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SOME PRELIMINARY RESULTS OF CLIMATIC STUDIES BASED ON TWO PINE TREE SPECIES OF HIMALAYAN AREA OF PAKISTAN

MOINUDDIN AHMED, MUHAMMAD WAHAB, NASRULLAH KHAN, JONATHAN PALMER, KANWAL NAZIM, MUHAMMAD UZAIR KHAN AND MUHAMMAD FAHEEM SIDDIQUI*[*]

Laboratory of Dendrochronology and Plant Ecology, Department of Botany, Federal Urdu University of Arts, Science and Technology, Gulshan-e-Iqbal, Karachi 75300, Pakistan
[*]Department of Botany, Govt. Degree Science/Commerce College, Landhi/Korangi, Karachi, Pakistan
Gondwana Tree-Ring Laboratory, Christchurch, New Zealand

Abstract

Standardized ring-width chronologies of *Pinus wallichiana* A.B. Jackson and *Pinus gerardiana* Wall. ex Lamb., are presented, covering maximum period from AD 1300-2000 and 1400-2000AD respectively. These chronologies are based on highly correlated (0.636) and cross-matchable wood samples. Response function analysis was used to investigate the climatic signals in these chronologies. Both response function analysis were statistically significant at $p<0.05$ level. Kalash response function showed 40% while Astore explained 22% variance due to climate. It is shown that though both sampling area fall under dry temperate area, good growth in *Pinus wallichiana* (Astore) is associated with hot and dry conditions, while reverse is the case with *Pinus gerardiana* (Kalash). However, despite these differences, both species showed some similar effects, responses and trends. Therefore it may be concluded that both species are suitable for paleoclimatic reconstruction back to at least 500 years. It is also suggested that more and detailed investigations are required before making concrete conclusion and reconstruction of past climatic variations.

Introduction

The behavior of the weather and climate is an immediate concern to all mankind as it effects each individual or societies during the daily life. Developed countries are spending a lot of money each year to obtain information about the weather and are supporting professional staff to gain the day to day forecast which are of great practical importance to seaman, airman, tourist, farmer and sportsman etc.

The study of past climatic variation and its effect is also necessary for a better understanding of the future planning potential specially in the climatic change scenario. The record of past climatic variation, based on meteorological observations, extend back only a short period and does not represent the range of natural climatic states that have existed in the geological recent past (La Marche, 1974). Furthermore, most of the underdeveloped and remote areas do not have even this type of information; therefore the study of past climatic variation should not depend entirely on recorded data. Other sources of climate data are needed to fill the gaps.

The annual growth rings of many trees are very important for past climatic study. They show climatic variations in the form of narrow and wide rings and such recorded information is available in long-lived and fossil trees. The possibility and potentiality of past climatic reconstruction is entirely based on

1. Accurately standardized tree-ring chronologies.
2. Calibration of the tree-ring data against modern climatic condition (Response function)

Once the response to climate is properly understood, climatic reconstruction is relatively easily undertaken. Only a limited amount of tree-ring researches have been published in Pakistan (Ahmed, 1987; 1989; Esper *et al*., 1995; Esper, 2000; Ahmed & Naqvi, 2005; Treydte *et al*., 2006; Esper *et al*., 2007). Ahmed *et al*., 2009, 2010) described some growth climatic response of *Picea smithiana* and *Abies pindrow*, respectively. Beside these investigations no work has been published from Pakistan. This paper presents a preliminary result of growth climatic response of *Pinus wallichiana* and *Pinus gerardiana*. At this stage, reconstruction of past climatic variations was not the aim of the present paper.

Materials and Methods

Wood samples in the form of cores were obtained from two pine species of *Pinus wallichiana* and *Pinus gerardiana*, using Swedish increment borer. For sampling, handling in field, drying, mounting and preparation, standard dendrochoronological techniques of Stockes & Smiley, (1968) and Ahmed (1984) were followed.

Wood samples were cross-matched under a stereo microscope and skeleton plot method was used for cross-dating. After visual cross-dating, samples were measured on Volmex measuring stage which was attached to a microscope, video camera, computer, screen and printer.

