Pak.J.Bot., 23(1): 78-89, 1991.

DENDROCHRONOLOGICAL APPROACH TO ESTIMATE AGE AND GROWTH RATE OF VARIOUS SPECIES FROM HIMALAYAN REGION OF PAKISTAN

MOINUDDIN AHMED* AND ATTA MOHAMMAD SARANGEZAI

Department of Botany
University of Balochistan, Quetta, Pakistan.

Abstract

Dendrochronological methods were used to determine age and growth rate of nine species from various forests of Himalayan region of Pakistan. Importance of these methods in such determination is discussed. Age and growth rate vary among closely growing trees of the same species. Diameter is a poor predictor of age in the absence of ring count. Dry temperate species show from 5.34 years/cm to 13.2 years/cm growth rate while growth rate of moist temperate species range from 2.54 to 7.59 years/cm. *Pinus gerardiana* was found as a slowest growing tree among all species tested. A significant negative correlation was observed between altitude and growth rate.

Introduction

Growth rings are being used in forest mensuration studies by the Pakistan Forest Institute, Peshawar. Khan (1968) calculated ages of several individuals of *Pinus wallichiana* from Trarkhal Forests of Azad Kashmir. Age of a *Pinus gerardiana* tree from Zhob District is given by Champion *et al.*, (1965) while Sheikh (1985) estimated age of a *Juniperus excelsa* from Ziarat. A specimen of *Juniperus* had 1000 rings with a diameter of 40 inches (Swathi, 1953). All these estimates of ages were generally based on simple ring count and measurement of growth rings without any extrapolation for any missing rings (absent ring), double rings (false rings) or the time required for the tree to reach the height at which wood samples were taken for investigation. It is therefore likely that the age estimates contain error.

Using dendrochronological techniques Ahmed (1988 A) presented ages and growth rates of a few planted tree species of Quetta. Ahmed (1988 B) also discussed various problems encountered in age determination. Ahmed *et al.,* (1990) and Ahmed *et al.*, (1991) calculated ages and growth rates of various individuals of *Juniperus execlsa* and *Pinus gerardiana* from Balochistan. Beside this no comprehensive work has been published on native tree species specially from Balochistan. Therefore, the purpose of present study was to introduce dendrochronological methods in age and growth rate studies as well as to present ages and growth rates of various native tree species from different areas of dry temperate (Balochistan) and moist temperate (Murree, Swat) Himalayan regions of Pakistan.

*Plant Protection, Maftech, Ruokura Agricultural Centre, Hamilton, New Zealand.

Table 1. Summary of sites and species.

S.No.	Name of species	Location	Code	Elevation feets.	Aspect	Latitude S	Longitude E	No. of trees sampled	Type of samples
1-A	*Juniperus excelsa* M.Bieb.	Susnamana Forest	JESUSH	8000	W	30°31	67°68	8	CS
B	-do-	-do-	JESUSP	7500	VA	30°31	67°68	8	-do-
C	-do-	Beba Khur-wari	JEBABK	8500	W	30°31	67°68	6	-do-
D	-do-	Ziarat	JEZIAR	8600	N	30°31	67°68	5	-do-
E	-do-	PASHIN	JEPASH	7500	N	30°31	67°68	2	-do-
2	*Pinus gerardiana* Wall. ex Lamb.	Shinghar Forest	PGZHOB-	900	E	31°32	70°	11	CR
3-A	*Pinus wallichiana* A.B.Jackson.	Takht-i-Suleiman	PWTSUL	10000	N	31°32	70°	14	-do-
B	-do-	Ayubia	PWAYUB	8200	NE	33°34	73°74	10	-do-
C	-do-	Khansupr	PWKHAN	8000	N	33°34	73°74	8	-do-
D	-do-	Murree	PWMURR	7200	S	33°34	73°74	3	-do-
4	*Pistacia khinjuk* Stocks.	Baloor Forest	PKZHOB	6000	VA	31°32	70°	4	CS
5	*Olea ferruginea* Royale	-do-	OFZHOB	-do-	VA	31°32	70°	6	-do-
6	*Ephedra gerar-diana*	Shinghar Forest	EGZHOB	7800	W	31°32	70°	1	-do-
7-A	*Ables pindrow* Royale	Murree	APMRNE	7500	NE	33°34	73°74	3	CR
B	-do-	Ayubia	APAYEN	8800 .	N	33°34	73°74	5	-do-
C	-do-	-do-	APAYBS	7972	S	33°34	73°74	10	-do-
D	-do-	-do-	APAYEW	9000	W	33°34	73°74	7	-do-
8	*Pinus roxburghii* Sargent.	Marghazar	PRSWAT	6000	E	34°35	72°73	4	-do-
9	*Cedrus deodara* (Roxb.) Loud	Kalam	CDSWAT	7000	RT	35°36	72°73	3	-do-

