Relationship of Cone and Seed Traits on Progeny Growth Performance in *Casuarina equisetifolia* FORST. & FORST.f.

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Abstract

An experiment was carried out to elucidate the relationship of cone and seed traits on juvenile and adult growth of *Casuarina equisetifolia* FORST. & FORST.f. Cones and seeds were collected from 18 selected trees. Samples of 10 cones and 25 seeds were taken in 4 replications to measure 2D surface area, length, breadth, weight, roundness and aspect ratio. Five seedlings in 4 replications from each seedlot were planted in randomized block design at 2 m spacing. Progeny height and diameter were recorded at juvenile (18 months after sowing – 18 MAS) and mature (60 months after sowing – 60 MAS) stages. Significance test and estimation of variability, heritability and genetic advance were carried out. The seed and cone morphological characters were found to have high heritability and genetic advance values than tree growth characters. Correlation of cone or seed traits on progeny growth characters and path analysis of seed traits on diameter at 60 MAS were carried out. The 100 seed weight was found to have significant correlation consistently on progeny growth characters both at juvenile and mature stages. Shape characters like roundness and aspect ratio also showed significant correlation on progeny growth. Juvenile-adult correlation was established with diameter growth of juvenile on both height and diameter growth at 60 MAS. Seed 2D surface area had high direct and indirect effect on diameter at 60 MAS. Identification of better seed sources or grading of seeds may be carried out based on seed weight and/or size and/or shape to get better progenies.

Key words: correlation, grading, seed size, seed weight, roundness, image analyzer.

Introduction

Casuarina equisetifolia FORST. & FORST.f. has a wide natural range in hot humid climatic zones of subtropical and tropical coast-lines from northern Australia throughout Malesia, Melanesia and Polynesia and northwards to the Kra Isthmus in south Thailand (PINYOPUSARERK and HOUSE, 1993). In Indian sub-continent it occurs in wild state in eastern side of the Bay of Bengal (HOOKER, 1894). The distribution become widened after introduction in the Indian sub-continent in the sixties of the last century for supply of firewood to steam locomotive (KONDAS, 1986). Farmers cultivate it extensively in east coasts of Tamil Nadu, Andhra Pradesh and Orissa and west coasts of Kerala and Karnataka. It is the most important fuel wood species having high calorific value. Poles of Casuarina are widely used due to straightness and thin branches.

Casuarina is predominantly a dioecious species with 2% to 3% monoecious trees (DORAIRAJ and WILSON, 1981). It has two flowering seasons in April and October and two fruiting seasons in June and December (TROUP, 1921). The female inflorescence after fertilization forms a woody cylindrical multiple fruit termed as "Cone". Each female flower has two lateral bracteoles and a single bract. The unilocular ovary contains two ovules, only one of which forms a seed (BEADLE, 1980). A cone may contain 70 to 90 seeds. The cones and seeds of Casuarina vary greatly in size, shape and colour. HALOS (1983) observed different sizes of cones with exact cylindrical shape and cylindrical with conical tip.

Casuarina is propagated through seeds. Fresh seeds are reported to have 40% to 50% germination which deteriorate to 5% in one year (KONDAS, 1986). There exist a high demand for quality seeds of Casuarina. The commercial large scale cultivation of this species at the spacing of 1 m x 1 m in five years rotation created high demand for seed material. To meet the demand, the farmers use seeds collected from their own plantation without considering the quality of the seeds.

Early identification of superior genotype through correlation studies between seed and seedling characters have assumed greater significance in forestry. Though the effect of seed size and weight on progeny growth in tree species have been studied by many researchers (KANDYA, 1978; CHAUHAN and RAINA, 1980; KHALIL, 1981; TOON *et al.,* 1991; ABDUL ASSIS *et al.,* 1992; SRIMATHI *et al.,* 1993; MOHD SALEEM *et al.,* 1994; NEGI and TODARIA, 1997) only few have studied the relationship of seed traits on progeny growth traits up to rotation age.

