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Estimation of genetic variability, heritability, genetic gain and correlation studies on seed and seedling traits in *Grewia Optiva* Drummond

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Abstract
The present investigations aimed to evaluate various seed and seedling characters of 35 open pollinated progenies of *Grewia optiva* from Himachal Pradesh, for which significant variations were observed. Progeny SI-3 (Deothal) excelled in almost all traits followed by SO-6 (Amberkothi), HA-1 **(**Bharari**)**, SI-5 (Deyoltikkeri) and CH-5 (Rajpura). Seed weight was highly correlated with germination capacity (r_g=0.980 and r_p=0.642) and germination energy (r_g=0.967 and r_p= 0.551). Variability estimates were highly significant (P<0.01) and genetic traits exhibited high variability for these traits. Higher variability estimates were aided by high heritability and genetic gains, which implied that the variations noticed in such traits, were genetically controlled in *Grewia optiva* and good amount of heritable additive genetic component can be exploited for population improvement of the species through selection and breeding programmes.

Keywords: Genetic gain, *Grewia optiva***,** Heritability, Seedlings, Variability

Introduction
Grewia optiva Drummond (Family Tiliaceae), locally called Beul or Bhimal, is a multipurpose species with a variety of economic and environmental values. It occurs between 30°22′44″ N to 33°12′40″ N latitude and 75°45′55″ E to 79°04′20″ E longitude along with *Bombax ceiba, Celtis australis, Acacia* species*, Toona ciliata, Acer oblongum* and *Bauhinia variegata*. The species occurs up to an elevation of 2000 m above sea level in western Himalayas. It is a moderate sized tree with a spreading crown, reaching height upto 12 m with clear bole of 3-4 m and girth 80 cm, when fully grown. It grows well on sandy loam soils with adequate moisture. Flowers 1-8, either solitary or axillary and are insect pollinated. The fruit is fleshy drupe, 2-4 lobed, olive green when immature and black when ripe, and edible. It is a frost hardy, drought hardy, strong light demander, coppices and pollards well, and coppice shoots have rapid growth. The species is susceptible to fire and young foliage is readily browsed by livestock.

There is a growing interest to conserve forest genetic resources in general and setting of improvement programmes for meeting the heavy demand of fodder and fuel in the western Himalayan states in India. Any forest tree improvement programme starts with the study of existing natural variation on the entire range of species distribution and delineation of populations capable of providing best adapted and productive trees (Suri, 1984). These variations evolved from complex interactions between plant attributes such as life form, floral architecture, modes of reproduction, mating system and ecological and environmental factors that may influence pollination events, population size and isolation (Coates and Byrne, 2005). Breeding system of trees, distribution of their genetic variability and the evolutionary forces that have shaped them, is a preliminary requisite for any tree improvement program (Muona, 1990). Since *Grewia optiva* is insect pollinated, it probably reduces gene flow and thus enhance genetic differentiation between populations, consequently leading to genetic differentiation in the species. The individual trees in the sample population will maintain their genetic integrity during their lifespan. Individual trees can be progeny tested and used for breeding, and superior phenotypic variants can be vegetatively propagated for establishment of clonal seed orchard and conservation.

Variation in seed and seedling traits and its significance for seed source has been studied in a number of tree species. To achieve higher productivity of quality fodder from the trees, it is important to study the genetic variability among different seed sources for fodder and seed/ seedling traits, and delineate the ones with higher potential for mass multiplication and plantation at the farmer's fields. Use of the proper seed sources is must for achieving the most successful tree improvement programme. The loss from using the wrong seed can be great and even disastrous. Taking care of the same in *Grewia optiva*, thirty five progenies of *Grewia optiva* were collected from Himachal Pradesh and established as a seed orchard at the Nauni Campus of Dr. Y.S. Parmar University of Horticulture and Forestry during July 2000 at a spacing of 2m x 2m in three blocks. Evaluation of this orchard for various seed and seedling traits is an important tool to evaluate the orchard for long term breeding programme to achieve significant gains from the population, for which the present investigations were conducted. Here we quantified variability for seed size, seed weight, germination and seedling growth characteristics for production of better quality planting stock in higher quantity to suffice the current demand of quality fodder.

