DENDROCHRONOLOGICAL POTENTIAL OF BLUE PINE (PINUS WALLICHIANA A.B. JACKS.) OF KULDANA RESERVE FOREST OF TEHSIL MURREE, PAKISTAN

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ABSTRACT: Age and growth rate studies of blue pine, *Pinus wallichiana* (A.B. Jacks.) were carried out in Kuldana reserve forest of Tehsil Murree, Pakistan. Forest was divided into ten stands and cores from fifty trees were taken. Fifty samples (cores) were extracted from this forest by using Swedish increment borers. Velmex Measuring System was used in measuring tree ring widths. Diameter at breast height (Dbh) was measured and GPS (Global Positioning System) reading of each sample was also noted. Crossdating of every sample was done manually by this system. The oldest tree was observed 454 years of age and youngest was 65 years of age. Most of the trees were more than 130 years of age in the study area. Overall, a good growth rate was observed which indicated the climate conditions favored the growth of species in this site. Regression analysis was performed in between Dbh (inches) and age, (years) and Dbh (inches) and growth rate (inches). Maximum value (R^2=0.8272) was observed from mid-point to endpoint of Forest which showed significant positive correlation and no significant correlation was observed in both marked points between growth rate (inches) and Dbh (inches) at this site.

Key words: Dendrochronology, Kuldana, *Pinus wallichiana,* Velmex, Regression.

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INTRODUCTION

Age and growth of trees have prime importance in science of dendrochronology. Growth is increase in size of tree with passage of time which involves the formation and differentiation of cells (tracheids) or vessels in case of angiosperms. Growth rate of particular species is affected by climatic conditions. So, this technique is used to record natural and unnatural past events by dating exact year of ring formation, so it can be said that "every tree tells a story" (Champion *et al.,* 1965; Sheikh 1985; Fritts and Swetnam, 1989). Applications of this field of dendrochronology is widely used in science of silviculture, ecology, forestry, seismology, hydrology, climatology and other population dynamic studies (Khan *et al*., 2013; Bhuju and Gaire, 2012).

Dendrochronology was commenced by Moin ud din Ahmed in 1986 in Pakistan. He determined age and growth of several species in Quetta and also explained the problems encountered in age and growth estimation. Ahmed and Sarangzai (1991, 1992) determined dendrochronological potential of conifers. However, its systematic studies were continued until Wahab *et al*. (2008) studied age and growth rate of conifers from territory of Afghanistan border. Later on, Ahmed *et al*. (2009) estimated age and growth of tree species from different areas of their distribution. Siddique *et al*. (2013) conducted survey of moist temperate areas to find objectives regarding to this technique. Then, Nazim *et al*. (2011) applied this technique for mangroves. Song and Zhou (2015) determined age of Haloxylon. Fontana *et al*. (2016) determined dendrochronological potential of *Licaria bahiana* from Brazil forests.

Problem Statement: However, by considering, the magnitude and importance of this field, the present research work was carried out to develop chronologies which may prove beneficial for better understanding of past and future climate and conservation of one of the most reserve forest (Kuldana) of Tehsil Murree.

Study site: Murree Forest Division is considered as part of west Himalaya, and one of global 200 ecoregions of world. According to Punjab Forest department this division covers 47285 acres of Forest land. Kuldana is one of most climatically sensitive forest which is located between 33.91^o North and 73.40^o East. It is situated in outer Himalaya with high altitude. It has snowy winters and cool summer with rain and frequent fog. Annual precipitation is 1789 mm (70.4 inches). During a year temperature never exceeds 28^o in summer while in winter temperature can be as low as -8^o (Critelli and Garzanti, 1994). Kuldana reserve forest also possesses great diversity of vegetation including plants of many habits while forests of *Pinus roxburghii* and *Pinus wallichiana* are also abundant present in it. A large variety of wild plants growing in this area are used for food and to meet many substantial needs of local communities such as medicine, edible fruits, fodder, fuel, timber and many other purposes. Thus the forest products constitute an important source of livelihood for lots of people living there.