In trees like *C. equisetifolia,* which is propagated through seeds, the tree growth correlated seed or cone traits are useful to improve the seed quality through seed grading. The present study was taken up to explore the relationship of seed and cone traits on juvenile as well as adult tree growth attributes of *C. equisetifolia.*

Materials and Methods

The cones and seeds

The cones and seeds used in this study were collected from 18 selected open pollinated 5 year old *C. equisetifolia* trees distributed in coastal districts of Tamil Nadu. Samples of 10 cones and 25 seeds at four replications were collected from each selected 18 trees for morphological character measurements. Image analyzer (Leica Quantimet 500+) was used for measurements. Cones or seeds of above mentioned sample quantity were spread on a glass platform of macro-viewer in replication-wise and images were captured and taken into the software called Quantimet 500+ or QWin. The captured images were calibrated to actual scale. The QWin identifies the object based on our specification for cone or seed colour. The QWin measures 2D Surface area, length, breadth, roundness and aspect

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ratio of the identified images of cones and seeds. Roundness and aspect ratio are shape factors. Roundness gives a minimum value of unity for a circle. This is calculated from the ratio of perimeter square to area (Anon., 1995).

$$\text{Roundness} = \frac{(\text{Perimeter})^2}{4 \times \pi \times \text{Area} \times 1.064}$$

The adjustment factor of 1.064 corrects the perimeter for the effect of the corners produced by the digitization of the image.

When the seeds are perfectly round the roundness will be one and when the seeds are elliptical and other shapes it is more than one. Aspect ratio is a ratio of length divided by breadth. The 100 seed weight was taken separately with four replications for each seedlot.

The progenies

Samples of five trees in four replications from each selected 18 trees were planted in randomized block design after 12 months. Growth measurements like total height and diameter at the collar region at juvenile stage (18 months after sowing – 18 MAS) and adult stage (60 months after sowing – 60 MAS) were taken in all the planted individuals.

The analysis

The parent tree cone and seed measurements and progeny growth measurements were analysed for Duncan multiple range test (DMRT) to understand the significance of differences between the seedlots and progenies (GOMEZ and GOMEZ, 1984). The genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) and environmental coefficient of variation (ECV) were calculated using genotypic variance (σ^2_g), phenotypic variance (σ^2_p) and environmental variance (σ^2_e) as given below:

$$\text{Genotypic coefficient of variance (GCV)} = \frac{(\sigma^2_g)^{1/2}}{\text{Mean}} \times 100$$

$$\text{Phenotypic coefficient of variance (PCV)} = \frac{(\sigma^2_p)^{1/2}}{\text{Mean}} \times 100$$

$$\text{Environmental coefficient of variance (ECV)} = \frac{(\sigma^2_e)^{1/2}}{\text{Mean}} \times 100$$

Broad sense heritability (h^2) was calculated as a ratio of genotypic variance to the phenotypic variance and the genetic advance (GA) was calculated using the following formula:

Genetic advance (GA) = $i \times h^2 \times \sigma_p$

Where i = standardized selection differential

h^2 = heritability

σ_p = phenotypic standard deviation

The genotypic correlation coefficient (r_g) and path analysis adopted to partition the genotypic correlation coefficient into direct and indirect effects were calculated using the method given by VARGHESE *et al.*, 1976.

$$\text{Genotypic correlation coefficient } (r_g) = \frac{Cov_g\, x_1 x_2}{(V_g(x_1) \cdot V_g(x_2))^{1/2}}$$

Table 1. – Parent tree cone and seed characters with their progeny growth characters studied in *C. equisetifolia*.

