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Clone variation of seed traits, germination and seedling growth in *Dalbergia sissoo* Roxb. clonal seed orchard

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Abstract. A clonal seed orchard (CSO) of *Dalbergia sissoo* Roxb. at Hoshiarpur, India consisting of 20 clones originating from different agro-climatic conditions of four northern states (Uttar Pradesh, Rajasthan, Haryana and Uttarakhand) was the source of seeds for variability studies. There was lot of variation in seed size, seed weight, germination percent, germination value and growth rate in nursery of different clones over the years. Seed length, seed width and seed weight were positively correlated to each other but seed size had no effect on germination percent and germination value under laboratory conditions. However, seed weight was found positively correlated with germination percent in nursery with the seed lot of 2008 collection. The genetic parameters for seed traits and seedling growth also showed a wide range of variations in the orchard clones. Heritability values were found to be over 50 percent for seed weight and seed length. However, only seed weight showed high heritability value coupled with more genetic gain across the years, which indicate the presence of good amount of heritable additive component in seed weight. There was no consistency in the seed characters, germination and seedling growth parameters studied across the two years. Effect of clones was dominant and accounted for variation in seed size, seed weight, seed germination and growth parameters. Seed size or seed weight should not be used as criteria for grading of bulked seed lots of different clones, as it can narrow down genetic diversity by rejecting small seeds. The impact of these genetic differences in handling of seed lots during bulking and grading for mass propagation of nursery planting stock of *D. sissoo* is also discussed.
Keywords: CSO, *Dalbergia sissoo*, seed variability, clones, correlation, growth.

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Introduction

Dalbergia sissoo commonly called 'Sissoo' or 'Shisham' belongs to the family Leguminosae or Papilionaceae. It is one of the important indigenous multipurpose tree species in northern India and occurs naturally in the foothills of the Himalayas mostly in the tarai and bhabhar areas up to 1404 m above mean sea level from Jammu and Kashmir in the west to Bangal Dwar in the east. Commonly found in bouldery alluvial soils adjoining rivers, often occurs in association with *Acacia catechu*. It fixes atmospheric nitrogen and is among the villagers most preferred plantation species. *D. sissoo* has higher timber value and is classified as one of the four primary timbers of India, the others being Teak, Sal and Deodar. Its high quality sawn timber is used for furniture manufacture and building construction. It has been planted in tropical countries especially in arid and semi arid regions for timber, fuelwood, fodder, shade and stabilization of eroding landscape. Though various tree species are planted every year in India, 90% of the plantation programs consist of bamboos, *Eucalyptus, Acacia, Prosopis*, *D. sissoo*, conifers and teak. The productivity of *D. sissoo* plantations can be increased through improvement programmes. The planting stock genetic improvement programme of the species includes the establishment of seed production areas (SPA's), provenance testing, candidate plus tree (CPT) selection, clonal propagation of CPT's and establishment of seed orchards and vegetative multiplication gardens. The growth rate and quality of shisham plantations can be improved to a great extent through use of better quality seed procured from seed orchards. Use of seed orchards is one means to achieve mass production of improved material as a seed orchard is a plantation of selected clones or progenies that are isolated or managed in order to avoid or to reduce pollination from out-side sources.

Forest tree improvement programmes are structured on three main stages; selection, breeding and testing (El-Kassaby et al. 1992). Superior genotypes from the testing stage are propagated to establish orchards for the production of seeds (Hawkins 1998). Seeds collected from these orchards are then used for seedling production for reforestation success. Seed orchards and forest seedling nurseries are interconnected phase of reforestation process (Long & Peoples 1991). Seed size fractionation is a common practice used to increase uniformity in seedling size (Champbell & Sorenson 1984). However, the effect of seed size on germination behavior is controversial (Chaisurisri et al. 1994, Reich et al. 1994). Seed size, especially seed weight is regarded as an important aspect of reproductive strategy as it plays a key role in the establishment of the juvenile phase of life cycle. A number of selective advantages with large seed size have been documented, such as prolonged dormancy during unfavourable light conditions, development of large amounts of photosynthetic tissue, allowing quick seedling growth, and dispersal modes (Harms et al. 2000). Seed weight depends on reserve food material, which is produced as a result of double fertilization (endosperm) and is dominated by the maternal traits and is also influenced by the nutrient availability at the time of seed setting and environment factors (Allen 1960, Johnsen et al. 1989). Embryo development and its physiological function are contributed by the maternal as well as paternal (pollen grain) traits in the species.