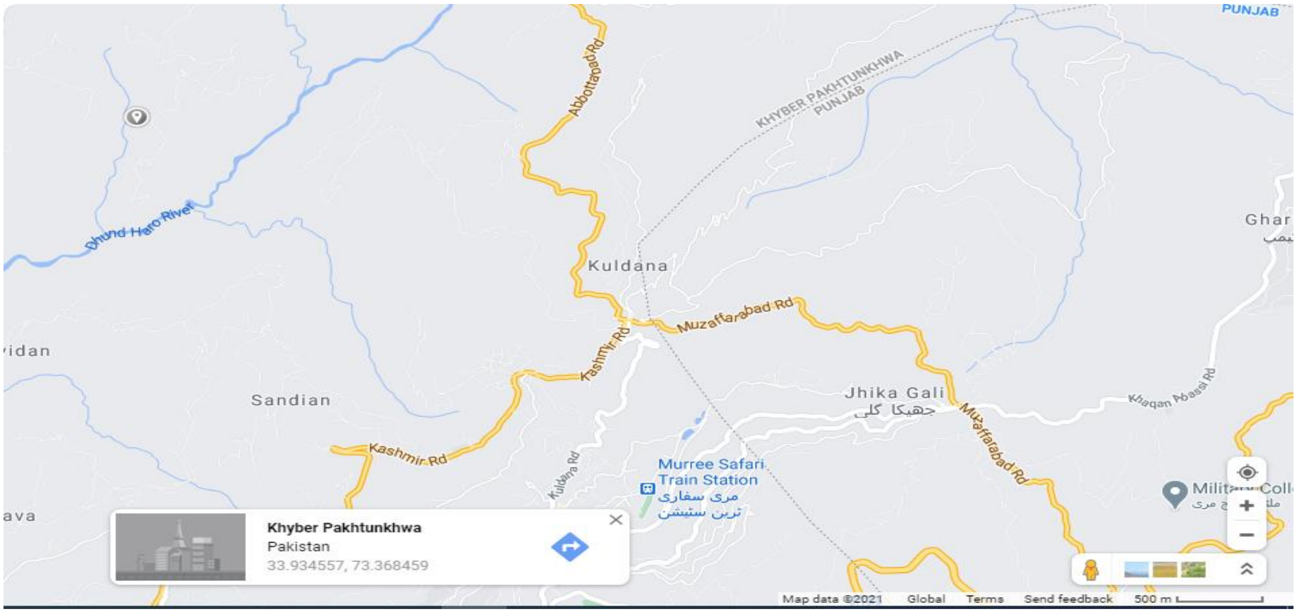

Fig. 1: Map of Kuldana Reserve Forest of Tehsil Murree, Pakistan

MATERIALS AND METHODS

Coring and Preservation of samples: After selection of particular species (*Pinus wallichiana)* from Kuldana Reserve Forest, samples (cores) were obtained from trees which were erect, sound, branchless and have uniform diameter while bent and rotten trees were rejected. Swedish increment borers (having length of 18 and 24 inches) were used to obtain cores at an average height (1.3 m) above ground level (Fritts, 1976; Mares, 2009). After extracting samples from trees, holes created in trees by increment borers were closed by wax to save them from any destructive organism (fungi and pathogens etc.). The samples were preserved in plastic straws and closed their ends with paper tape and also labeled them with their code, diameter, site name and GPS reading with GPS meter (Hart and Grissino-Mayer, 2008; Orvis and Grissino-Mayer, 2002).

Preparation of samples and their microscopic studies in Lab.: These samples were drawn out from straws with extra care and dried these samples for 5-7 days in Lab. The purpose of drying was to avoid samples of crack formation during mounting step (Arnott, 2008). Then samples were mounted properly on wooden frames with help of special glue. Paper tape was used to fit cores with wooden frames and removed when glue fixed these cores with frames. Next sanding was performed to clear tree rings with help of sandpapers (120, 180 and 320 grit sizes) fixed with electric sander machine. Then polishing was done to clear cross section of each cell of sample. Then age and growth rate was determined by velmex measuring system. Voortech's Measure J2X software helped in measuring tree rings width and then results were compiled (Stokes and Smiley, 1968; Cook and Kairiukstis, 1990; Speer, 2010; Volney and Mallet, 1992; Yamaguchi, 1991).

RESULTS

The results were compiled by dividing this forest into two parts, the upper part of Kuldana reserve forest and lower part of Kuldana reserve forest.