Seed lot No.	Cone characters						Seed characters						Progeny growth characters in cm			
	2D Surface Area (cm^2)	length (cm)	Breadth (cm)	10 Fruit wt.(g)	Round ness	Aspect ratio	2D Surface Area (cm^2)	Length (cm)	Breadth (cm)	100 Seed wt.(g)	Round ness	Aspect ratio	Height (18 MAS)	Diameter (18 MAS)	Height (60 MAS)	Diameter (60 MAS)
S1	2.68 ^{def}	2.12 ^{c}	1.64 ^{fg}	9.7 ^{de}	1.30 ^{gh}	1.30 ^{bc}	0.16 ^{de}	0.65 $^{d-g}$	0.33 ^{de}	0.17 ^{b}	1.31 ^{ef}	1.98 ^{cd}	109.2 $^{d-g}$	0.97 $^{a-d}$	835.1 $^{a-d}$	7.57 ^{abc}
S2	2.78 ^{def}	2.14 ^{c}	1.69 ^{def}	9.1 ^{ef}	1.40 ^{bc}	1.26 ^{c}	0.13 ^{ghi}	0.60 ^{ij}	0.29 ^{gh}	0.14 ^{c}	1.34 ^{cde}	2.03 ^{bc}	149.5 ^{abc}	1.04 $^{a-d}$	832.0 $^{a-d}$	7.46 $^{a-d}$
S3	3.49 ^{ab}	2.38 ^{ab}	1.86 ^{a}	15.0 ^{a}	1.29 ^{gh}	1.27 ^{c}	0.20 ^{b}	0.74 ^{b}	0.36 ^{bc}	0.21 ^{a}	1.32 ^{def}	2.04 ^{bc}	137.2 $^{a-d}$	1.04 $^{a-d}$	844.5 $^{a-d}$	7.69 ^{ab}
S4	3.44 ^{abc}	2.41 ^{ab}	1.82 ^{ab}	14.8 ^{a}	1.41 ^{bc}	1.31 ^{bc}	0.17 ^{cd}	0.67 ^{cd}	0.35 ^{cd}	0.16 ^{b}	1.30 ^{f}	1.91 ^{e}	112.1 $^{d-g}$	0.98 $^{a-d}$	791.4 $^{a-e}$	7.87 ^{ab}
S5	2.56 ^{f}	2.13 ^{c}	1.50 ^{hi}	8.4 ^{ef}	1.32 ^{efg}	1.41 ^{a}	0.13 ^{hi}	0.59 ^{ij}	0.29 ^{gh}	0.17 ^{b}	1.36 ^{bc}	2.06 ^{b}	160.7 ^{a}	1.10 $^{a-d}$	874.2 ^{abc}	7.09 $^{a-e}$
S6	3.66 ^{a}	2.53 ^{a}	1.80 ^{abc}	14.7 ^{a}	1.42 ^{b}	1.39 ^{a}	0.23 ^{a}	0.80 ^{a}	0.40 a	0.23 ^{a}	1.32 ^{def}	1.98 ^{cd}	139.8 $^{a-d}$	0.98 $^{a-d}$	763.9 $^{a-f}$	7.01 $^{a-e}$
S7	3.05 ^{cde}	2.28 ^{bc}	1.71 $^{b-f}$	11.2 ^{c}	1.37 ^{cd}	1.33 ^{b}	0.12 ^{i}	0.60 ^{hij}	0.28 ^{hi}	0.13 ^{cde}	1.40 ^{a}	2.20 ^{a}	93.2 ^{efg}	0.77 ^{d}	675.1 $^{c-f}$	6.04 ^{def}
S8	2.83 ^{def}	2.20 ^{c}	1.67 ^{ef}	9.7 ^{de}	1.35 ^{de}	1.31 ^{bc}	0.12 ^{hi}	0.60 ^{hij}	0.28 ^{h}	0.13 ^{cde}	1.37 ^{bc}	2.15 ^{a}	131.1 $^{a-d}$	1.11 ^{abc}	923.3 ^{a}	7.21 $^{a-e}$