Genetic variation for seed germination and seedling growth among the seed sources of *D. sissoo* has been recorded (Vakshasya et al.1992, Rehman et al.1994, Sagta & Nautiyal 2001). Clonal variation in growth, flowering and seed production of *D. sissoo* in one of the seed orchard at Dehradun was also reported by Nautiyal et al. (2003). Bagchi and Sharma (1989) observed significant genetic variability in seed size and seed weight from seed of a few of the selected plus trees seeds of *Santhalum album*. Annapurna et al. (2005)

also studied the impact of clones in clonal seed orchard on the variation of seed traits, germination and seedling growth in *Santalum album* and found vast variation in seed size, weight, germination, vigour and seedling growth of seed of different clones over the years. Mamo et al. (2006) reported the variation in seed and germination characteristics among *Juniperus procera* populations in Ethiopia.

The Forest Research Institute, Dehradun has selected plus trees of *D. sisooo* from northern states of India based on the phenotypic characters and established a clonal seed orchard of this species during the year 1998 at Hoshiarpur in the state of Punjab. Seeds of this orchard (CSO) are collected every year and used as a source of quality seed for improved planting stock of the species in northern India. As such there is no information about seed variability in terms of seed size, seed weight, germination percent, germination value, seedling growth and pattern of seed characters during different collection years among various clones of the orchard, which is essential for production of quality planting material for afforestation purposes. In addition, efforts were made to study clonal variability in terms of seed size, seed weight, germination percent, germination value, seedling growth performances among various clones of CSO of *D. sissoo* during different collection years.

Material and methods

Seeds of 20 clones from CSO comprised of eight clones from Uttar Pradesh (33, 40, 189, 192, 198, 204, 232, 242), seven clones from the state of Rajasthan (78, 83, 85, 87, 88, 90, 94), three clones from Haryana (57, 61, 66) and two clones from Uttarakhand (12, 19) were used for the study.

Pods were collected from clones of the studied seed orchards during January 2007 and 2008. Pod collections were made from five trees per clone from the orchard. Collection trees were selected randomly from each block of the orchard. Pods of each clone were bulked and kept separate by clone in marked polythene bags and brought to the laboratory for further studies. Extraction of seed from pods was made manually and extracted seeds of different clones were put in plastic boxes and stored at 15^0 C in the refrigerator to carry out further germination and nursery studies.

Seed variability. Four replicates of 25 randomly selected and undamaged seeds per replication were measured for their length and width in mm up to 2 decimal places using an electronic vernier caliper. Seed weight determination was made on 8 random samples having 100 seeds per sample as per standard rules (ISTA 1993) using an electronic top pan balance (Sartorius-MA 4o).

The seed germination studies of the 20 clones were carried out in a laboratory using 100 seeds per replication in four replications. Petri plates were used for the germination test and seeds were put on wet germination papers. These petri plates were placed in the germinator having temperature of 30^0C. The seed was considered germinated when the radicle was about 1.0 cm long. Germination count was recorded daily and the test was run for 21 days. The data of seed germination were recorded and quantified according to ISTA (1993) procedures.

Seedling variability. Seeds of each clone were sown in polythene bags (20×10 cm) containing soil + FYM + sand in equal proportion as potting media. There were five seedlings of each clone and replicated four times in the experiment. Watering was done daily until the completion of germination, and thereafter weekly till the commencement of rainy season. Weeding was done manually. Seeds were considered germinated when the sprouted plumule had emerged about 1 cm above the soil and germination was recorded accordingly. All seedlings of each clone of the orchard seed were tagged and plant height (cm) and root collar diameter (mm) were measured using ruler

and electronic vernier caliper, respectively, at the age of one year.