Age and growth rate and Dbh of *P. wallichiana* at upper part of Kuldana Reserve Forest: Table 1 clearly shows dendrochronological potential of *Pinus wallichiana* in this study site. 25 samples of *Pinus wallichiana* were taken out and each was given a specific code i.e. *P. wal*. 1 to *P. wal*. 25. All these trees showed different growth rates with different diameters. The maximum age calculated in this area of study was 239 years while the minimum was 65 years. The growth rate also varied from 0.090 to 0.152 inches per year. The oldest tree was with 239 years age and 0.08 inches per year growth rate while the youngest tree was with 65 years age and 0.07 inches per year. Moreover, correlation between Dbh and age was also observed as shown in Fig. 2. It was observed positive which showed age of tree is increasing with increase in diameter of tree and on the other hand negative correlation was found between Dbh and growth rate as shown in Fig. 3. The false ring formation observed in this species was too rare.

Table 1. Age, Growth Rate and Dbh (inches) of *P. wallichiana* present at upper side of Kuldana Reserve Forest.

Sr. No.	Core No.	Rings count	Average Growth Rate (inches) (± Standard Error)	Dbh (inches) (± Standard Error)	Average Age (Years)	GPS (N)	GPS (E)
1	*P. wal. 1*	60	0.1±0.01	26.4±0.11	158±3.45	33.91406	73.40069
2	*P. wal. 2*	71	0.1±0.02	30±1.11	213±4.56	33.91407	73.40071
3	*P. wal. 3*	57	0.12±0.1	16.8±1.87	114±2.23	33.91408	73.40080
4	*P. wal. 4*	43	0.15±0.01	20.4±2.11	131±1.45	33.91400	73.40086
5	*P. wal. 5*	46	0.13±0.04	21.6±0.89	129±3.32	33.91406	73.40100
6	*P. wal. 6*	51	0.13±0.03	21.6±0.89	143±1.45	33.91411	73.40104
7	*P. wal. 7*	49	0.15±0.04	21.6±0.75	159±3.25	33.91418	73.40104
8	*P. wal. 8*	86	0.08±0.01	34.8±0.71	239±2.88	33.91437	73.40151
9	*P. wal. 9*	51	0.13±0.02	32.4±1.12	215±2.95	33.91448	73.40155
10	*P. wal. 10*	41	0.13±0.01	15.6±2.13	83±3.45	33.91449	73.40164
11	*P. wal. 11*	42	0.14±0.02	19.2±1.15	113±3.85	33.91449	73.40164
12	*P. wal. 12*	37	0.15±0.02	20.4±0.89	113±2.45	33.91452	73.40157
13	*P. wal. 13*	41	0.07±0.01	22.8±1.85	65±1.45	33.91465	73.40151
14	*P. wal. 14*	67	0.1±0.01	22.8±1.98	153±2.43	33.91469	73.40147
15	*P. wal. 15*	39	0.15±0.01	18±2.13	105±1.85	33.91468	73.40139
16	*P. wal. 16*	77	0.08±0.01	26.4±2.11	163±2.37	33.91469	73.40119
17	*P. wal. 17*	53	0.11±0.02	20.4±1.85	119±1.87	33.91475	73.40168
18	*P. wal. 18*	80	0.08±0.02	28.8±1.95	184±1.45	33.91485	73.40174
19	*P. wal. 19*	52	0.11±0.02	26.4±2.13	151±1.42	33.91493	73.40184
20	*P. wal. 20*	52	0.10±0.01	24±1.15	125±2.13	33.91510	73.40180
21	*P. wal. 21*	51	0.12±0.01	18±1.75	94±1.85	33.91575	73.40236
22	*P. wal. 22*	55	0.13±0.01	24±1.32	172±1.45	33.91582	73.40236
23	*P. wal. 23*	49	0.14±0.01	24±2.13	165±1.65	33.91581	73.40229
24	*P. wal. 24*	37	0.19±0.03	15.6±1.11	110±2.13	33.91590	73.40249
25	*P. wal. 25*	52	0.12±0.02	20.4±1.12	127±2.11	33.91597	73.40241