CS = cross sections
CR = cores
RT = Ridge top
VA = Valley. Flat surface

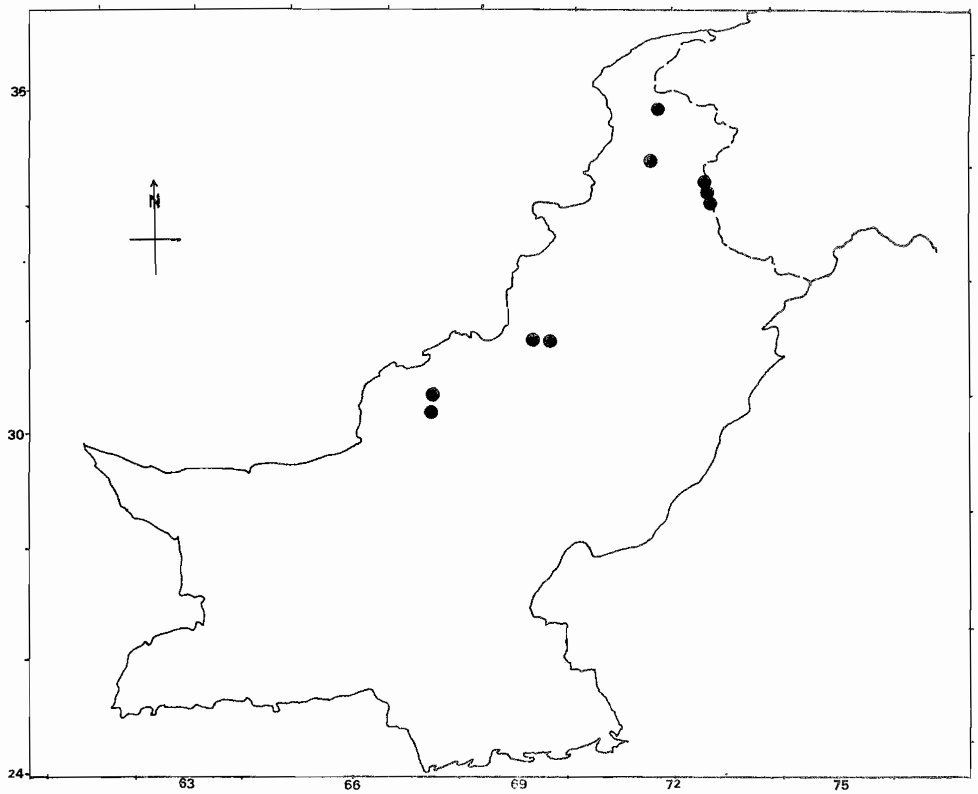

Fig.1. Locations of the sampling sites.

Materials and Methods

Wood samples, in the form of cross-sections and cores were collected from various locations of Himalayan regiŏn (Fig.1). Elevation and aspect of the sampling sites were recorded. Diameter of the tree and height where the sample was taken were also measured. A swedish Increment Borer was used to obtain cores from the trees. At least two cores per individual tree were obtained. Cores were allowed to air dry and then mounted on a grooved wooden frame. Sample were prepared as suggested by Stokes & Smiley (1968).