Statistical analysis. The data on seed length, seed width, seed weight, germination percentage, seedling height, and root collar diameter for both years were analyzed using ANOVA as per (Sukhatme & Amble 1989). Ranks of clones in terms of seed traits, germination and growth parameters for both the years were analyzed according to Wilcoxon Matched Pairs Signed Rank test (Phanse & Sukhatme 1978). The genotypic and phenotypic components of variance were calculated by pooled data of two years and correlation coefficients of seed characters, germination parameters and seedling growth were calculated using SPSS package- 2010 (Anonymous 2007).

Germination values were calculated as: $GV = MDG \cdot PV$ (Czabator 1962), where *MDG* - mean daily germination calculated as the percentage of seed germination at the end of the test divided by the number of days to the end of the test, *PV* - the peak value, or the maximum quotient derived from all of the cumulative seed germination percentages on any day divided by the number of days to reach this percentages.

The genotypic and phenotypic components of variance were calculated from ANOVA as described by Burton (1952)(Table 1). The environmental variance (EV) is the error variance of ANOVA; the broad sense of heritability was calculated as per Lush (1994). The genetic advance was calculated as per Johnson et al. (1955). Selection differential (*K*) - 2.06 at 5% selection intensity (Cotterill & Dean 1990). The expected genetic gain, in percent of mean, was calculated following (Burton & Devane 1993).

Results

Data on seed length, seed width, 100 seed weight, germination and germination value of seeds from 20 different clones in both years revealed significant differences among clones (Table 2). For the 2007 data, mean seed length varied from 6.21 mm in clone 198 to 7.85 mm in clone 87. The highest value for seed width was recorded 4.44 mm in clone 189 and the lowest 3.45 mm in clone 232. Seed weight varied from 1.11 g in clone 204 and 66 to 1.72 g in clone 189. During 2007 variability was observed in germination percentage, which varied from 71 to 84%. The maximum germination of 84% was recorded in clone 88 and minimum 71% in clone 66. The germination value (*GV*) varied significantly among seeds of different clones and highest *GV* was observed in clone 88 (87.04) which was significantly superior to all other clones, and the same clone seed also exhibited maximum germination percentage. Minimum *GV* was observed in clone 66 (63.04) which also exhibited minimum germi-

Table 1 Genotypic and phenotypic components of variance

Component	Formula
Genotypic variance	$\sigma^2 g = (\sigma^2 c - \sigma^2 e)/r$
Phenotypic variance	$\sigma^2 p = \sigma^2 g + \sigma^2 e$
Genotypic coefficient of variance	$GCV = p\sigma^2 g/Mean \cdot 100$
Phenotypic coefficient of variance	$PCV = p\sigma^2 p/Mean \cdot 100$
Heritability	$H^2 = \sigma^2 g / \sigma^2 p \cdot 100$
Genetic advance	$Gs = K \cdot H^2 \cdot p\sigma^2 p$
Genetic gain	$Gs \cdot 100/ Mean$

Note: $\sigma^2 c$ - clone mean squares, $\sigma^2 e$ - error mean squares, *r* - number of replicates

Table 2 Variability in seed size, weight, germination, germination value of seed collection in 2007 and 2008 from clonal seed orchard of *D. sissoo* (mean ± standard deviation).