Materials and Methods

Experimental materials and site: Out of sixty progenies in the aforesaid seed orchard, only thirty five progenies were in seed bearing stage in 2008. These belonged to various districts of Himachal Pradesh, *viz*., Bilaspur, Chamba, Hamirpur, Kangra, Mandi, Shimla, Sirmour and Solan (Fig 1; Table 1) and evaluated in the experimental farm of the department of Tree Improvement and Genetic Resources of the University main campus. The experimental site is located at an altitude of 1250 m above mean sea level with geographical location 30^0 51' N latitude and $76^0$11' E longitude. The region has subtropical climate, with moderately hot summers and cold winters. Maximum temperature often exceeds 35^0C in May-June and minimum temperature drops to as low as 0^0C in January. Relative humidity ranges from 40-85%, maximum during monsoon season. Frost occurrence in winter is quiet common. Mean annual rainfall of the site is 1000-1300 mm, majorly monsoon rainfall. Winter rains due to western disturbances are common. Soil has sandy loam texture with pH 6.5. Available nitrogen, phosphorus, potassium and calcium were 273.62 kg/ha, 35.08 kg/ha, 181.23 kg/ha and 522.70 kg/ha, respectively in the soil.

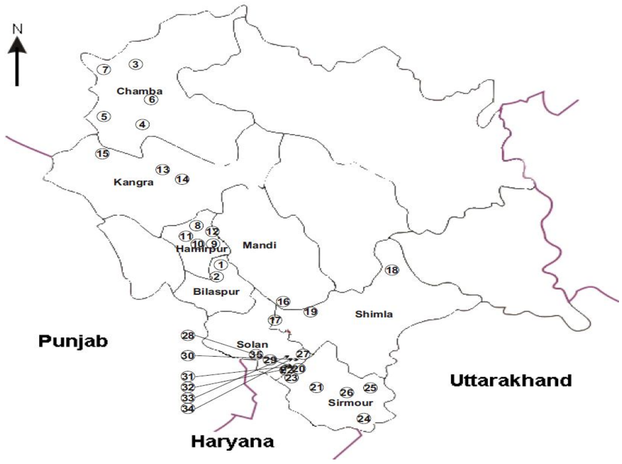

Fig 1. Map showing the source of different progenies undertaken for variability studies for seed and seedling traits of *Grewia optiva* in Himachal Pradesh, India

Table 1. Description of different progenies undertaken for variability studies for seed and seedling traits of *Grewia optiva*

District	Progeny	Code	No.	District	Progeny	Code
Bilaspur	Kuthira	BI-4	19	Shimla	Sunni	SH-5
	Talvano	BI-5	20	Sirmour	Deothal	SI-3
Chamba	Chanad	CH-1	21		Deyoltikkeri	SI-5
	Shahu	CH-2	22		Kalaghat	SI-6
	Balu	CH-3	23		Nandel	SI-7
	Rajpura	CH-5	24		Seenaghat	SI-10
	Saru	CH-6	25		Sarpadol	SI-13
Hamirpur	Bharari	HA-1	26		Madhobag	SI-15
	Patta Balakhar	HA-2	27		Gaura	SO-1
	Bassi	HA-3	28		Nauni	SO-2
	Hamirpur Kanal	HA-4	29	Solan	Badhlech	SO-5
	Ghahar	HA-5	30		Amberkothi	SO-6
Kangra	Dharamshala	KA-1	31		Kailar	SO-8
	Bhalun	KA-2	32		Deothi	SO-9
	Varal	KA-3	33		Jaunaji	SO-10
Mandi	Bachhwan	MA-2	34		Mishuar	SO-11
Shimla	Daugi	SH-1	35		Kasholi	SO-12
	Jeury	SH-3				

