International Journal of Pharma and Bio Sciences

VARIABILITY IN CONE AND SEED CHARACTERISTICS AMONG PLUS TREES OF BLUE PINE (*PINUS WALLICHIANA* A. B. JACKSON) IN THE KASHMIR HIMALAYA, INDIA

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ABSTRACT

Eighty eight plus trees representing the entire distributional range of *Pinus wallichiana* (Blue pine or Kail) in Kashmir Himalaya were sampled to determine the extent and nature of variability and character association in eight cone and seed traits. Wide variations were observed in cone weight (28.16-46.0 g), number of seeds/cone (41.6-90.6) and 1000 seed weight (42.0-67.0 g). Genetic coefficient of variation, phenotypic coefficient of variation, heritability estimates and genetic advance were higher for cone length, cone width, cone weight, seed length and seed thickness. Genotypic correlation in all the traits was greater than the phenotypic correlation. Seed thickness exhibited significant variability, heritability and maximum genetic gain (29.44%) followed by cone width and seed width. Cone weight, seed length, seed width and seed thickness showed positive direct effect on 1000 seed weight whereas cone length and cone width showed negative direct and indirect effect on 1000 seed weight. The investigation revealed that cone weight, seeds/cone, seed length and seed thickness are important characters because of their direct effect on 1000 seed weight. Thus, these traits should be given top priority while selecting superior genotypes.

KEYWORDS

Pinus wallichiana, Blue pine, phenotypic and genotypic coefficient of variation, genetic gain, heritability.

INTRODUCTION

Pinus wallichiana A.B. JACKSON, the blue or Bhutan pine, commonly known in the trade as *Kail,* is found in the Himalayas from Kashmir to Bhutan, at altitudes of 2,000 to 3,500 m[1]. It is a graceful tree with horizontally spreading branches and is predominantly exploited for timber, high quality resin, and fuel wood. Significant area of Kashmir Himalaya in the drainage basin of Jehlum river and its tributaries is dominated by blue pine[2], which displays immense diversity all over the state of Jammu and Kashmir due to wide range of soil and climatic conditions[3].

In view of excessive exploitation of the species for the economic values stated above and resultant erosion of its gene pool, it is imperative to document the extent of variability

in the existing germplasm of the species in Kashmir Himalaya as the same has been reported to be an indispensable pre-requisite for bringing about genetic improvement in wind pollinated conifers, including blue pine[4]. While reproductive traits are believed to be the most conserved traits and least affected by the environment, yet they have been consistently ignored while selecting plus trees and upgrading the existing seed orchards[5]. Since any detectable variation in these traits could be attributed to genetic causes, cone and seed traits can be effectively used as markers to characterize superior plus trees. Further, use of morphological markers is an essential step in the early period of tree breeding, when molecular markers are not readily available. It is in light of this that the present study was initiated to assess the extent of genetic variation in different fertility traits among plus trees growing in the entire distributional range in Kashmir Himalaya. Importance of such studies in plant breeding[6, 7, 8, 9, 10] and gene conservation programmes[11] has been highlighted [11, 12]. While studies detailing the variations in the reproductive attributes of several species of *Pinus*, such as *P. nigra*[13] , *P. halepensis*[14], *P. coulteri, P. sabiniana, P. torreyana*[15], *P. brutia* [16,17] are available, but no such study has so far been carried out on *P. wallichiana* which warranted investigation of the extent and nature of variability in the cone and seed attributes of the blue pine so as to lay firm foundation for a sound scientific programme of genetically superior seed production for use in afforestation and reforestation programmes currently underway in Kashmir Himalaya.