**P. wal.* (*Pinus wallichiana*); **Dbh (Diameter at Breast Height); ***GPS (Global Positioning System).

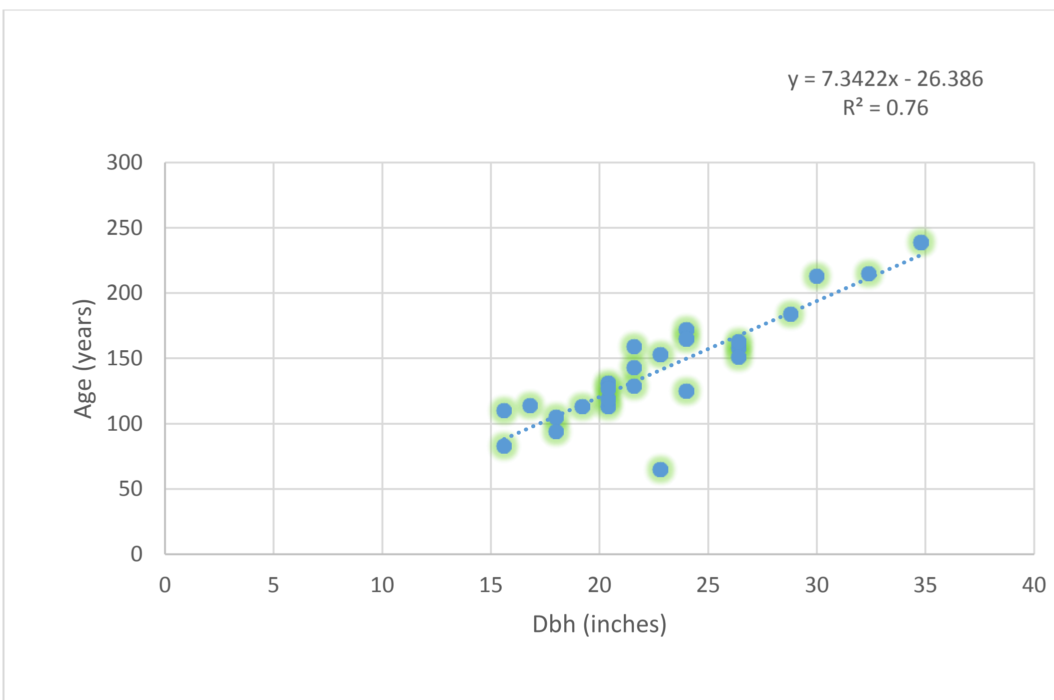

Fig. 2: Correlation between Dbh (inches) and age (years) of *Pinus wallichiana* of Kuldana Reserve Forest.

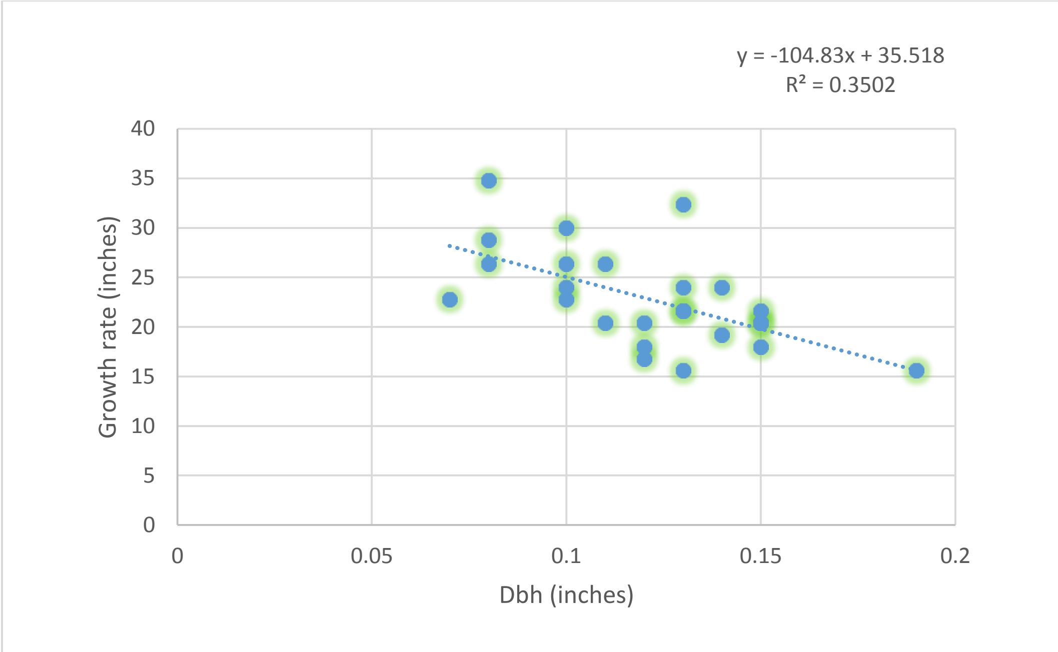

Fig. 3. Correlation between Dbh (inches) and growth rate (inches) of *Pinus wallichiana* of Kuldana Reserve Forest.