At each stand a few sections of small saplings were also obtained from breast height. The rings on these sections were counted. It was assumed that the average height growth rate shown by these saplings could be used to approximate the time required for the tree to reach the height at which wood samples were taken (Ogden, 1981). These years were added to the age of each wood sample to obtain the total age of the tree. In some cases where, cores do not pass through the centre of the tree missing radius was estimated by the method described by Ogden (1980). The missing rings were calculated from the growth rate of the inner most 20 rings (Ahmed,

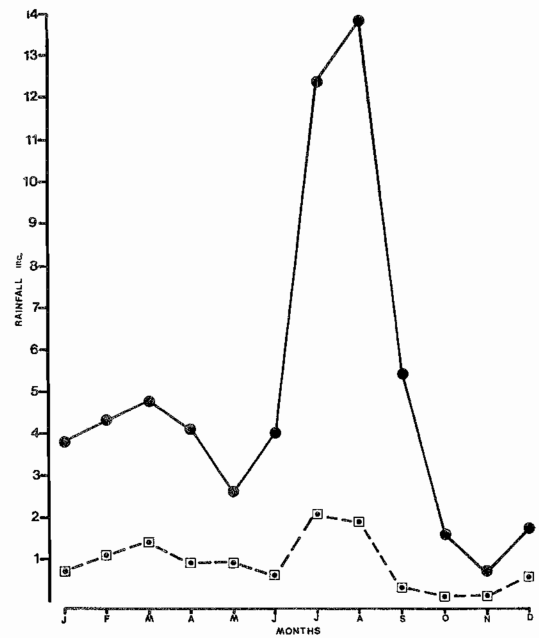

Fig.3. Distribution of mean monthly temperature in two climatic zones. Broken and solid lines indicate the same climatic zone as shown in Fig.2.

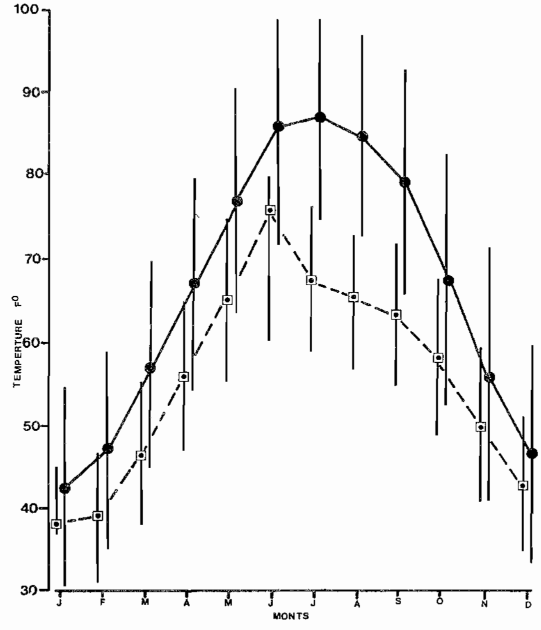

Fig.2. Distribution of rainfall in two climatic zone. Broken line indicates the rainfall of Zhob District (Dry Temperatre area) while solid line shows the rainfall of Murree (Moist temperate area).

1988B) and added to the total age of the core. In this case reliability of the core was also calculated by dividing the core length by the crude radius and expressing it as a precentage. This measure gives an idea of how near the end of the core is to the presumed tree centre and hence how reliable the age estimate is. An attempt was made to cross date the core or radii of a single tree then woodsamples were examined under the microscope. Data from *Juniperus excelsa, Abies pindrow* and *Pinus wallichiana* were used to obtain possible relationship between diameter and age.

Results

Location of sampling sites are shown in Fig.1, while details of sampling sites and species are given in Table 1. Fig.2 and 3 are graphical representation of the climate of the two main regions of the Himalayas. *Juniperus excelsa, Pinus gerardiana, Pinus wallichiana, Pistacia khinjuk, Olea ferruginea* and *Ephedra gerardiana* from dry temperate Himalayan region while *Abies pindrow, Pinus roxburghii, Pinus wallichiana* and *Cedrus deodara* belong to the moist temperate Himalyan region of Pakistan. Diameter, reliability, age and growth rate of each individual plant of various species from different sampling areas are given in Table 2.

Juniperus trees of same diameter (20.9 dbh cm) from JESUSH show ages of 105 and 187, while trees of similar diameter from JEZIAR range from 75 to 169 years. A tree of *P. wallichiana* with 20.5 dbh from PWTSUL attains age of 112 years, while same age is estimated from an individual of the same species having a dbh of 65 cm from PWAYUB. Similarly a specimen from PWKHNN had 112 rings with diameter of 58.0 cm while similar sized tree from PWMURR was 71 years old. Other species of similar diameter also show great variation in there ages in different sites and also different individuals of the same site (Table 2).