The ring-width measurements were subjected to a cross-matching quality control program, COFECHA (Holmes, 1994). At this stage, samples or time series with low correlation were reanalyzed or rejected. After this analysis, a program based on detrending and Autoregressive time series model, known as Auto Regressive Standardization (ARSTAN, Cook, 1985 & Holmes, 1994) was used to produce standardized ring-width chronologies.

To illustrate the quantitative relationship between tree-rings of two Pine species and climatic variables and to assess the dendroclimatological potential of these species, Response function analysis of Fritts (1976) with modification of Palmer (1989) and Palmer & Xiang (2003) was used. Standardized ring-width series of both pine species were individually correlated with CRUTS 2.1 (http://www.cru.uea.ac.ukl) climate data. Each tree-ring chronology was analysed with their respective climate data using 0.5^{o} girded data for the period 1901-2002 (Mitchell & Jones, 2005).

Results and Discussion

Sampling sites and its characteristics are shown in Table 1a. A moist temperate species *Pinus wallichiana* was sampled from a steeper west facing slope on higher elevation while the dry temperate species *Pinus gerardiana* was located on less steep North facing slope at a lower elevation. Both pine species are distributed in dry temperate zone due to higher elevation and permanent snow on the top, the Astore sampling area showed no water deficit condition.

Wood samples of both pine species were easily cross-matched without any missing rings and a few false rings (*Pinus wallichiana* only). This visual cross-matching under the stereomicroscope itself is an indicator that these species are suitable for dendroclimatic studies, however for statistical analysis ring-width series is transformed into a quantitative data by measurements.

The non-transformed row chronologies of both species are presented in Fig. 1. Both chronologies showed different growth trends from 1400 to 1500 AD and 1600 to 2000 AD, while similar trend was evident from 1500 to 1600 AD. Since both species are distributed on different topographical locations (aspect, slope, elevation and moisture condition), differences in growth trends are not surprising.

Table 1a. Sites characteristics of Astore *Pinus wallichiana* and Kalash *Pinus gerardiana*.

Sites	[1]Lati N	[2]Long E	[3]Ele m	[4]Asp	Slope $^{(0)}$
Astore	35 ° 20 `	74 ° 48 `	3450	W	47
Kalash	35 ° 23 `	72 ° 06 `	2530	N	39

Note: 1= Latitude, 2= Longitude, 3= Elevation (m), 4= Aspect

Table 1b. Summary statistics of Cofecha of Astore *Pinus wallichiana* and Kalash *Pinus gerardiana.*

Sites	//------------- Unfiltered -------------\\					//--- Filtered ---\\			
	[1]Corr with master	[2]Mean msmt	[3]Max msmt	[4]Std dev	[5]Auto corr	[6]Mean sens	[7]Max value	[8]Std dev	[9]Auto corr
Astore	0.636	0.95	6.85	0.594	0.893	0.173	1.33	0.215	0.001
Kalash	0.637	0.67	5.93	0.294	0.733	0.220	1.29	0.275	0.007

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

Table 1c. Summary of standardized chronologies ARSTAN Statistics of Astore *Pinus wallichiana* and Kalash *Pinus gerardiana.*

Sites	[1]Ch. Sp	[2]Mean sens	[3]Std dev	[4]Skw	[5]Kurts	[6]Tr. Var	[7]Pa. Au. Cor		
							Order 1	Order 2	Order 3
Astore	1317-2005	0.112	0.126	0.012	0.354	-0.0023	0.38	0.06	-0.03
Kalash	1403-2006	0.162	0.173	0.472	5.440	-0.0011	0.25	-0.04	0.06

Note: 1= Chronology span, 2= Mean sensitivity, 3= Standard deviation, 4= Skewness, 5= Kurtosis, 6= Trend Variance, 7= Partial autocorrelation

Samples depth is also shown in Fig. 1. Astore chronology span from 1350 to 2000 AD, however for a better cross-dating and statistical analysis, beyond 1800 AD (1350 to 1800 AD), sample size should be increased. It is also suggested for *Pinus gerardiana* that more samples are required for better cross-dating from 1700 to back 1400 AD.

To check accuracy of visual cross-matching a computer program COFECHA was used (Table 1b), and the results show that within a species samples are highly correlated with each other. Values of mean sensitivity are low, but these seem within the range of other Pakistani tree species. A higher amount of auto correlation is recorded from the ring width series however use of filter technique almost vanished the autocorrelation. A summary of standardized chronologies of both pine species are presented in Table 1c, where growth trends and effect of autocorrelation have been removed (Fig. 1).