Age and growth rate of *P. wallichiana* at lower part of Kuldana Reserve Forest: Table 2 clearly shows dendrochronological potential of *P. wallichiana* in this study site. 25 samples of *P. wallichiana* were taken out and each was marked with a specific core code i.e. *P. wal*. 26 to *P. wal*. 50. All these trees showed different growth rates with different diameters. The maximum age calculated in this area of study was 128 years while the minimum was 51 years. The growth rate also varied from 0.09 to 0.14 inches per year. The oldest tree was with 454 years age and 0.13 inches per year growth rate while the youngest tree was with 118 years age and 0.13 inches per year. Moreover, correlation between Dbh and age was also observed as shown in Fig. 4. It was observed positive which showed age of tree is increasing with increase in diameter of tree and no correlation (neither negative nor positive) between Dbh (inches) and growth rate (inches) as shown in Fig. 5. The false ring formation observed in this species was too rare.

Table 2. Age, Growth Rate and Dbh (inches) of *Pinus wallichiana* present at lower side of Kuldana Reserve Forest.

Sr. No.	Core No.	Rings count	Average Growth Rate (inches) (± Standard Error)	Dbh (inches) (± Standard Error)	Average Age (Years)	GPS (N)	GPS (E)
26	*P. wal. 26*	48	0.15±0.01	20.4±2.10	147±2.33	33.91593	73.40230
27	*P. wal. 27*	49	0.13±0.02	19.2±1.10	122±2.11	33.91581	73.40256
28	*P. wal. 28*	54	0.13±0.01	16.8±2.30	118±1.89	33.91582	73.40255
29	*P. wal. 29*	52	0.13±0.02	18±01.80	122±3.12	33.91587	73.40256
30	*P. wal. 30*	101	0.08±0.01	21.6±2.23	175±2.85	33.91611	73.40248
31	*P. wal. 31*	112	0.07±0.01	21.6±1.75	170±2.88	33.91617	73.40241
32	*P. wal. 32*	80	0.09±0.01	22.8±1.85	164±2.93	33.91613	73.40242
33	*P. wal. 33*	84	0.09±0.02	21.6±2.13	163±1.45	33.91626	73.40224
34	*P. wal. 34*	87	0.08±0.01	19.2±2.11	134±2.11	33.91620	73.40227
35	*P. wal. 35*	91	0.09±0.01	19.2±2.45	157±2.23	33.91624	73.40227
36	*P. wal. 36*	94	0.08±0.1	20.4±1.95	153±2.45	33.91618	73.40230
37	*P. wal. 37*	85	0.07±0.1	22.8±2.23	136±1.46	33.91619	73.40247
38	*P. wal. 38*	96	0.09±0.1	24±1.89	207±2.13	33.91634	73.40249
39	*P. wal. 39*	111	0.07±0.01	22.8±2.11	177±2.45	33.91631	73.40260

40	*P. wal. 40*	105	0.06±0.01	19.2±1.85	121±1.99	33.91633	73.40260
41	*P. wal. 41*	83	0.12±0.01	26.4±1.88	263±3.56	33.91675	73.40245
42	*P. wal. 42*	69	0.10±0.01	24±2.45	165±2.77	33.91674	73.40252
43	*P. wal. 43*	75	0.10±0.01	24±2.13	180±2.11	33.91668	73.40249
44	*P. wal. 44*	57	0.09±0.01	24±2.15	123±2.15	33.91679	73.40260
45	*P. wal. 45*	61	0.12±0.01	18±1.88	131±1.85	33.91693	73.40255
46	*P. wal. 46*	62	0.12±0.02	18±2.13	133±2.11	33.91703	73.40204
47	*P. wal. 47*	65	0.14±0.02	19.2±1.97	174±2.18	33.91702	73.40225
48	*P. wal. 48*	81	0.13±0.01	43.2±3.45	454±4.32	33.91706	73.40217
49	*P. wal. 49*	68	0.1±0.02	38.4±1.45	261±2.19	33.91696	73.40215
50	*P. wal. 50*	109	0.1±0.02	34.8±1.12	379±3.15	33.91699	73.40218