S9	3.12 ^{bcd}	2.30 ^{bc}	1.76 $^{a-e}$	14.9 ^{a}	1.30 ^{fgh}	1.30 ^{bc}	0.16 ^{def}	0.65 $^{d-g}$	0.33 ^{de}	0.17 ^{b}	1.31 ^{f}	1.94 ^{de}	153.1 ^{ab}	0.89 ^{bcd}	756.6 $^{a-f}$	7.18 $^{a-e}$
S10	2.91 ^{def}	2.19 ^{c}	1.68 ^{def}	9.8 ^{de}	1.23 ^{i}	1.29 ^{bc}	0.18 ^{c}	0.66 ^{def}	0.38 ^{b}	0.17 ^{b}	1.25 ^{g}	1.74 ^{f}	131.0 $^{a-d}$	1.25 ^{a}	893.3 ^{ab}	8.35 ^{a}
S11	2.88 ^{def}	2.19 ^{c}	1.70 $^{c-f}$	11.9 ^{c}	1.38 ^{bcd}	1.28 ^{bc}	0.15 ^{def}	0.66 ^{de}	0.31 ^{fg}	0.12 ^{de}	1.39 ^{ab}	2.15 ^{a}	90.6 ^{fg}	0.95 $^{a-d}$	675.8 $^{c-f}$	6.13 $^{c-f}$
S12	2.90 ^{def}	2.20 ^{c}	1.72 $^{b-f}$	12.0 ^{c}	1.30 ^{gh}	1.27 ^{c}	0.14 ^{efg}	0.62 ^{ghi}	0.32 ^{ef}	0.13 ^{cd}	1.32 ^{ef}	1.98 ^{cd}	126.3 $^{b-e}$	0.90 ^{bcd}	568.9 ^{f}	5.36 ^{f}
S13	2.65 ^{ef}	2.12 ^{c}	1.62 ^{fg}	10.7 ^{cd}	1.35 ^{def}	1.30 ^{bc}	0.14 ^{gh}	0.63 $^{f-i}$	0.31 ^{fg}	0.13 ^{cde}	1.35 ^{cd}	2.06 ^{b}	126.2 $^{b-e}$	0.10 $^{a-d}$	619.5 ^{ef}	5.76 ^{ef}
S14	2.04 ^{g}	1.86 ^{d}	1.43 ^{i}	6.8 ^{g}	1.24 ^{i}	1.31 ^{bc}	0.12 ^{i}	0.58 ^{j}	0.28 ^{h}	0.16 ^{b}	1.37 ^{bc}	2.05 ^{b}	108.5 $^{d-g}$	0.98 $^{a-d}$	747.0 $^{a-f}$	6.16 $^{c-f}$
S15	1.50 ^{h}	1.55 ^{e}	1.29 ^{j}	4.1 ^{h}	1.26 ^{hi}	1.20 ^{d}	0.10 ^{j}	0.51 ^{k}	0.26 ^{i}	0.09 ^{f}	1.31 ^{ef}	1.98 ^{cd}	116.1 $^{c-f}$	1.02 $^{a-d}$	683.9 $^{c-f}$	6.73 $^{b-f}$
S16	2.13 ^{g}	1.85 ^{d}	1.55 ^{gh}	7.9 ^{fg}	1.37 ^{cd}	1.19 ^{d}	0.15 ^{efg}	0.64 $^{d-g}$	0.31 ^{ef}	0.12 ^{e}	1.33 ^{def}	2.04 ^{bc}	80.6 ^{g}	0.79 ^{cd}	672.0 ^{def}	6.42 $^{b-f}$
S17	3.09 $^{b-e}$	2.27 ^{bc}	1.81 ^{abc}	13.3 ^{b}	1.47 ^{a}	1.25 ^{c}	0.16 ^{de}	0.70 ^{c}	0.32 ^{ef}	0.16 ^{b}	1.39 ^{ab}	2.22 ^{a}	123.6 $^{b-f}$	0.88 ^{bcd}	698.3 $^{b-f}$	6.52 $^{b-f}$
S18	2.89 ^{def}	2.11 ^{c}	1.79 $^{a-d}$	11.7 ^{c}	1.29 ^{gh}	1.18 ^{d}	0.14 ^{gh}	0.63 $^{e-h}$	0.30 ^{fgh}	0.16 ^{b}	1.39 ^{ab}	2.16 ^{a}	151.6 ^{ab}	1.15 ^{ab}	792.0 $^{a-e}$	6.92 $^{a-e}$
Mean	2.81	2.16	1.67	10.9	1.33	1.29	0.15	0.64	0.32	0.15	1.35	2.04	124.5	0.99	758.1	6.86