Some ARSTAN statistics of some other Pakistani gymnospermic species are available (Ahmed *et al*., 2009-2010). Highest mean sensitivity (0.237) was recorded from *Picea smithiana* (Astore) while lowest value was obtained from *Pinus wallichiana* (Astore) Table 1c. Mean sensitivity of *Pinus gerardiana* from Kalash is within the range of *Abies pindrow* (Ayubia) and *Picea smithiana* (Nalter).

Response function comprises the regression coefficient for each of the 18 climatic variables including prior growth. Each coefficient is a measure of the positive or negative effect of that variable on the ring-width index. The function of both species and sites are shown graphically with the 95% confidence limits for each coefficient (Fig. 2).

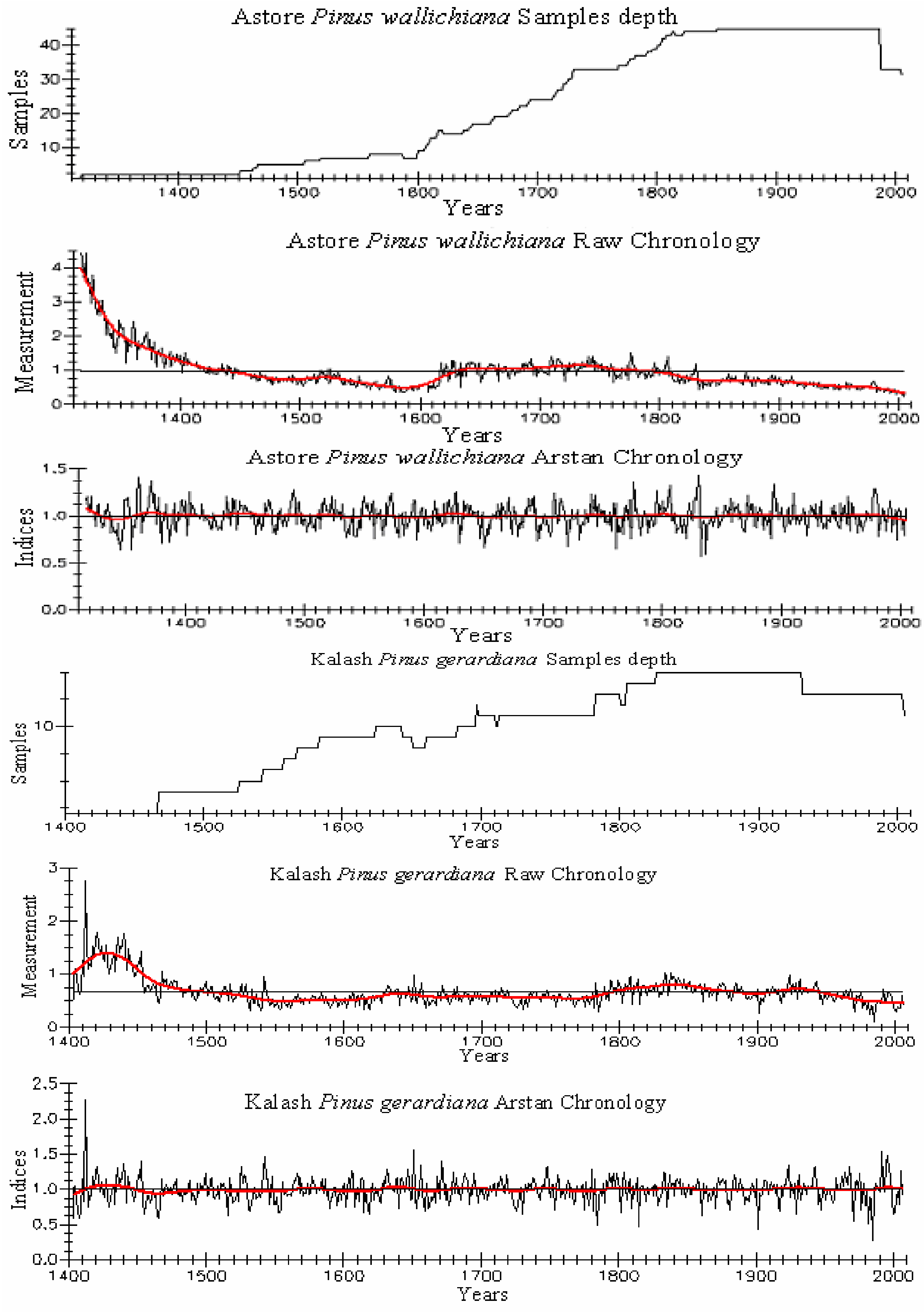

Fig. 1. Comparison of two individual chronologies of *Pinus wallichiana* and *Pinus gerardiana*. Outcome of standardization program ARSTAN.

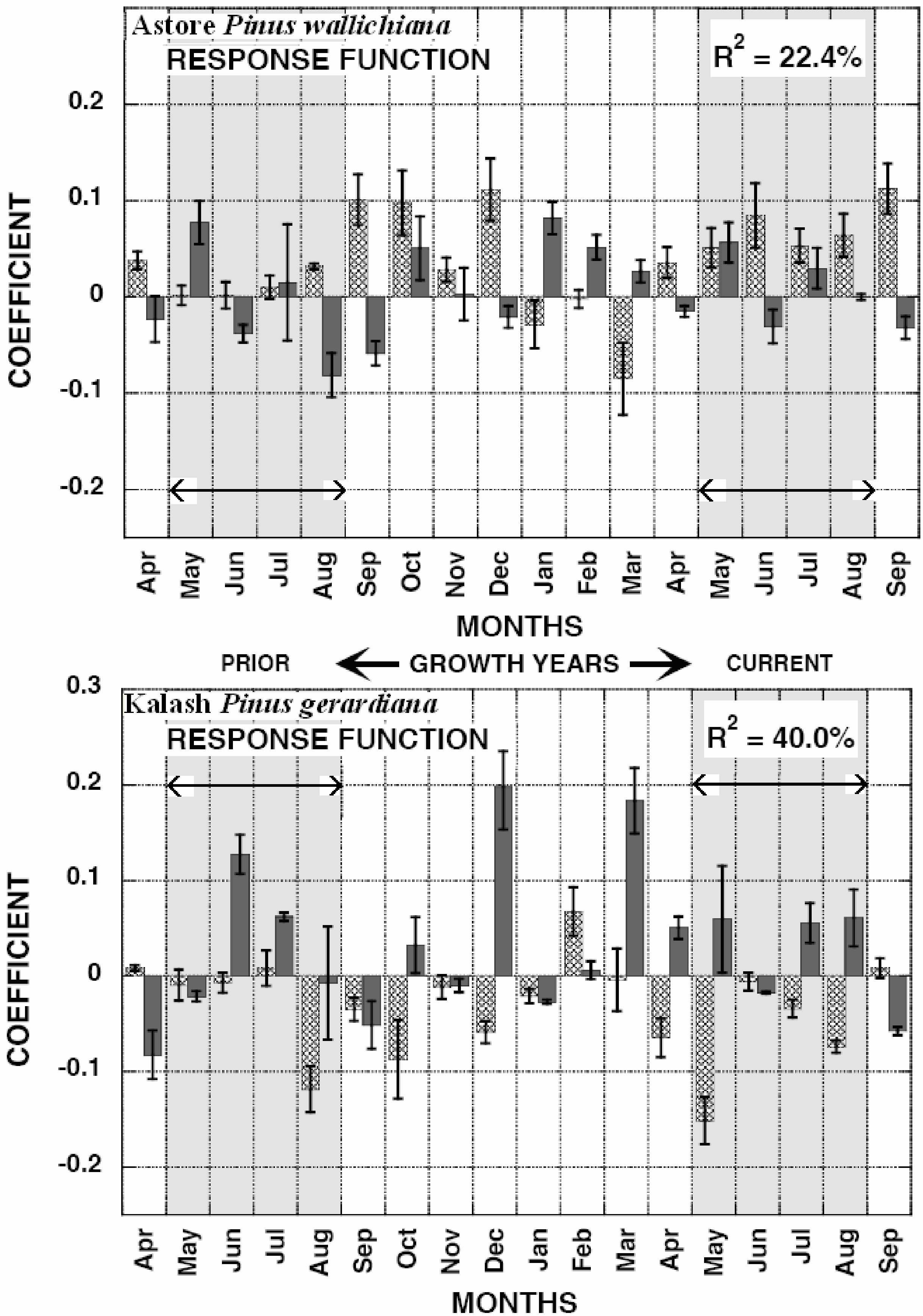

Fig. 2. Individual response functions of two Pine chronologies. Bars indicate 95% confidence limits of each element. Solid bar = Rainfall, shaded bar = Temperature.

