data scarce Himalayan region should help in understanding the probable recurrence of extreme climatic events.

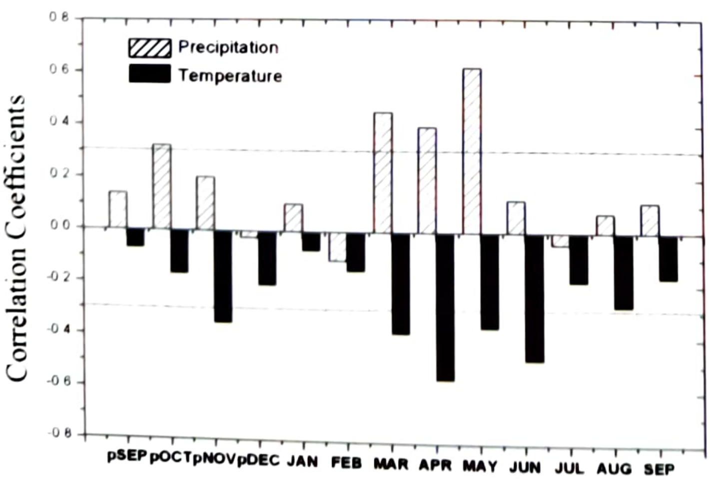

Figure 4. Correlation analyses between the residual version of the Neoza pine chronology and monthly temperature data of Srinagar and precipitation data of Purbani station. The dotted line represents 95% confidence limit.

CONCLUSIONS

1546-year (AD 466-2011) long chronology has been developed using increment core samples collected from old Neoza pine still growing in healthy conditions in Barang and adjoining areas in Kinnaur, Himachal Pradesh. The present discovery extends the earlier record of Neoza pine chronology by 453-years and further opens the possibility of getting much older trees in Kinnaur, Himachal Pradesh and other sites in the western Himalaya. Such old trees provide the living archive of weather variations, the tree faced over its life time. The long-term climate records derived from such old archives should provide base line data to understand natural variability in climate in long-term perspective.

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