MATERIALS AND METHODS

The material for the present study consisted of 88 plus trees (*Table 1*) selected in natural forest stands of Kashmir Himalaya (32^o 17' to 37^o 16' N latitude and 73^o 26' to 80^o 06' E longitude). Intensive survey and inspection of the blue pine dominated forest divisions of Kashmir Himalaya (Lidder, Pirpanjal, Shopian, Sindh and Kamraj) resulted in the selection of 100 candidate plus tress along with 500 check trees on the basis of quantitative (height, diameter at breast height, girth at breast height, bole length, crown size, bole volume) and qualitative characters (straightness, tapper, branch thickness, branch angle, pruning ability).Each candidate plus tree was compared with the five randomly selected check trees and trees with superior phenotype were identified employing scoring method[18].Only those candidate plus trees were approved as plus trees which showed highest score in respect of the studied traits than the mean score of 5 check trees and accordingly only 88 trees were recognised as plus trees among the 100 candidate plus trees. Superiority per cent for each quantitative trait of the selected plus trees was calculated using the following formula[19]:

$$S = \frac{C}{A} \times 100 - 100$$

where S = superiority percent;

C= value of a trait in a candidate plus tree

A= average value of the same trait in 5 comparison trees.

To study the variation in eight cone and seed traits, namely, cone length (cm), cone width (mm), cone weight (g), number of seeds/cone, seed length (mm), seed width (mm), seed thickness (mm) and seed weight (g) among the 88 plus trees, thirty mature cones per plus tree were collected at physiological maturity (when the cones turn reddish brown from bluish green) and the cones so obtained were randomly divided into three replicates of ten cones each. The cones were weighed and length and width was measured by making use of digital vernier caliper and centimeter scale followed by sun drying for 7-8 days. The dried cones were shaken manually to facilitate total seed recovery and the cones were then weighed on digital balance. The seeds thus procured were then dewinged manually, cleaned, weighed and counted. A random sample of 10 seeds in three replications from each tree was taken to measure length and width of seeds. Likewise

another random sample of 1000 seeds in three replications of each tree was used to record seed weight.

Table 1
Geographic location, climatic and seed source details of Pinus wallichiana in the Kashmir Himalaya.

Forest Division	Latitude (N)*	Longitude (E)*	Altitude (m/amsl)*	Annual rainfall (mm)!	Location	Forest compartment no.	No. of plus trees selected.
Lidder	34° 02′	75° 20′	2400	1075.2	Batakote	28/L	6
Lidder					Pahalgam	47/L	8
Lidder					Arthnari	38/L	7
Lidder					Seer	3/L	5
Lidder					Braid	10/L	4
Lidder					Hapatnar	12/L	7
Lidder					Liddru	31/L	4
Pirpanjal	34° 05′	74° 20′	3000	2012.5	Batawooder	11/D	10
Pirpanjal					Neegu	18/D	10
Pirpanjal					Haijan	22/D	10
Shopian	33° 50′	74° 40′	2166	768.5	Haripora	5/Rb	10
Shopian					Sedow	7/V	1
Shopian					Sedow	9/V	1
Sindh	32° 58′	72° 30′	1660	549.4	Kangan	22/S	1
Kamraj	34° 29′	76° 20′	2166	793.9	Sogam	63/SL	4

Source: *Digest of Forest Statistics, 2000, Forest Department (J&K Government);! Indian Meteorological Centre Rambagh, Srinagar, Kashmir (J&K).

Statistical analysis:

Data generated were subjected to analysis of variance (ANOVA) to decompose the variability into genetic and environmental components[20]. Correlation coefficients and path coefficients were worked out as per[21]. The genotypic (GV), phenotypic (PV) and environmental (EV) components of variance were calculated for each trait using the relationships suggested by[22]:

$$GV = \frac{Mt - Me}{r}$$

where Mt = variance due to treatments (genotypes/plus trees)

Me = Variance due to error (environmental variance)

r = number of replicates

$$PV = GV + EV$$

$$EV = Me$$

where GV= genotypic variance of the characteristic

PV= phenotypic variance of the characteristic

EV= environmental variance of the characteristic

Phenotypic coefficient of variation (PCV %) and genotypic coefficient of variation (GCV %) were estimated according to[22], [23] :

$$PVC\,(\%) = \frac{\sqrt{PV}}{\overline{X}} \times 100$$

$$GVC\,(\%) = \frac{\sqrt{GV}}{\overline{X}} \times 100$$

where PV = phenotypic variance of the characteristic

GV= genotypic variance of the characteristic

$\overline{X}$ = population mean for each characteristic

Heritability (h^2) in broad sense was calculated according to[22] using the following expression:

$$h^2 = \frac{GV}{PV} \times 100$$

Genetic advance (GA) and Genetic gain (GG) were calculated following [24]:

$$GA = K \times h^2 \times \sqrt{PV}$$

$$GG = \frac{GA}{\overline{X}} \times 100$$

where K = selection differential (2.06 at 5% selection intensity following[25])

h^2 = heritability in broad sense

$\sqrt{PV}$ = phenotypic standard deviation

$\overline{X}$ = population mean for each characteristic

RESULTS AND DISCUSSION

The performance of plus trees for different cone and seed characteristics is given in *Table 2* and *3*. The data revealed that cone length varied from 16.20 cm to 25.30 cm with an overall mean of 20.50 cm. Maximum length (25.30 cm) was recorded for plus tree no. 15 and minimum was recorded (16.20 cm) for plus tree no. 40. Cone width varied from 3.46 cm to 6.80 cm with an overall mean of 5.17cm. Maximum cone width (6.80 cm) was recorded in plus tree no.15 and minimum (3.46 cm) in plus tree no. 48. The cone weight varied from 28.16 g to 46.0 g with overall mean of 40.93 g. Maximum cone weight (46.0 g) was recorded for plus tree no.15 and minimum (28.16 g) for plus tree no. 27. [26]also recorded overall mean of 13.44 cm, 7.19 cm and 183.87 g for cone length, cone width and cone weight, respectively in Chir pine (*Pinus roxburghii*). Number of seeds extracted per cone ranged from 41.66 to 90.66 with an overall mean of 67.28. Maximum number of seeds/cone (90.66) was recorded for plus tree no.15 and minimum (41.66) for tree no. 66. Seed length varied from 5.33 mm to 13.33 mm with overall mean of 9.80 mm. Maximum seed length (13.33 mm) was recorded for tree no. 15 and minimum (5.33 mm) for tree no.66. Compared to present observation, [27]reported higher mean cone length of 15-32.5 cm in blue pine but mean seed length and width were almost similar to the values recorded during the present study. Means values for cone width (3.46 to 6.80 cm) recorded in the present study are also in conformity with the findings of [28] wherein mean values for cone width of blue pine ranged from 4 cm to 5 cm while during the present study seed width ranged from 3.33 mm to 7.66 mm with an overall mean 5.45 mm. Maximum seed width was exhibited by tree no. 15 (7.66 mm) and minimum (3.33) by tree no. 38. The mean seed thickness varied from 3.00 mm to 5.33 mm with an overall mean of 3.93 mm. Highest seed thickness (5.33 mm) was recorded for tree no.12 and lowest (3.0 mm) for tree no.77. Wide ranges in the mean seed weight/1000 seeds were recorded (42.0 g to 67.0 g) during the present study with an overall mean of 54.65 g. Maximum 1000 seed weight (67.0 g) was recorded for the tree no. 15 and minimum (42.0 g) for tree no. 60. Such results are in agreement with those of a previous study wherein the mean weight of 1000 seeds in blue pine was 56.6 g [27]. Similar trend was also reported by [28] for cone length, cone width, seed length and seed width in Aleppo pine (*Pinus halepensis*). The coefficient of variation ranged from 7.72% for cone length to 53.64% for cone weight (*Table 3*). These results are also in line with those of *P. roxburghii*[29] and of *C. deodara* [4]. Variability in cone and seed attributes detailed in the present study run parallel to similar findings reported in other species of the genus, such as *Pinus radiata*[30], *P. halepensis*[31], *P. tecunumanii*[32], *P. strobes* [33] and *P. canariensis*[34]. Geographical (latitude and longitude) and local ecological conditions (altitude and other associated environmental conditions) has often been recognised as primary factors contributing to the variability in natural populations of different pines[35]

Table 2

Performance of plus trees with respect to cone and seed characteristics.