Seed collection was done in November 2008, and seed was de-pulped, dried, packed, labeled and stored in the laboratory of Department of Tree Improvement and Genetic Resources. In order to examine the variability in seed size traits, seed length, seed width, and 100-seed weight were determined. From a bulk of seeds from each progeny, 100 seeds were randomly sampled and used for measuring each morpho-metric trait. Seed length and seed width were measured on individual seeds using a digital micro-caliper while seed weight was taken for each progeny for one hundred seeds using a sensitive electronic balance prior to sowing.

Experimental design: Seed sowing was done on 15th May, 2009 under three replications for each progeny with 10 seeds sown per replication, after pretreatment with hot water for 24 hours. Seeds were sown in poly-bags containing potting mixture of sand, clay and FYM (2:1:1). The sown seeds were watered regularly till seedlings achieved good vigour. Weeding was done regularly to protect the juvenile seedlings. Germination capacity, germination energy, seedling height, collar diameter, number of leaves per seedling, root-shoot ratio and leaf area were recorded for the different progenies evaluated for variability studies. Seedling collar diameter was measured by Digital Vernier Caliper. Germination capacity was calculated from the number of seeds germinated and germination energy was calculated as the number of seeds germinated up to the time of peak germination from the total number of seeds sown, following standard procedures as per Schmidt (2000). Germination capacity and germination energy was calculated after 28 days and 15 days, respectively from the date of seed sowing during the investigations, and the data was recorded daily for twenty-eight days. Leaf area was measured by leaf area meter, on lower, middle and upper leaves randomly from the seedling. Root-shoot ratio of seedlings was calculated by measuring the length of roots and shoots of the seedlings during the first week of December, 2009.

Statistical analysis: The general linear model (GLM) procedure of SPSS-16 was employed for analysis of variance (ANOVA). Prior to ANOVA, the percentage data set was square root transformed to meet the normality assumption for the analysis of vari-ance (Zar 1996). ANOVA for each seed and seedling-related trait was performed based on the following linear model:

$y_{ij} = \mu + P_i + e_{ij}$

where y_{ij} is seed or seedling trait of *j*th replication of the *i*th progeny, μ is the overall mean, P_i the effect due to *i*th progeny (i = 1...35) and e_{ij} is the error.

Phenotypic (Vp) and Genotypic (Vg) variances were calculated as Vp =MSG/r; Vg= (MSG-MSE)/r and Ve= MSE/r, where, MSG, MSE and r are the mean squares of progenies, mean squares of error and number of replications, respectively.

To compare the variation among traits, phenotypic (PCV) and genotypic (GCV) coefficients of variation were computed as (Burton and DeVane, 1953).

PCV (%) = $\sqrt{(Vp/\bar{x}}$ × 100

GCV (%) = $\sqrt{(Vg/\bar{x}}$ × 100

where, Vp and Vg are phenotypic and genotypic variances respectively and 'x' the population mean of the character. Broad sense heritability (h^2B) was calculated as suggested by Burton and DeVane, (1953) and Johnson *et al*. (1955)

h^2B = (Vg/Vp) x 100

where, h^2B, Vp and Vg are broad sense heritability, phenotypic variance and genotypic variances, respectively.

Genetic advance (GA) expected and GA as per cent of the mean (Genetic gain) assuming selection of the superior 5% of the progenies were estimated in accordance with Johnson *et al*. (1955) as:

Genetic advance = (Vg/Vp) $\sqrt{Vp}$ × K

Genetic gain (%) = (Genetic advance / x) × 100

where, K selection differential at 5% selection intensity, K = 2.06 at 5 per cent selection intensity.