Generally age increases with increasing diameter. A significant correlation was obtained between diameter and age in nearly all species and sites (Table 2). However, it was observed that variation is always high. Table 2 also indicates that specimens having low value of reliability over estimate the true age and growth rate. Slowest growth rate was recorded in *P. gerardiana* while fastest growth rate was observed in *P. khinjuk*. Both species grow in dry temperate area of Zhob district. However former species is disturbed on higher elevation. Among moist temperate species, *A. pindrow* on North east facing slopes of APMRNE showed slowest growth rate while *C. deodara* from CDSWAT had fastest rate of growth. It may be observed from the Fig.4 that *A. pindrow* a species from moist Himalyan Region grows slower than a few dry temperate species, like *Juniperus* (JEPASH), *Pinus wallichiana*, *Olea ferruginea, Ephedra gerardiana* and *Pistacia khinjuk*.

Fig.5, shows possible relation between altitude and rate of growth. Taking all growth values together from both climatic zones, a negative significant correlation was observed between altitude and growth rate ($y = -2.51+1.19X$, $n=19$, $r = .47$). Growth rates of dry temperate species occupy the upper position on the regression line while moist temperate species are distributed on lower side of the line (Fig.5).

Table 2. Age and growth rates of individuals of nine species from different Himalayan regions of Pakistan. Relation between diameter and age is shown in column six.

			1	2	3	4	5	6
							Growth rate	
S.No.	Code	Tree No.	Diam	Reli	Age	cm/y	y/cm	Regression
IA	JESUSH	1	25.2	100	219	.07±.0008	13.59±.99	
		2	21.7	100	204	.06±.0005	16.05±1.16	
		3	20.9	100	105	.11±.0009	8.44±.49	
		4	21.0	100	134	.09±.0004	10.24±.32	
		5	20.0	100	125	.10±.0005	9.52±.48	y = - 16.95 + 8.2 x
		6	23.9	100	182	.09±.01	11.42±1.42	n = 8
		7	20.9	100	187	.08±.0008	12.03±1.20	r = .7467
		8	33.5	100	243	.07±.0008	13.23±1.05	p < .05
IB	JESUSP	1	23.8	100	200	.07±.01	13.71±1.68	
		2	23.6	100	93	.20±.02	5.09±.63	
		3	20.2	100	171	.09±.0008	11.18±.09	
		4	25.4	100	199	.12±.01	7.91±.98	
		5	29.9	100	146	.12±.0007	9.93±.16	Y = 270 - 4.70 x
		6	28.3	100	140	.15±.0005	6.78±.33	N = 8
		7	29.1	100	130	.14±.0005	6.23±.43	r = .7467
		8	29.6	100	97	.16±.01	6.23±.43	p < .05
IC	JEBABK	1	24.5	100	176	.08	11.07	
		2	23.3	100	90	.16	6.00	
		3	28.5	100	175	.08	10.84	y = - 85.32 + 9.14 x
		4	33.2	100	226	.07	12.08	n = 6
		5	44.5	100	306	.12	8.30	r = .9688
		6	49.3	100	373	.09	11.11	p = .001
ID	JEZIAR	1	18.5	100	136	.10	9.46	
		2	19.5	100	197	.06	15.61	y = 327.2-8.89 x
		3	21.3	100	169	.11	13.90	n = 5
		4	22.5	100	140	.13	8.23	r = .317
		5	21.5	100	75	.18	5.39	p = NS
IE	JEPASH	1	28.4	100	248	.11	8.7	
		2	28.2	100	119	.15	6.37	**
								y = .92 = 6.55 x
								n = 29
								r = .6967
								p < .001