Clone	Seed length (mm)		Seed width (mm)		100 seed weight (g)		Germination percent (%)		Germination value (*GV*)	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
12	6.88±0.54	6.89±0.24	3.60±0.13	3.57±0.17	1.39±0.03	1.44±0.10	82	90	82.99	100.00
19	6.75±0.23	6.08±0.23	4.32±0.28	3.58±0.36	1.17±0.05	1.20±0.01	80	90	78.85	100.00
33	6.69±0.28	6.45±0.11	3.87±0.30	3.87±0.27	1.13±0.05	1.06±0.03	82	90	82.99	100.00
40	6.85±0.34	7.23±0.39	3.59±0.04	3.57±0.07	1.12±0.08	1.04±0.06	80	86	78.85	91.20
189	7.29±0.15	7.59±0.29	4.44±0.14	3.97±0.33	1.72±0.08	1.71±0.05	78	85	74.99	89.11
192	6.86±0.40	6.79±0.25	3.53±0.03	3.66±0.17	1.15±0.10	1.04±0.02	81	92	81.00	104.44
198	6.21±0.77	6.34±0.85	3.81±0.42	3.62±0.29	1.21±0.04	1.09±0.09	76	78	71.23	74.99
204	6.43±0.08	6.44±0.22	3.98±0.01	3.90±0.17	1.11±0.10	1.05±0.02	82	93	82.99	106.70
232	6.36±0.52	6.34±0.39	3.45±0.18	3.29±0.28	1.13±0.11	1.07±0.01	80	83	78.85	85.00
242	6.49±0.17	6.57±0.25	3.51±0.22	3.50±0.21	1.30±0.08	1.10±0.07	78	76	74.99	71.23
78	6.48±0.40	6.55±0.42	3.73±0.36	3.91±0.17	1.29±0.01	1.22±0.04	79	95	76.91	111.30
83	7.13±0.10	7.07±0.04	4.10±0.06	4.11±0.09	1.42±0.02	1.39±0.03	72	97	64.00	115.99
85	6.97±0.25	6.33±0.53	4.13±0.50	4.30±0.25	1.24±0.02	1.12±0.07	82	80	82.99	78.85
87	7.85±0.33	8.24±0.23	4.09±0.15	4.07±0.16	1.52±0.08	1.71±0.07	79	90	76.91	100.00
88	7.41±0.15	7.58±0.19	3.91±0.21	4.01±0.30	1.57±0.04	1.72±0.05	84	87	87.04	92.16
90	6.60±0.55	6.56±0.59	3.76±0.37	3.81±0.40	1.21±0.02	1.17±0.02	80	83	78.85	85.00
94	6.34±0.18	6.25±0.13	3.86±0.08	3.73±0.11	1.24±0.03	1.23±0.03	80	93	78.85	106.70
57	7.13±0.62	7.97±0.49	4.00±0.24	4.06±0.20	1.33±0.11	1.31±0.15	76	86	71.23	91.20
61	7.48±0.27	7.78±0.46	4.19±0.23	4.15±0.35	1.20±0.03	1.04±0.10	79	78	76.91	74.99
66	7.22±0.38	7.12±0.35	3.83±0.28	3.92±0.28	1.11±0.09	1.04±0.059	71	66	63.04	53.72
Mean	6.87	6.90	3.88	3.83	1.27	1.23	79.05	85.90	77.22	91.62
SE	0.24	0.24	0.16	0.16	0.04	0.05	1.87	1.45		
CD 0.05	0.48	0.48	0.32	0.31	0.09	0.10	3.68	2.84	-	-

nation percentage. In the year 2008, germination percentage varied from 66% in clone 66 to 97% in clone 83. The *GV* was also highest in clone 83 (115.99). Minimum *GV* was observed in clone 66 (53.72) with minimum germination percentage.

Growth of seedlings raised from seeds of various clones exhibited significant variation in terms of nursery germination, height, and root collar diameter for both the years (Table 3). In first year, the nursery germination varied from 25 % in clone 12 to 70% in clone 198. Seedling height varied from 29.16 cm to 59. 36 cm, tallest in clone 242 and shortest in clone 57. Root collar diameter varied from 3.75 mm to 5.70 mm. The maximum root collar diameter was found in clone 189, 232, 94 and minimum in clone 88. In the second year, the maximum nursery germination was found in clone 94 (75%) and minimum in clone 198, 85, 90 and 66 (20%). Seedling height was greatest in clone 204 (62.16 cm) and least in clone 85 (30.64 cm). The root collar diameter varied from 3.35 mm to 6.60 mm and it was maximal in clone 204 and minimum in clone 85. In a majority of the clones, nursery germination

Table 3 Nursery germination and seedling growth of *D. sissoo* at the age of 12 months in 20 clones seedlings of 2007 and 2008 seed collection (mean ± standard deviation)