**P. wal.* (*Pinus wallichiana*); **Dbh (Diameter at Breast Height); ***GPS (Global Positioning System).

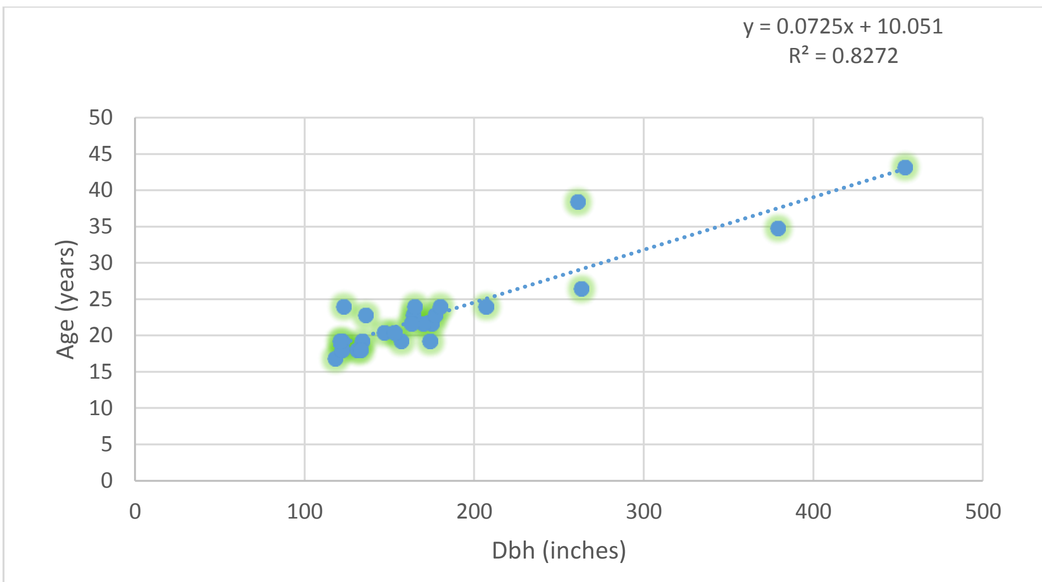

Fig. 4. Correlation between Dbh (inches) and age (years) of *Pinus wallichiana* of Kuldana Reserve Forest.