2	PGZHOB	1	33.0	100	93	.16	6.14	
		2	30.5	100	98	.15	6.42	
		3	35.0	100	101	.15	6.40	
		4	100.5	60	505	.05	21.47	
		5	48.0	77	434	.04	22.80	
		6	62.3	100	427	.04	21.13	
		7	80.00	100	288	.09	10.16	
		8	64.9	51	411	.04	23.86	$y = -27.5 + 5.32x$
		9	68.0	100	206	.08	11.47	$n = 11$
		10	26.5	100	99	.10	8.31	$r = .7970$
		11	22.5	100	76	.14	7.03	$p < .001$
3A	PWTSUL	1	20.5	100	112	.12	5.78	
		2	14.6	100	95	.18	5.46	
		3	20.0	100	90	.32	3.13	
		4	19.5	100	107	.12	9.00	
		5	15.5	100	97	.21	4.72	
		6	19.5	100	94	.24	4.12	
		7	17.9	100	91	.27	3.76	
		8	20.5	100	127	.16	6.15	
		9	60.0	25*	230	.04	14.28	
		10	11.1	100	108	.12	8.75	
		11	23.0	100	101	.25	3.91	$y = 50.28 + 2.82x$
		12	29.0	66	120	.17	5.93	$n = 13$
		13	29.3	100	135	.19	5.37	$r = .9348$
		14	29.3	100	127	.14	7.17	$p < .001$
3B	PWAYUB	1	73	100	129	.29	3.4	
		2	53	100	100	.34	2.9	
		3	48.5	100	100	.60	1.64	
		4	67.5	100	152	.25	3.85	
		5	48.5	87	108	.21	4.36	
		6	46.2	71	94	.17	5.66	
		7	27.5	100	116	.25	3.98	$y = 71.96 + .73x$
		8	57.5	96	125	.25	3.98	$n = 10$
		9	52.0	100	78	.36	2.72	$r = .4563$
		10	65.0	100	111	.24	4.12	$p =$ NS
3C	PWKHAN	1	98	35*	417	.40	23.69	
		2	97.5	74	116	.31	3.19	
		3	77.0	100	141	.25	3.86	
		4	66.5	100	164	.22	4.45	
		5	63.0	100	120	.26	3.50	$y = 141.68 - .15x$
		6	68.0	74	131	.19	5.17	$n = 7$
		7	70.0	98	132	.25	3.92	$r = -.11$
		8	58.0	100	112	.28	3.56	$p =$ NS

Table 2 (Cont'd)

S.No.	Code	Tree No.	Diam	Reli	Age	Growth rate cm/y	y/cm	Regression
3D	PWMURR	1	83	100	102	.40	2.45	**
		2	82	79	104	.31	3.20	y = 87.65 + .43 x
		3	58.5	100	71	.51	1.98	n = 20
								r = 2036
								p = NS
4	PKZHOB	1	3.7	100	15	.18	5.24	
		2	4.6	100	11	.27	3.66	
		3	3.9	100	15	.14	6.81	NC
		4	3.7	100	13	.17	5.65	
5	OFZHOB	1	5.6	100	16	.21	4.68	
		2	2.4	100	11	.11	8.24	
		3	4.3	100	21	.10	9.96	NC
		4	4.2	100	19	.14	7.03	
		5	3.4	100	8	.22	4.69	
		6	2.8	100	14	.15	6.66	
6	EGZHOB	1	3.5	100	14	.13	7.38	
7A	APMRNE	1	92	100	150	.25	3.94	
		2	11.3	86	351	.06	16.39	NC
		3	71.2	100	103	.30	2.44	
7B	APAYUB	1	51	100	88	.28	3.53	
		2	55	100	82	.32	3.10	
		3	89	38	277	.08	12.20	NC
		4	86	62	208	.12	7.75	
		5	69	76	107	.24	4.05	
7C	APAYBS	1	96	13	134	.05	19.68	
		2	65.9	78	171	.16	6.21	
		3	47.6	100	170	.24	4.03	
		4	53.0	100	87	.26	3.67	
		5	84.0	100	133	.25	3.90	
		6	55.0	100	74	.30	2.70	
		7	80.0	78	156	.21	4.63	y = 59.82+.91x
		8	44.8	100	87	.30	2.65	n = 10
		9	52.0	100	80	.32	3.07	r = .40
		10	65.0	100	92	.39	2.52	p = NS

7D	APAYBW	1	55.0	100	82	.26	3.8	y = -35.45 + 3.09x
		2	64.5	100	283	.12	8.7	n = 7
		3	76.4	94	200	.19	5.15	r = .34
		4	73.5	100	170	.23	4.21	p = NC
		5	71.5	49	242	.07	12.74	**y = -43.79 + 2.79x
		6	75.8	100	134	.27	3.59	n = 25
		7	63.5	100	124	.18	5.46	r = .64
								p = < .001
8	PRSWAT	1	62	100	95	.23	4.2	
		2	56.2	100	105	.17	5.64	
		3	56.0	100	145	.18	5.49	NC
		4	33.5	100	30	.47	2.09	
9	CDSWAT	1	200	34	346	.09	10.2	
		2	37.5	100	48	.39	2.5	NC
		3	44.88	100	63	.43	2.30	

Note: Standard deviation was calculated if more than three radii were analysed in a cross-section or tree.