Phenotypic (r_p) and genotypic (r_g) correlations were further computed to examine inter character relationships among seed and seedling traits following Varghese *et al*. (1976) as:

Phenotypic correlation coefficient between character x and y,

$r_{(xy)}p = V_p(xy) / \sqrt{Vx(p) \times Vy(p)}$

Genotypic correlation coefficient between character x and y,

$r_{(xy)}g = V_g(xy) / \sqrt{Vx(g) \times Vy(g)}$

where, $V_p(xy)$ and $V_g(xy)$ are the phenotypic and genotypic variance between x and y, respectively. The significance of correlation coefficients were tested against 'r' values at (n-2) degree of freedom.

Results and Discussion

Variability studies: It was found that all these traits varied significantly amongst the different progenies. The highest values of germination capacity (65.33%) were observed for the progenies CH-5, CH-6 and SI-3 and lowest for SO-10 (37.33%) (Table 2). Germination energy was found maximum in the progeny SO-6 (46.67%) while the maximum 100 seed weight was recorded in progeny SI-3 (13.93 g). Maximum seed length (7.20 mm) and seed width (5.75 mm) were found in the progeny KA-3. Maximum height was observed with progeny S0-8 (72.25 cm) while the maximum value of basal diameter of the seedlings was recorded for SI-3 (7.34 mm). Maximum root-shoot ratio was observed for SI-6 and KA-2 (0.55), while as SI-3 excelled all progenies for average number of leaves (75.33). Maximum leaf area was also achieved in the progeny SI-3 (58.83 cm^2).

Table 2. Variation in seed and seedling traits among the different progenies of *Grewia optiva*