Plus tree No*.	Cone length (cm)	Cone Width (cm)	Cone Weight (g)	No. of seeds/cone (no.)	Seed length (mm)	Seed width (mm)	Seed thickness (mm)	Seed weight / 1000 seeds (g)
1	21.10	5.66	39.66	80.00	10.33	6.66	4.00	52.33
2	19.90	5.60	42.00	77.60	10.00	5.33	3.33	50.60
3	19.36	5.16	41.90	70.66	10.00	6.00	4.66	50.50
4	17.43	4.90	43.00	76.66	11.00	5.33	3.66	61.00
5	21.23	4.90	42.83	75.33	9.33	6.00	4.33	63.33
6	20.73	5.00	40.30	68.33	8.33	5.66	3.66	60.33
7	19.66	5.50	41.00	76.00	9.00	5.00	4.00	51.66
8	19.86	5.33	40.10	71.66	6.66	4.66	3.33	51.00
9	18.83	5.66	42.33	73.66	7.00	6.33	5.00	54.00
10	19.83	5.16	44.74	73.00	9.00	4.66	4.00	50.00
11	19.10	4.93	42.76	73.00	8.66	5.00	3.33	44.33
12	18.30	5.06	40.70	81.33	7.33	7.66	5.33	44.33
13	17.96	5.06	39.16	71.66	6.33	5.33	3.00	43.33
14	17.50	4.83	40.16	60.66	9.33	5.33	4.00	60.00
15	25.30	6.80	46.00	90.66	13.33	7.66	5.00	67.00
16	23.66	5.53	43.66	85.66	11.33	5.00	4.33	61.00
17	21.53	5.30	42.93	79.00	10.66	5.66	3.00	63.33
18	23.33	5.23	42.50	88.00	10.66	7.66	4.33	64.00
19	21.00	4.66	42.86	82.33	10.00	5.00	3.33	50.33
20	22.03	5.23	45.50	84.00	10.33	6.33	4.00	58.66
21	22.16	5.63	38.80	87.00	10.33	5.66	4.00	61.00
22	23.80	5.66	42.66	78.66	12.00	7.66	4.33	62.33
23	23.43	5.43	43.00	78.33	10.00	5.66	4.66	61.00
24	23.33	4.30	40.83	74.66	10.66	6.00	3.66	57.33
25	21.16	5.10	41.36	80.00	8.33	6.00	4.33	55.66
26	21.16	6.00	40.00	72.66	10.66	5.00	4.33	56.33
27	22.46	5.23	28.16	73.33	11.00	6.33	4.33	55.00
28	22.43	5.50	28.16	71.66	11.33	6.00	4.00	51.00
29	21.20	4.26	43.00	71.33	10.00	6.00	4.33	61.33
30	21.50	5.60	40.66	70.00	9.66	6.33	4.00	62.66
31	21.83	5.70	40.00	60.00	11.66	6.00	4.66	53.33
32	21.33	5.70	41.33	70.66	7.00	5.33	3.66	52.33
33	23.76	4.86	40.23	83.00	12.66	6.00	3.33	55.66
34	20.96	4.40	40.16	75.66	12.00	5.00	3.66	58.33
35	20.06	4.23	39.93	77.66	11.00	5.33	3.33	52.66
36	22.16	4.76	39.66	66.00	10.33	6.00	4.66	53.33
37	20.40	4.70	40.66	73.00	9.33	5.66	4.33	61.66
38	22.83	4.40	40.00	72.00	11.66	3.33	4.00	50.00
39	19.70	3.83	38.10	63.00	9.33	4.33	4.00	62.00
40	16.20	4.46	40.70	68.00	11.66	5.33	4.00	61.33
41	18.83	4.60	40.76	64.00	9.00	5.66	4.00	54.00
42	22.03	5.13	40.66	60.00	12.00	5.00	4.33	57.33