Clone	Germination % in nursery		Seedling height (cm)		Root Collar diameter (mm)	
	2007	2008	2007	2008	2007	2008
12	70±1.00	50±1.29	50.28±12.77	44.30±4.41	4.20±0.81	4.38±0.68
19	55±0.57	50±0.57	40.25±6.27	43.38±8.25	4.29±0.63	5.14±0.52
33	45±0.95	50±1.73	42.23±6.65	41.10±4.80	4.52±1.01	4.77±0.45
40	55±1.70	35±0.95	39.19±10.88	59.00±6.70	5.10±1.04	6.16±0.24
189	50±0.95	45±1.70	52.29±8.36	47.96±6.80	5.70±0.85	5.14±0.90
192	35±0.57	40±1.15	46.22±7.57	47.40±3.87	4.94±0.97	5.53±0.62
198	25±0.95	20±1.15	47.26±11.14	47.02±9.36	5.20±0.76	5.24±0.80
204	40±1.5	35±0.95	48.24±12.66	62.16±8.47	4.95±0.99	6.60±0.36
232	55±0.81	45±2.21	56.27±8.92	60.42±7.76	5.70±1.00	6.52±0.12
242	40±0.95	30±1.91	59.36±7.59	53.02±6.13	5.55±0.50	5.05±0.69
78	50±1.4	45±0.95	56.28±11.22	51.10±12.20	4.50±1.41	4.68±0.48
83	60±1.29	65±0.5	49.24±11.29	54.40±11.79	4.17±0.79	4.54±0.55
85	35±0.81	20±0.81	58.29±12.42	30.64±3.70	4.40±0.85	3.35±0.55
87	50±0.95	70±0.57	38.18±6.47	37.66±7.23	4.00±1.03	3.98±0.83
88	55±0.57	35±0.95	40.18±9.94	38.28±7.78	3.75±0.63	4.92±0.49
90	35±0.95	20±1.15	40.23±6.17	54.28±9.25	5.00±0.96	5.66±0.55
94	65±0.5	75±0.5	49.24±11.10	30.70±4.13	5.70±0.52	4.33±0.81
57	35±0.95	40±1.41	29.16±5.92	43.58±8.03	3.96±0.98	4.54±0.50
61	35±0.5	30±1.73	46.21±14.13	36.14±6.68	3.94±1.05	4.27±0.98
66	30±0.95	20±0.81	30.21±5.23	49.62±3.81	3.80±0.75	4.17±0.33
Mean	46	41	45.94	46.60	4.66	4.94
SE	0.67	0.68	6.80	4.67	0.59	0.40
CD 0.05	1.31	1.35	13.34	9.16	1.15	0.78

was greatest in the seed of 2007 as compared to 2008 but vice versa in respect of growth parameters.

Correlation coefficients for seed length, seed width, seed weight, germination and germination value in laboratory, germination in nursery, seedling height and collar diameter are presented in table 4 and table 5 for the years 2007 and 2008, respectively. In both years seed length was positively correlated to seed width (0.507, 0.491) and 100 seed weight (0.556, 0.578). Seed weight of the 2008 seed collection was positively correlated to nursery germination (0.447). Seedling height in both the years showed positive correlation with root collar diameter. The 2008 nursery germination showed a positive correlation with germination and germination value in the laboratory.

The estimates of phenotypic and genotypic variances as well as the coefficient of phenotypic and genotypic variation of different characters across the years are shown in table 6. The relative amount of variation in different characters can be correlated by comparing the coefficient of phenotypic and genotypic variation of each character. Heritability in seed characters was found highest in seed weight 0.84 followed by seed length 0.58 and seed width 0.42. Expected genetic gain was highest in seed weight 29.72 and lowest in seed length 7.10. Heritability in nursery parameters was found highest in root collar diameter 0.34 followed by seedling height 0.23 with expected genetic gain of 14.84 and 12.30, respectively.

Table 4 Correlation coefficient of seed size, weight, germination, germination value and seedling growth of 2007 seed collection from clonal seed orchard of *D. sissoo*

Characters	Seed length	Seed width	100 seed weight	Germination in lab	Germination value	Germination in nursery	Seedling height	Root collar diameter
Seed length	1	.507*	.556*	-.138	-.127	.026	-.431	-.656**
Seed width		1	.433	-.133	-.138	-.034	-.171	-.315
100 seed weight			1	-.010	-.018	.344	.086	-.112
Germination in lab				1	.999**	.267	.269	.136
Germination value (GV)					1	.263	.254	.111
Germination in nursery						1	.209	.075
Seedling height							1	.543*
Root collar diameter								1