Trait means not followed by the same superscript letter are significantly different at $p = 0.05$. MAS – Months after sowing

Results and Discussion

The *table 1* lists the mean values for parent tree cone and seed characters and progeny growth characters along with their statistical significance at 5% level of probability. There exist significant difference for all the studied traits of cones, seeds and progenies. The *figure 1* shows representative seeds of 18 studied seedlots. The variation in shape and size of seeds between different seedlots is depicted in the figure. The roundness of the seedlot 10 was 1.25 and seedlot 7 was 1.40 giving near round and elliptical shapes respectively. The roundness values are close to 1.00 when the seeds are perfectly round and greater than 1.00 when the seeds are elliptical and other shapes.

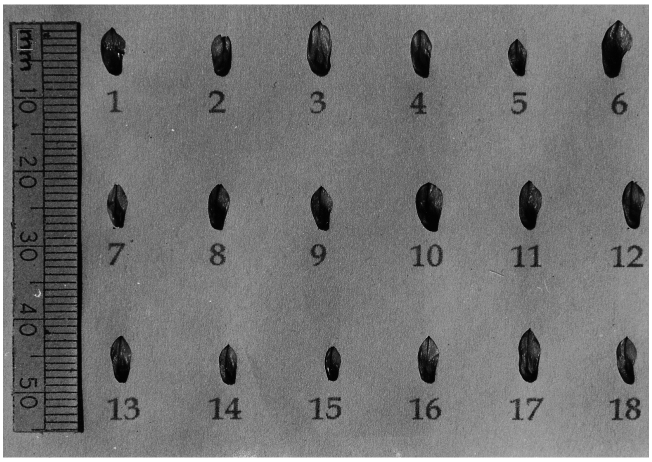

Figure 1. — Representative seeds of 18 seedlots studied.

The estimates of genotypic, phenotypic and environmental coefficient of variations, heritability and genetic advance estimates of different characters are shown in *table 2.* The genotypic and phenotypic coefficient of variations were of comparable magnitude in all the traits. VOLKER *et al.* (1990) reported that heritability estimates along with estimates of expected genetic advance is more useful for identification of better traits. The 10 cone weight was found to have high heritability and genetic advance values (0.92 and 54.71%) followed by seed 2D surface area (0.91 and 42.08%) and 100 seed weight (0.90 and 43.42%). But the heritability and genetic advance values of growth characters like height and diameter of the progenies were lower than the cone and seed traits.

Genotypic correlation coefficient of cone traits on their progeny growth traits is represented in *table 3.* The cone 2D surface area and cone length were found to have significant correlation with height at 18 MAS and height and diameter at 60 MAS. The juvenile diameter was found to have higher positive correlation with both height (1.028) and diameter (0.767) of mature trees. In *Eucalyptus spp.* such high positive correlation of juvenile diameter on mature tree growth was observed (VINAYA RAI *et al.,* 1982). To get better progenies, inferior seedlings with poor diameter may be culled in the nursery itself.

The 100 seed weight was found to have significant correlation consistently on height and diameter at juvenile stage (18 MAS) and adult stage (60 MAS) of the progenies (*Table 4*). RAI (1990) observed enhanced seedling quality in density graded seeds of *C. equisetifolia.* Present study indicates correlation of seed weight to growth of trees at rotation age. Positive correlation between seed weight and seedling height in *Pinus spp.* was found but it disappeared with the growing age of the seedlings (RIGHTER, 1945). However, persistent correlation between seed weight and height till 15 years was observed in *Pinus taeda* (ROBINSON and VAN BUIJTENEN, 1979). KHALIL (1981) stated that significant positive correlation and regression between 1000

Table 2. – Genetic variability, heritability and genetic advance values of parent tree cone and seed traits with their progeny growth characters.

	GCV	PCV	ECV	Heritability	GA (%) of Mean
Cone traits					
2D surface area	18.12	20.60	9.78	0.77	32.85
Length	10.12	11.47	5.40	0.77	18.40
Breadth	8.69	9.59	4.05	0.82	16.24
10 cone weight	27.66	28.82	8.07	0.92	54.71
Roundness	4.82	5.30	2.19	0.82	9.05
Aspect Ratio	4.41	5.23	2.81	0.71	7.66
Seed traits					
2D surface area	21.41	22.43	6.71	0.91	42.08
Length	9.72	10.30	3.41	0.89	18.89
Breadth	11.97	12.67	4.13	0.89	23.32
100 seed weight	22.09	23.16	6.95	0.90	43.42
Roundness	2.96	3.29	1.44	0.81	5.48
Aspect Ratio	5.55	5.92	2.03	0.88	10.75
Progeny growth traits					
Height (18 MAS)	16.19	23.26	16.70	0.48	23.22
Diameter (18 MAS)	7.65	20.28	18.79	0.14	5.94
Height (60 MAS)	11.46	16.81	12.29	0.46	16.11
Diameter (60 MAS)	9.55	15.99	12.82	0.35	11.76

MAS – Months after sowing

Table 3. – Genotypic correlation coefficient matrix of cone traits on their progeny growth traits.