* Due to extremely low reliabilities these values were not included in regression analysis.

** Overall Regression of a species.

cm/y = cm per year

y/cm = years per cm

column 1 Diameters on breast height

2 Reliabilty in percentage

6 Regression between diameter and age.

For code refer to Table 1.

NC = not calculated due to less number

NS = not significant.

Discussion

Age and growth rate greatly vary from species to species, site to site and even two closely situated same sized trees of the same species. Since previous data on age and growth rate of Himalayan species is scanty, present results are not comparable in most cases. It is suggested that largest tree is not necessarily the oldest tree of the population, same is true for the oldest tree. Swathi (1953) and Sheikh (1985) presented *J. excelsa* as extremely slow growing tree. Their ages are 1000 and 2000 years for two individuals respectively. Cross-dating is a basic principle and most important technique of dendrochronology (Fritts, 1976). Without using this method in most cases false and absent rings could not be identified. Hence different radii of the same specimen may show different number of rings and growth rate. In addition, it is also suggested that the specimen with low percent of reliability overestimate the age and growth rate. It is therefore likely that Swathi (1953) and Sheikh (1985) overestimated

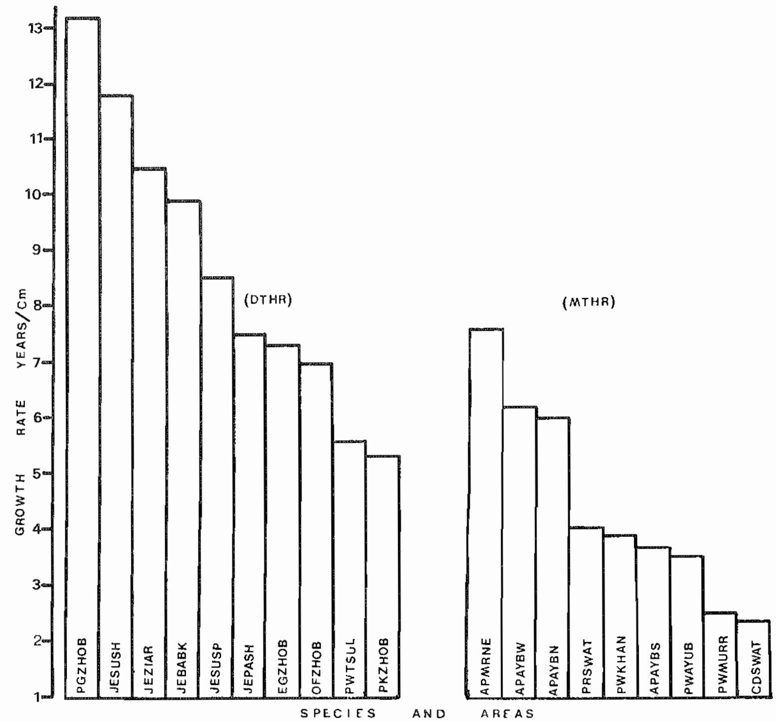

Fig.4. Mean growth rate of each species in different locations of each climatic zone.
DTHR = Dry temperate Himalyan Regions
MTHR = Moist temperate Himalyan Regions.
For abreviation of species and location refer to the Table 1.

the ages. It is advisable that less reliable core or specimen should be excluded during further analysis. *P. gerardiana* is characterised as an extremely slow growing tree species in dry temperate Himalayan region while *A. pindrow* gives similar response in moist temperate Himalayan region of Pakistan. Species from moist temperate areas generally grow faster, however it is not the same case with all species. A few species from dry temperate area grow faster than a few species of moist temperate area. *P. khinjuk*, a dry temperate species grows faster. This species prefers to grow on moderate to gentle slopes and also on the flat areas close to the dry stream beds, therefore its faster growth may be related to the better moisture regime of the soil. Khan (1968) found significant correlation between diameter and age in *P. wallichiana*. Present study also shows the similar correlation in most cases between these two variables. However, due to wide variance associated, it is not advisable to draw conclusions about the age of even closely situated trees of the same species. Similar conclusions were also made by Ward (1982), Ahmed (1984) Ahmed, (1987) Ahmed *et al.,* (1990, 1991). Though variation exists between altitude and growth rate among different species, in general, growth rate decreases with increasing altitude and a