43	21.46	5.20	40.33	63.00	9.66	5.33	4.00	59.33
44	21.53	4.86	40.33	70.00	9.33	5.66	4.00	48.33
45	21.03	5.16	40.30	67.66	10.66	5.33	4.00	52.00
46	20.33	4.23	41.10	51.00	10.00	5.33	4.66	51.00
47	19.53	4.96	41.10	70.00	9.66	5.00	4.00	53.00
48	20.86	3.46	39.23	60.66	8.00	5.33	4.66	56.33
49	20.13	5.00	42.00	52.00	9.00	4.66	4.00	50.33
50	22.26	4.36	41.40	67.00	10.00	5.00	4.00	45.66
51	19.13	4.06	39.66	62.33	19.00	5.33	4.00	57.33
52	20.56	6.00	41.66	60.33	8.66	5.66	4.66	43.33
53	19.90	6.00	41.33	64.66	8.33	6.00	3.33	45.00
54	18.70	5.33	40.33	63.33	9.00	5.33	3.66	45.00
55	20.06	5.33	40.33	65.33	10.66	5.33	3.33	50.00
56	20.30	5.13	39.93	50.00	8.66	5.00	3.33	42.66
57	20.06	5.00	42.06	57.00	9.33	5.00	4.00	42.33
58	20.66	5.50	41.00	56.33	7.66	5.66	3.66	42.00
59	20.46	6.00	42.20	54.66	12.00	4.33	3.66	49.33
60	20.66	5.40	41.66	61.00	9.33	5.33	3.66	42.00
61	19.93	4.90	38.93	61.33	9.66	5.00	4.00	44.00
62	19.80	5.00	39.33	57.00	12.66	5.33	3.33	52.66
63	18.86	5.20	44.33	55.66	9.33	5.33	4.33	59.33
64	21.30	5.30	41.66	47.00	10.66	5.00	3.66	59.33
65	18.40	5.40	39.66	42.66	8.33	5.66	4.00	50.66
66	18.76	5.76	39.10	41.66	5.33	5.00	3.66	46.00
67	19.26	5.40	40.33	47.00	7.66	4.66	3.66	56.00
69	18.80	5.03	40.06	56.33	8.00	5.66	3.33	57.33
71	21.06	5.33	39.66	71.66	12.00	5.00	3.66	53.33
72	18.46	4.66	43.66	67.00	10.66	5.33	3.66	56.33
73	20.36	4.60	39.63	67.33	10.00	5.33	4.33	53.66
74	21.03	51.30	41.33	62.66	7.66	5.33	4.33	51.66
75	21.53	4.83	40.03	63.66	10.00	5.00	4.33	59.00
77	21.43	5.50	39.16	73.33	10.00	5.33	3.33	52.00
78	20.00	5.03	39.80	72.00	8.33	5.66	3.66	48.33
79	20.76	5.10	40.66	72.33	13.00	5.00	3.66	55.00
81	20.53	5.26	41.66	62.33	10.33	5.06	3.66	53.66
87	20.50	4.33	41.66	74.33	8.00	5.00	3.33	62.33
89	22.20	4.70	39.93	69.33	9.33	4.33	3.66	61.33
91	21.00	4.40	41.00	70.33	10.33	5.66	4.33	52.33
92	20.20	5.00	42.00	64.33	11.33	5.66	3.66	52.00
93	20.50	5.00	40.36	79.66	10.66	5.00	3.00	58.00
94	21.30	5.20	39.56	51.66	7.33	4.66	4.00	54.33
95	20.80	5.03	40.10	68.00	8.33	5.33	3.33	51.33
96	18.00	4.00	42.33	77.33	12.33	5.00	4.66	72.00
97	17.10	4.10	42.00	71.33	11.00	5.33	7.66	65.66
99	16.30	4.36	42.66	70.66	11.33	5.00	3.33	66.33
100	21.50	4.53	41.00	73.33	9.33	4.66	3.33	57.66

* Plus tree number were given on the basis of initial selection of 100 candidate trees by Aslam (2005)

Table 3

Means, ranges, standard error, standard deviation and coefficient of variation for different cone and seed traits.

	Cone and Seed characteristics							
	Cone length (cm)	**Cone width (cm)**	**Cone weight (g)**	**Seeds/ cone (no.)**	**Seed length (mm)**	**Seed width (mm)**	**Seed thickness (mm)**	**Seed weight/1000 seeds**
Mean	20.50	5.17	40.93	67.28	9.80	5.45	3.93	54.65
Minimum	16.20	3.46	28.16	41.66	5.33	3.33	3.00	42.00
Maximum	25.30	6.80	46.00	90.66	13.33	7.66	5.33	67.00
S.E	0.18	0.14	1.39	1.08	0.16	0.06	0.05	0.69
S.D	1.74	1.35	13.07	10.17	1.59	0.63	0.49	6.50
C.V	7.72	43.10	53.64	8.89	24.77	20.65	18.76	10.45