Characters	Length	Breadth	10 fruit weight	Round ness	Aspect ratio	Height (18 MAS)	Diameter (18 MAS)	Height (60 MAS)	Diameter (60 MAS)
2D surface area	0.987**	0.943**	0.981**	0.441**	0.402**	0.346**	0.091	0.235*	0.359**
Length		0.899**	0.947**	0.460**	0.522**	0.346**	0.048	0.256*	0.317**
Breadth			0.964**	0.450**	0.099	0.268*	0.033	0.138	0.306**
10 fruit weight				0.451**	0.261*	0.257*	-0.229	-0.014	0.191
Roundness					0.135	-0.157	-0.701**	-0.214	-0.183
Aspect ratio						0.299*	0.086	0.357**	0.123
Height (18 MAS)							0.562**	0.500**	0.372**
Diameter (18 MAS)								1.028**	0.767**
Height (60 MAS)									0.983**

*significant at p = 0.05; **significant at p = 0.01

Table 4. – Genotypic correlation coefficient matrix of seed charaters on their progeny growth traits.

Characters	Length	Breadth	100 seed weight	Round ness	Aspect ratio	Height (18 MAS)	Diameter (18 MAS)	Height (60 MAS)	Diameter (60 MAS)
2D Area	0.962**	0.965**	0.826**	-0.299*	-0.366**	0.191	0.177	0.224	0.485**
Length		0.870**	0.798**	0.040	-0.107	0.126	-0.029	0.130	0.305**
Breadth			0.781**	-0.551**	-0.580**	0.190	0.309**	0.247*	0.582**
100 seed weight				-0.243*	-0.261*	0.589**	0.475**	0.542**	0.589**
Roundness					1.175**	-0.195	-0.541**	-0.268*	-0.695**
Aspect ratio						-0.209	-0.616**	-0.262*	-0.672**

*significant at p = 0.05; **significant at p = 0.01
MAS – months after sowing

seed weight and height at four years in *Picea glauca* which is not mere carryover of the initial effect in the first year growth but appears to be genetically correlated and recommended that seed weight may be included among the criteria for selection of plus trees. Among different seed weight components viz., seed coat, gametophyte and embryo weight, the embryo weight had strong relation with seedling growth traits in *Pinus elliottii* (SURLES *et al.,* 1993).

Seed roundness and aspect ratio were found to have significant negative correlation on progeny growth characters except on height at 18 MAS (*Table 4*). Among the seed traits roundness had the highest genotypic correlation coefficient (–0.695) with diameter at 60 MAS. The negative correlation of roundness indicates that the round seeds are correlated with the better progenies.

Path analysis of seed traits on diameter at 60 MAS was carried out to elucidate the direct and indirect contributions of seed traits on diameter growth of progenies (*Table 5*). Though the correlation coefficient of 2D surface area on 60 MAS is slightly low (0.485) when compared to other traits, it had highest direct and indirect effect on diameter at 60 MAS through length, breadth and 100 seed weight. Hence, the seeds with

Table 5. – Path analysis of seed characters on diameter growth of progenies at 60 MAS.

Characters	2D surface area	Length	Breadth	100 seed weight	Roundness	Aspect ratio	Correlation co-efficient
2D surface area	5.442	-2.645	-2.598	0.170	-0.665	0.781	0.485
Length	5.235	-2.750	-2.340	0.164	-0.232	0.229	0.305
Breadth	5.254	-2.391	-2.691	0.160	-0.988	1.239	0.582
100 seed weight	4.495	-2.195	-2.102	0.205	-0.373	0.558	0.589
Roundness	-2.175	0.384	1.600	-0.046	1.663	-2.120	-0.695
Aspect ratio	-1.989	0.294	1.562	-0.054	1.651	-2.135	-0.672

large surface area may be selected for producing better progenies in addition to 100 seed weight. In practice, the importance of large size seeds were realised in *C.equisetifolia* by SRIMATHI *et al.* (1993), who observed better germination and seedling growth in size graded seeds. Though 100 seed weight, roundness and aspect ratio were significantly correlated with diameter at 60 MAS, the direct effect was less. The 100 seed weight had high positive contribution from 2D surface area (4.495). In Douglas fir, similar contribution of seed weight to seedling height with lack of direct effect of seed weight on seedling height was reported (SORENSON and CAMPBELL, 1993).

From the above study, the 100 seed weight directly and seed 2D surface area indirectly correlated with growth of trees at rotation age. In addition, roundness and aspect ratio also expressed strong correlation on tree growth. Hence, identification of better seed sources or grading of seeds carried out based on seed weight and/or size and/or shape is advantageous for getting better progenies. Since the heritability and genetic advance values are high for these characters, consideration may be given for these characters during selection of trees. This will also reduce the practical difficulties in grading the seeds for roundness and aspect ratio.

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Reference

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