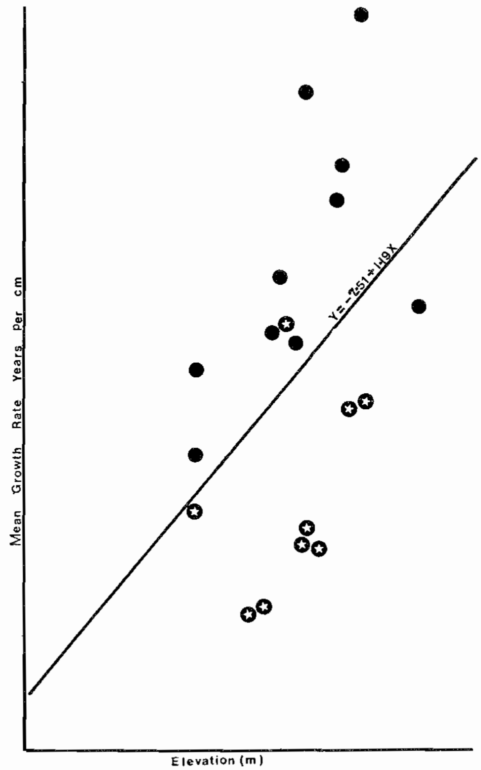

Fig.5. An overall relationship between altitude and mean growth rates. Dry temperate. Moist temperate.

negative significant relation is observed between these variables. Norton (1983) and Ahmed (1984) made similar observations while working on *Nothofagus* and *Agathis* species in New Zealand.

References

Ahmed M. 1984. *Ecological and dendrochronological studies on Agathis australis* (Salisb) Kauri. Ph.D. Thesis. Univ. of Auckland. New Zealand.

Ahmed, M. 1987. Dendrochronology and its scope in Pakistan. Proc. of Third Nat. Conf. of Plant Scientists.

Ahmed, M. 1988 A. Population structure of some planted tree species in Quetta. *J. Pure and Applied Science*,7:25-29.

Ahmed M. 1988 B. Problems encountered in age estimation of forest tree species. *Pak. J. Bot.*, 20:143-145.

Ahmed, M., S.S. Shaukat and A.H. Buzdar. 1990. Population structure and dynamics of *Juniperus excelsa* in Balochistan. *Pak. Jour. Vegetation Science*, 1:271-276.

Ahmed, M., M. Ashfaq, M. Amjad and M. Saeed. 1991. Vegetation structure and dynamics of *Pinus gerardiana* forests in Balochistan. *Pak. Jour. Vegetation Science*, 2: 119-124.

Champion, H.G., S.K. Seth and G.M. Khattak. 1965. *Forest types of Pakistan.* Pakistan Forest Institute, Peshawar, 238 pp.

Fritts, H.C. 1976. *Tree ring and climate*. Academic Press. London.

Khan, A.H. 1968. Ecopathological observations in Trarkhal Forests with special reference to damage by *Fomes pini*. Part 1-Regeneration status of the Forest. *Pak. J. Forestry*, 18: 169-228.

Norton, D.A. 1983. *A dendroclimatic analysis of three indigenous tree species, South island, New Zealand.* Ph.D. Thesis, Univ. of Canterbury, New Zealand.

Ogden, J. 1980. Dendrochonology and dendro ecology, an introduction. *New Zealand Jour. Ecology,* 3: 154-156.

Ogden, J. 1981. Dendrochronological studies and the determination of tree age in the Australian tropics. *Jour. Biogeography,* 8: 405-420.

Sheikh M.I. 1985. *Afforestation in Juniper forests of Balochistan.* Pakistan Forest Institute. 46. pp.

Stokes, M.A. and T.L. Smiley. 1968. *An Introduction to tree-ring dating.* Univ. of Chicago Press, Chicago.

Swathi, A.S. 1953. Note on the Juniper forest of Balochistan, unpublished report of Balochistan Forest Department.

Ward, L.K. 1982. The conservation of Juniper: Longevity and old age. *Jour. Applied Ecology,* 19: 917-928.

(Received for publication 11 July 1989)