Note: * - correlation is significant at 0.05 level (2-tailed), ** - correlation is significant at 0.01 level (2-tailed)

Table 5 Correlation coefficient of seed size, weight, germination, germination value and seedling growth of 2008 seed collection from clonal seed orchard of *D. sissoo*

Characters	Seed length	Seed width	100 seed weight	Germination in lab	Germination value	Germination in nursery	Seedling height	Root collar diameter
Seed length	1	.491*	.578**	-.077	-.086	.125	-.181	-.283
Seed width		1	.327	.032	.037	-.026	-.477*	-.627**
100 seed weight			1	.304	.288	.447*	-.289	-.295
Germination in lab				1	.998**	.718**	.020	.149
Germination value					1	.728**	.033	.135
Germination in nursery						1	-.213	-.155
Seedling height							1	.799**
Root collar diameter								1

Note: * - correlation is significant at 0.05 level (2-tailed), ** - correlation is significant at 0.01 level (2-tailed)

The clones having maximum and minimum values for specific seed, germination and growth characters also exhibited first or last rank, respectively, as shown by Wilcoxon Matched Pairs Signed Ranks (Table 7). There was no trend or relationship between seed characters, germination & germination value in laboratory, nursery germination and growth parameters among different clones in both years. Data subjected to Wilcoxon matched pairs signed ranks test also revealed significant differences between clones in different years. The ranks differed significantly between the years for seed length, seed width, 100 seed weight, germination & germination value, nursery germination and growth parameters.

There was no consistency in the ranks of seed characters, germination and seedling growth parameters studied in the two years.

Discussion

In the present study, the seeds of various clones of CSO exhibited significant variability in seed

Table 6 Variance, coefficient of variation, heritability and genetic gain in *D. sissoo* across the years

Characters	Phenotypic variance	Genotypic variance	*GCV*	*PCV*	*EV*	Heritability	*Gs*	G. Gain
Seed length	0.41	0.24	7.11	9.29	0.16	0.58	0.48	7.10
Seed width	0.12	0.05	5.90	9.04	0.07	0.42	0.30	7.82
Seed weight	0.046	0.039	15.67	17.02	0.007	0.84	0.37	29.72
Seedling height	134.13	32.02	12.22	25.03	102.11	0.23	5.69	12.30
Root collar diameter	1.02	0.35	12.29	20.99	0.66	0.34	0.71	14.84

Note: *GCV* - genotypic coefficient of variance, *PCV* - phenotypic coefficient of variance, *EV* - environmental variance *Gs* - genetic advance, G. Gain - genetic gain

Table 7 Ranks of seed size, weight, germination, germination value and growth parameters of seed collection in 2007 and 2008 from clonal seed orchard of *D. sissoo*

Clone	Seed length (mm)		Seed width (mm)		100 seed weight (g)		Germination %		Germination value (*GV*)		Germination % in nursery		Seedling height (cm)		Root collar diameter (mm)	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
12	8	9	16	17	5	3	2	5	2	5	1	4	6	12	13	13
19	11	19	2	16	12	8	4	5	4	5	4	4	13	14	11	7
33	12	14	10	11	14	14	2	5	2	5	6	4	12	15	8	10
40	10	6	17	18	15	16	4	7	4	7	4	7	16	3	4	3
189	4	4	1	7	1	2	6	8	6	8	5	5	5	9	1	7
192	9	10	18	14	13	16	3	4	3	4	8	6	10	10	7	5
198	19	16	13	15	10	12	7	11	7	11	10	9	9	11	3	6
204	16	15	8	10	16	15	2	3	2	3	7	7	8	1	6	1
232	17	16	20	20	14	13	4	9	4	9	4	5	4	2	1	2
242	14	11	19	19	7	11	6	12	6	12	7	8	1	6	2	8
78	15	13	15	9	8	7	5	2	5	2	5	5	3	7	9	11
83	6	8	5	3	4	4	8	1	8	1	3	3	7	4	14	12
85	7	17	4	1	9	10	2	10	2	10	8	9	2	20	10	18
87	1	1	6	4	3	2	5	5	5	5	5	2	17	17	15	17
88	3	5	9	6	2	1	1	6	1	6	4	7	15	16	19	9
90	13	12	14	12	10	9	4	9	4	9	8	9	14	5	5	4
94	18	18	11	13	9	6	4	3	4	3	2	1	7	19	1	14
57	6	2	7	5	6	5	7	7	7	7	8	6	19	13	16	12
61	2	3	3	2	11	16	5	11	5	11	8	8	11	18	17	15
66	5	7	12	8	16	16	9	13	9	13	9	9	18	8	18	16
T obs.	79.50		105		79		144		144		48.50		93		101	