Both sites, April and late September are associated with significant positive temperature and negative precipitation. Some coefficients are not significant during July (Prior), February and March, however the climatic trends is similar. Both species showed positive significant response with precipitation in October, March, May and June while negative precipitation significant response was evident in the month of June and both September. Positive significant temperature response was apparent only in April and negative significant response was in January. Numbers of positive significant coefficient for rainfall at Astore were 7 while 9 were at Kalash. From Astore, 8 significant negative rainfall responses, while from Kalash, 6 negative significant responses were recorded. Astore also showed 12 positive and 2 negative significant response with temperature while Kalash showed 9 negative and only one positive significant response for temperate. Since more than 4 coefficient predictors were significant, (Fig. 2) overall response function analysis, from both sites and species are statistically highly significant (Grey *et al*., 1981).

It is also evident from Fig. 2 that at Astore above than average temperature is good for growth while at Kalash in many cases positive precipitation led to better growth and higher temperature is not good for plant growth. It is surprising that both areas fall under same dry temperature region, but *Pinus wallichiana* from Astore are controlled by temperature and *Pinus gerardiana* needs more precipitation. This may be due to the difference in elevation, degree of slope and difference in moisture availability, as reported by Daubenmire (1968), Fritts (1976), Ahmed (1984), Ogden & Ahmed (1989) elsewhere. Astore is located at higher elevation (920m higher) than Kalash and surrounding by snow covered peaks. Melting snow provides enough water to the plants, a situation is created by nature where a moist temperate species could easily survive in dry temperate region. Kalash is also facing snow covered peak from two sides, but plants are growing on separate ridge at lower elevation, where water from melting snow was not available. In addition *Pinus gerardiana* has lesser ecological amplitude than *Pinus wallichiana* and restricted to only drier sites of dry temperate area, hence showed different climatic response to the two climatic parameters (Precipitation and Temperate).

Some other preliminary results of response function analysis from Pakistan are available. *Abies pindrow*, (Astore) climate and growth response showed similar effects in current June where positive significant temperature coefficient was associated with negative significant precipitation (Ahmed *et al*., 2009-2010). Same response was evident in *Abies pindrow* Ayubia and *Picea smithiana* (Chera – Nalter). However *Pinus gerardiana* (Kalash) showed agreement with precipitation in current June only.

Pinus wallichiana (Astore) showed significant positive precipitation coefficients in the month of October, January, February, March and May while significant negative temperature response was evident in the month of November, December, April, July and September (Fig. 2). *Abies pindrow* from the same location (Astore) showed similar effects on these months, though growing on different ridge (Ahmed *et al*., 2010). *Pinus wallichiana* and *Pinus gerardiana* (Fig. 2) have similar though not significant, trends in the month of April (Prior) and September. Rainfall response of *Pinus gerardiana* (Kalash) are positive in the month of June, October, December, March and May while temperature response were negative in August, October and May. Similar response were also recorded in other response function analysis (Ahmed *et al*., 2009 and 2010). Similarly negative temperature and positive rainfall effect were indicated in the month of October and May. These responses were also evident in Astore, Nalter and Chera despite difference in area and species.

Difference in growth-climate responses between the sites species and even in the same species located in different area to be expected, due to topographic, edaphic factors, history, structure etc. Such differences cannot be confidently separated from “noise” in the data (Ogden & Ahmed 1989), however despite these differences, the response function analysis postulated some consistent effects, trends and patterns. Therefore it is suggested that these tree species may be used for long-term climatic reconstruction of the area, however it is necessary to run more response function analysis to achieve consistency for growth climate responses before we proceed to climatic reconstruction.

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