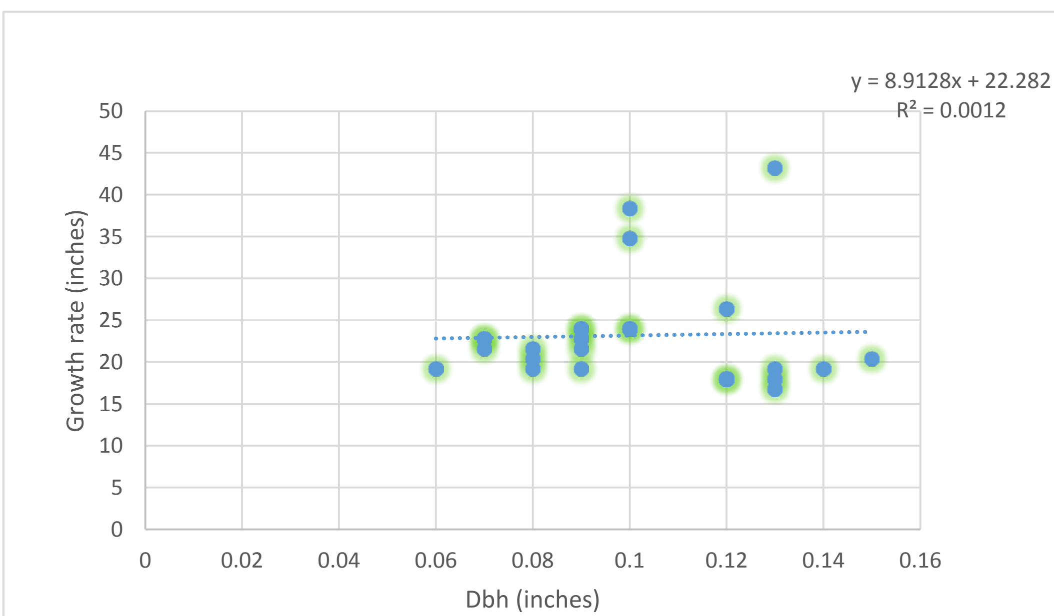

Fig. 5. Correlation between Dbh (inches) and growth rate (inches) of *Pinus wallichiana* of Kuldana Reserve Forest.

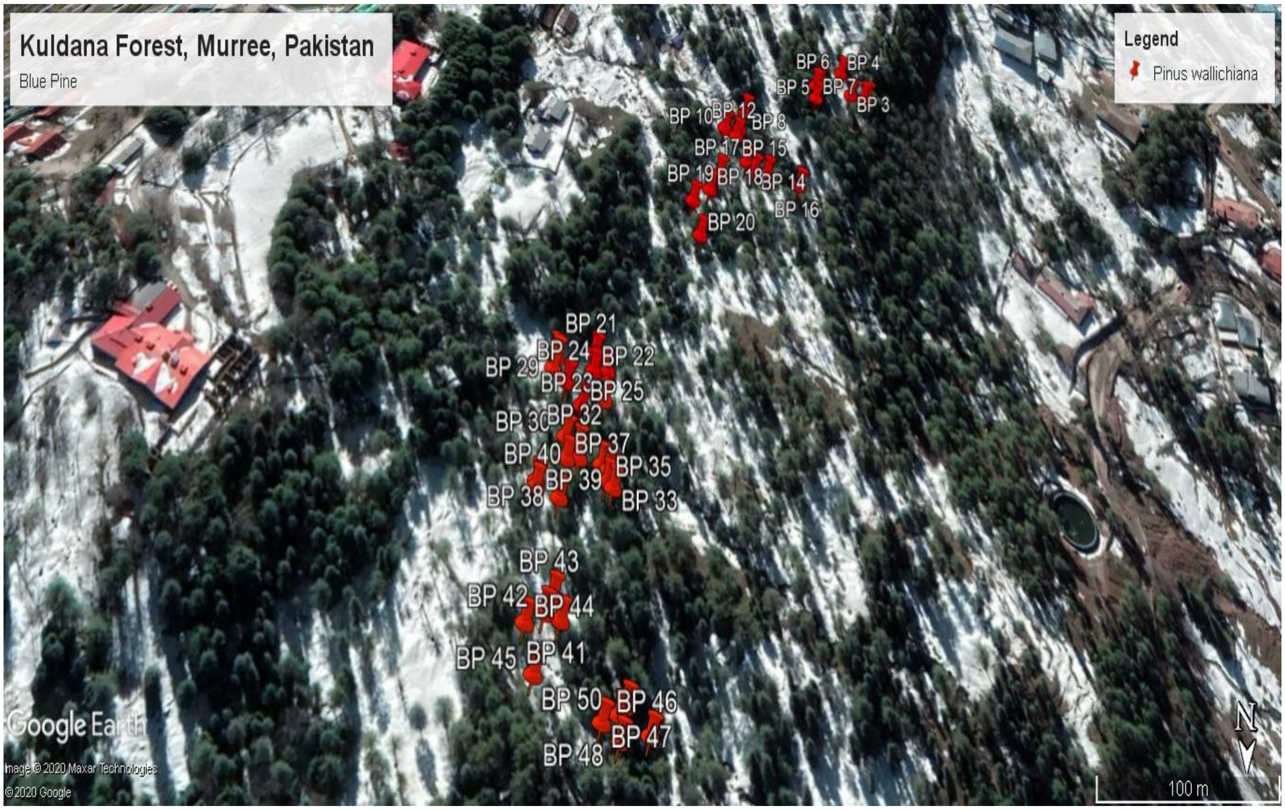

Fig. 6. Map showing GPS of Blue Pines of Kuldana Reserve Forest of Tehsil Murree, Pakistan.