size, seed weight, germination and germination value in laboratory, nursery germination and seedling growth. Significant variability in seed characters and seedling growth was also observed by Annapurna et al. (2005) in seed from clonal seed orchard of *Santalum album* and in seeds of the selected plus trees (Bagchi & Sharma 1989) of the same species in southern India. Different seed sources of *D. sissoo* also exhibited such significant variations in seed traits (Singh & Pokhriyal 2001).

The results of the study reveled that the genotype had a greater influence on germination and seed size had no relationship with germination percentage, germination value or seedling growth. However, seed weight may have had some influence on nursery germination as revealed by correlations in table 3 & 4. Similarly El-Kassaby et al. (1992) observed no relationship in seed size (weight) on germination capacity and speed in *Pseudotsuga menziesii* seeds of 19 seed orchard trees. Indira et al. (2000) found that fruit size (except for very small seeds) did not have influence seed germination, seedling survival or seedling growth in *Tectona grandis.* Toon et al. (1991) revealed that seed size did influence on seedling growth (height) at initial stage of nursery growth but gradually became non significant in 12 families of *Pinus caribaea*. They emphasized that culling at the nursery stage should not be based on seed size or speed of germination. The seed characters; seed length, seed width and seed weight were significantly and positively correlated to each other in this study. Similar positive correlation of seed characters were also observed in different seed sources of *D. sissoo* (Singh & Pokhriyal 2001, Gera et al. 2000), in different plus trees of *Santalum album* (Bagchi & Sharma 1989) and in *Leucaena leucocephala* (Hooda & Bahadur 1993).

The genetic parameters for seed traits and seedling growth also showed a wide range of variation in the orchard clones across the years. Heritability values were found to be over 50 percent for seed weight and seed length. However, only seed weight showed high heritability value coupled with more genetic gain, which indicate the presence of good amount of heritable additive component and is under strong genetic control. The results of the present study also showed the fact that the high heritability did not always mean high genetic gain. It happens due to non- additive gene effects. The characters like seed weight with high genetic gain together with high heritability indicates that high heritability obtained in this character is due to additive gene effects (Misra & Saini 1988).

The seed characters expressed in terms of germination & germination value in laboratory, nursery germination & seedling growth differed over the years during the study period indicating genotype environment interaction. This might be due to the difference in the genetic make up of various clones and environmental factors during seed development and preconditioning.

Conclusion

The seeds of various clones in the orchard exhibited significant variability in size, weight, germination and growth characters. Seed length, seed width and seed weight were positively correlated to each other but seed size had no effect on germination percent and germination value under laboratory conditions, however, seed weight has positive correlation with nursery germination in second year of study. The estimates of variability with regard to genetic parameters for seed traits in this study also showed a wide range of variation. The variation among clones is commonly used as an estimate of total genetic variation and to calculate the degree of genetic control for a particular trait.

The results of the study suggest that the genotype or clone had more influence on germination and seed size had no relationship with germination and seedling growth in nursery.

Seed size or weight should not be used as criteria for grading of bulked seed lots of different clones, as it can narrow down genetic diversity by rejecting small size seeds which are shown to perform as well as those larger. Similarly, Hawkins (1998) opinioned that seed size and its correlation to germination and using them as grading criteria can narrow down seed source genetic diversity. Grading of individual clones seed may be helpful in elimination of extremes of seed (too small and too large) sizes to obtain comparatively uniform seedlings. Bulking of seeds without knowing individual tree/clone seed behaviour can be disadvantageous in growing trees and production of quality planting stock to be used in plantation programmes.

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