Estimates of phenotypic, genotypic and environmental variance components are presented in *Table 5*. Variances for seed thickness, seed length and cone length were larger than other traits. Although the environmental components of variance for seed thickness, cone weight and seed length were relatively high, the genotypic components of variance accounted for 52.53%, 49.45% and 41.64% of total phenotypic variance for these characteristics, respectively. Results of the analysis of variance for all the characteristics examined are presented in *Table 4*. Difference in cone length, cone width, cone weight, number of seeds/cone and seed thickness among the 88 blue pine plus trees were significant at 5% level while differences in seed length, seed weight/1000 seeds were significant at 1% level. Perusal of the data on estimates of variability along with heritability percent, genetic advance and genetic gain for 8 traits examined during the present study (*Table 6*) revealed that PCV was greater than GCV. Maximum PCV and GCV were recorded for seed thickness followed by cone width. Heritability was high for cone length (0.779%), seed thickness (0.525%), 1000 seed weight (0.506) and seed width (0.497%). Genetic advance coupled with heritability was maximum for cone length followed by seed thickness and 1000 seed weight while the same was minimum for seed width and cone weight. High heritability together with high genetic advance is regarded as the true index of effective selection[24, 36] as GA is a product of both the heritability and the selection intensity, or selection differential. Predicted genetic advance for cone length, seed thickness, 1000 seed weight and seed width is 1.707, 1.157, 0.840 and 0.394, respectively when in remaining traits it ranged from 0.08 to 0.45. Phenotypic and genotypic coefficients of correlation are given in *Table 7*. All the cone and seed traits were found to have positive and significant correlation amongst them except for cone width and seed length at genotypic level. Cone length exhibited a highly significant association with all the characters. Correlation coefficient between cone weight and 1000 seed weight was highly significant and positive. Similar trend was recorded for cone length with 1000 seed weight. These characters can, therefore, be used by a breeder for selecting productive genotypes. In fact [37] and [38,39]also reported that heritability estimates along with genetic gain are more useful than heritability alone in selecting best genotypes for a given trait.

Relative importance of cone and seed attributes in determining 1000 seed weight was studied by partitioning the genotypic correlation coefficients into direct and indirect effects with the help of path coefficient analysis (Table 8). The data revealed that seed length significantly (0.267) influenced 1000 seed weight followed by seed thickness (0.246). Maximum indirect effect on 1000 seed weight was exerted by seed length via seed width (0.140) followed by seed thickness through seed width and seed length (0.139).

Table 4
Analysis of variance for different cone and seed traits.

Source of variation	df	MSS							
		Cone length	Cone width	Cone weight	Seeds /cone	Seed length	Seed width	Seed thickness	Seed weight/1000 seeds
Replication	2	0.903	0.945	1.646	0.991	0.535	0.339	0.329	1.784
Genotype/ Treatment	87	2.903**	1.975*	1.999**	1.431**	1.855*	0.398	2.352**	1.308*
Error	174	0.250	0.497	0.508	0.361	0.590	0.126	0.544	0.321

MSS= Mean sum of square
df = Degree of freedom
* = Significant at 5% level of significance.
** = Significant at 1% level of significance.

Table 5
Estimates of phenotypic, genotypic and environmental variance components of different cone and seed traits.

Characteristics	Variance		
	Phenotypic	Genotypic	Environmental
Cone length (cm)	1.134	0.884	0.250
Cone width (cm)	0.989	0.492	0.497
Cone weight (g)	1.005	0.497	0.508
Seeds/cone (no.)	0.717	0.356	0.361
Seed length (mm)	1.011	0.421	0.590
Seed width (mm)	0.216	0.090	0.126
Seed thickness (mm)	1.146	0.602	0.544
1000 seed weight (g)	0.65	0.329	0.321

Table 6
Estimates of variability, heritability, genetic advance and genetic gain for different traits.

Characteristics	PCV (%)	GCV (%)	H^2	GA	GG (%)
Cone length (cm)	5.194	4.586	0.779	1.707	8.32
Cone width (cm)	19.23	13.56	0.497	1.017	19.67
Cone weight (g)	2.449	1.722	0.494	1.019	2.48
Seeds/cone (no.)	1.258	0.886	0.496	0.864	1.28
Seed length (mm)	10.26	6.62	0.416	0.861	8.78
Seed width (mm)	8.52	5.50	0.406	0.397	7.28
Seed thickness (mm)	27.23	19.74	0.525	1.157	29.44
1000 seed weight (g)	1.475	1.04	0.506	0.840	1.53

PCV = Phenotypic coefficient of variation; GCV = Genotypic coefficient of variation
H^2 = Heritability in broad sense; GA = Genetic advance; GG = Genetic gain

Table 7

Estimates of genotypic (G) and phenotypic (P) correlation coefficients among different cone and seed traits.