DISCUSSION

Age of trees vary from zone to zone, species to species and even in trees of similar sizes of same species in an area (Ahmed *et al*., 2009). There is significant and positive correlation observed in between age and diameter of *Pinus wallichiana* as shown in Table 1 and 2 after (Bhuju and Gaire, 2012). But it's not a fact that age increases with increase in diameter because some species lie in different geographical positions (i.e. vary with different latitude, altitude and other environmental factors). Ahmed and Sarangezai (1991) stated that diameter is not an efficient indicator of age in conifers and other trees, however, climate may also prove as good indicator of age and growth of gymnosperms as healthy environment favors good growth of trees (Ahmed *et al*., 2011).

Growth rate also varies in different species and sites and among different individuals of same species and even in species of similar sites as shown in Table 1 and 2. Siddique *et al*. (2013) reported that growth rate of conifers is independent of diameter. There is no effective correlation present between diameter and growth rate of trees (*P. wallichiana*) as observed in Kuldana Reserve Forest of Tehsil Murree (Table 1 and 2). Growth rate of certain species also increases when there is sufficient availability of nutrients, suitable environmental conditions and avoidance from natural, man-made catastrophes or other interventions.

Growth rate of trees is highly correlated to moisture contents, useful for developing tree ring chronologies. Temperature and precipitation also play a key role in determining the growth rate of different species in temperate areas. The vigorious response of growth rate has been observed to rainfall after Ahmed *et al*. (2012). So strongly developed tree ring chronologies can be used for climate reconstruction (river discharge, dendrohydrology) from respective area (Singh and Yadav, 2012; Yadav and Bhutiyani, 2013).

The younger trees are more vulnerable to false ring formation than older ones and it's quite low in *P. wallichiana* as compared to other pines like *Picea*, *Abies*, *Cedrus* etc. after Borgaonkar *et al*., 1999; Vogel *et al*., 2001. While Fire scars were recorded at false ring boundaries during hot and dry periods in May and June before onset of monsoon rainfall beginning in mid-June in *Pinus roxburghii* (Brown *et al*., 2011; Copenheaver *et al*., 2006). The environmental factors like drought, air pollution, periodic flooding and mild frosts may also promote false ring formation in trees (Young *et al*., 1993; Kurczynska *et al*., 1997; Kozlov and Kisternaya, 2004).

The results obtained from Kuldana Forest of Tehsil clearly showed that none of tree was found with age more than 454 years while also in Mansehra and Lower Dir samples of *P. wallichiana* were not more than

130 years of age (Ahmed *et al*., 2009). Similar results were also observed by Bhuju and Gaire, (2012) in Khatmandu, Nepal where *P. wallichiana* trees were less than 150 years. It may be due to heavy exploitation for oleoresin tapping, as oleoresin is highly combustible material and people use it for home purposes. Moreover, these species are highly vulnerable to Forest fires, thus tree ring chronologies can be used for establishing long term fire histories of particular area.

Conclusion: It can be concluded from present research work that *Pinus wallichiana* (Blue Pine) has tremendous dendrochronological potential which is an indication that environmental changes has created impression on growth and developmental of the trees in the study area. More precisely it was also observed that environmental factors like, precipitation, temperature, rainfall and moisture content did play vital role in affecting the age and growth rate of the trees in this research site. Moreover, positive correlation was observed Dbh and age but no such relationship was found in between Dbh and growth rate. Thus it can be concluded that growth rate can be considered as independent factor of Dbh of tree.

Recommendations: Total 50 core samples of the trees were obtained out of which age of the 47 trees were recorded more than 100 years which indicates the forest dynamics and distribution of *Pinus wallichiana* in the study area. This study site also has tourist attraction, so in order to conserve these forests following recommendations can be considered by the policy makers and conservationists.

- Trees with more than 100 years of age should be protected by fencing etc. or proper information i.e. botanical name, locality should be mentioned by each tree.
- Illegal cutting and chopping of the trees should be restrained by creating awareness among local peoples
- Alternative means for fuel and daily use should be provided to local communities, in order to eradicate their dependence on these trees for any purpose.
- These trees of such an old age should be declared as Cultural Heritage of the country and concerned authorities should devise proper monitoring system.
- Ecotourism strategies should be developed in order to avoid the hazards of unplanned toursim

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