Characteristics		Cone width	Cone weight	Seed/cone	Seed length	Seed width	Seed thickness	1000 seed weight
Cone length	G	0.329**	0.496**	0.387**	0.375**	0.731**	0.390**	0.369**
	P	0.300**	0.094	-0.058	0.257*	0.171	0.149	0.086
Cone width	G		0.211*	-0.946	0.068	0.0432**	0.212*	0.260*
	P		0.129	0.002	0.022	0.095	0.110	-0.053
Cone weight	G			0.217*	0.174	0.21S3	0.677**	0.535**
	P			0.032	0.004	0.040	-0.005	-0.071
Seeds/cone	G				0.208*	0.287**	0.328**	0.210*
	P				0.310*	0.208*	0.233*	-0.013
Seed length	G					0.213*	0.538**	0.277**
	P					0.112	0.078	0.058
Seed width	G						0.21*3	0.220*
	P						0.204*	0.114
Seed thickness	G							0.321**
	P							0.093

** = Significant at 1% level of significance; * = Significant at 5% level of significance

Table 8

Direct and indirect effect of cone and seed characteristics on 1000 seed weight.

Characteristics	Cone length	Cone width	Cone weight	No. of seeds/cone	Seed length	Seed width	Seed thickness	Correlation Coefficient
Cone length	**-0.083**	-0.007	-0.004	0.069	0.042	0.008	0.047	0.28**
Cone width	-0.008	**-0.071**	0.000	0.025	-0.005	-0.005	0.052	-0.32
Cone weight	0.005	0.000	**0.031**	0.001	0.010	-0.007	0.055	0.36**
Seeds/cone	-0.021	-0.007	0.000	**0.089**	0.051	-0.001	0.059	0.19
Seed length	-0.014	0.002	0.003	0.056	**0.267**	0.005	0.139	0.86*
Seed width	0.021	0.112	0.061	-0.110	0.14	**0.072**	0.178	0.41**
Seed thickness	-0.007	0.004	-0.005	-0.003	0.12	0.092	**0.246**	0.66**

Residual effect = 0.8327; Figures in bold are direct effects

** = Significant at 1% level of significance; * = Significant at 5% level of significance

CONCLUSIONS

Thus on the basis of analysis of eight cone and seed characteristics in eighty eight plus trees of blue pine in Kashmir Himalaya, the following conclusion can be drawn:

1 Variability in the eight cone and seed attributes of the eighty eight plus trees was significant.
2 Most of the cone and seed characters (cone length, seeds/cone, seed thickness and 1000 seed weight) were highly heritable. The heritability value along with GCV and GA indicated that production and quality of seed of blue pine could be improved by simple selection of these characters. Therefore, attention must be paid to these characters while establishing a seed orchard of the species. Plus tree no. 15 located in compartment 38/L under Lidder forest division excelled in almost all the characters considered in the present study and hence could be used for production of seeds to raise the quality planting material for reforestation programmes.
3 Path coefficient analysis indicated that cone weight, seed length, seed width and seed thickness are the characters that have positive direct effect on seed weight.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support and guidance provided by Sh.P.C.Kapoor, IFS, then Director, SFRI-J&K, for conducting the present study. Thanks are also due to Dr. Neelu Gera, IFS (PI) in particular for her valuable guidance in the initial years of the project. First author (MA) is highly indebted to Director SFRI for providing fellowship on ICFRE-WB funded, project no-40-5/ ICFRE (R)-97 entitled, "Coordinated research project on improvement of *Pinus wallichiana*" in SFRI, J&K and to Jamia Hamdard (Hamdard University), New Delhi, India for the award of degree of Ph.D. in Botany (2005) and is also to Indian Society of Life Sciences, M.P. for the award of F.S.L.Sc.

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