Code	Germination capacity (%)	Germination energy (%)	100 seed weight (g)	Seed length (mm)	Seed width (mm)	Seedling height (cm)	Basal diameter (mm)	Root shoot ratio	Number of leaves	Leaf area (cm^2)
BI-4	48.00 (43.85)	33.33 (35.23)	9.52	5.78	5.46	46.83	4.34	0.48	50.00	32.31
BI-5	52.00 (46.10)	38.67 (36.82)	10.84	6.08	5.40	47.17	4.34	0.51	57.00	30.48
CH-1	54.67 (47.71)	34.67 (36.06)	9.99	5.86	5.37	63.17	5.51	0.48	67.33	41.10
CH-2	42.67 (40.75)	22.67 (28.29)	7.07	5.62	5.20	44.33	3.82	0.42	43.67	37.66
CH-3	60.00 (50.78)	37.33 (37.62)	10.12	6.00	4.49	69.93	6.83	0.47	69.33	47.93
CH-5	65.33 (54.02)	41.33 (39.98)	11.33	6.60	5.11	69.73	6.58	0.47	71.67	32.13
CH-6	65.33 (53.98)	37.33 (37.62)	11.88	5.62	4.39	63.33	6.32	0.47	61.00	26.93
HA-1	64.00 (53.29)	36.00 (36.81)	12.44	6.56	5.64.	51.33	4.45	0.52	52.33	34.76
HA-2	58.67 (50.14)	37.33 (37.47)	11.28	6.29	5.38	68.10	6.72	0.48	66.67	49.07
HA-3	48.00 (43.85)	32.00 (34. 42)	9.78	5.91	5.61	52.70	4.63	0.50	47.00	40.37
HA-4	41.33 (40.00)	29.33 (32.72)	9.61	5.86	4.92	40.87	3.61	0.49	46.00	35.29
HA-5	54.67 (47.71)	34.67 (35.53)	11.69	6.19	5.22	58.33	5.13	0.43	60.00	32.27
KA-1	64.00 (53.29)	37.33 (37.55)	11.61	6.23	5.42	68.77	6.32	0.42	71.33	42.73
KA-2	52.00 (46.28)	37.33 (37.45)	10.00	6.40	5.28	59.30	4.90	0.55	59.67	33.07
KA-3	54.67 (47.71)	34.67 (35.92)	8.19	7.20	5.75	72.03	6.00	0.44	61.33	41.83
MA-2	45.33 (42.31)	33.33 (35.15)	9.06	5.53	5.19	51.17	4.69	0.53	45.33	36.76
SH-1	62.67 (52.55)	42.67 (40.76)	13.75	6.09	5.00	66.87	5.92	0.43	65.33	35.61
SH-3	58.67 (50.01)	41.33 (39.95)	9.60	5.82	4.67	69.40	6.53	0.45	67.00	28.64
SH-5	45.33 (42.18)	29.33 (32.44)	9.23	5.62	4.16	58.53	5.08	0.53	54.33	31.19
SI-3	65.33 (53.94)	44.00 (41.55)	13.93	6.72	5.03	68.67	7.34	0.50	75.33	53.83
SI-5	61.33 (51.59)	44.00 (41.52)	11.82	6.62	5.48	66.84	6.24	0.50	74.33	39.60
SI-6	54.67 (47.69)	34.67 (35.92)	9.55	5.92	5.17	58.53	4.78	0.55	65.67	43.50
SI-7	54.67 (47.71)	33.33 (35.21)	10.90	6.33	5.11	63.97	5.82	0.48	70.00	38.37
SI-10	53.33 (46.91)	40.00 (39.22)	11.00	6.45	5.15	49.83	4.15	0.48	52.33	42.41
SI-13	42.67 (40.78)	26.67 (31.04)	7.83	5.51	4.14	43.50	3.88	0.46	44.67	27.10
SI-15	41.33 (39.99)	29.33 (32.63)	7.62	6.26	3.90	40.57	3.86	0.51	43.33	41.16
SO-1	49.33 (44.61)	34.67 (35.98)	9.59	6.11	4.91	57.03	4.44	0.45	63.67	35.47
SO-2	57.33 (49.29)	42.67 (40.76)	12.01	6.42	5.05	57.42	5.30	0.43	58.00	40.75
SO-5	57.33 (49.24)	32.00 (34.42)	11.60	6.37	5.45	67.23	5.72	0.44	70.00	33.36
SO-6	62.67 (52.24)	46.67 (43.05)	12.69	6.48	5.57	62.93	5.21	0.46	68.00	44.17
SO-8	56.00 (48.45)	32.00 (34.36)	11.14	6.37	5.30	72.25	5.87	0.49	71.67	42.10
SO-9	40.00 (39.22)	22.67 (28.29)	9.10	6.05	4.60	39.73	3.56	0.42	38.00	42.77
SO-10	37.33 (37.64)	17.33 (24.39)	9.38	5.51	5.17	50.17	4.23	0.48	51.67	32.62
SO-11	57.33 (49.24)	38.67 (38.43)	10.90	6.57	5.07	62.23	6.16	0.43	68.00	36.22
SO-12	53.33 (46.91)	36.00 (36.85)	10.01	6.03	5.12	41.50	3.76	0.41	42.67	32.31
Mean	53.75 (47.20)	35.16 (36.09)	10.46	6.14	5.08	57.84	5.20	0.47	59.25	37.60
CD (0.05)	9.93	9.13	0.876	0.398	0.343	10.09	0.7193	0.043	10.05	6.65

Values in parenthesis are square root transformed values

Critical appraisal of Table 3 showed that number of leaves in seedlings had the widest range (38.0-75.33; mean 59.25) followed by seedling height (39.73-72.25 cm, mean 57.84 cm). Minimum range was shown by root-shoot ratio (0.41-0.55, mean 0.47). Though the maximum standard deviation was found in number of leaves in the seedlings (10.76), but the minimum standard deviation was found in root-shoot ratio (0.04). The highest and the lowest values for the coefficient of variation were observed in basal diameter of seedlings (20.38%) and seed length (6.35%), respectively.

Variation in nature is an evolutionary product and serves as a base for population improvement. Since the seeds in the progenies were collected from trees of same age and crown exposure, therefore, the variation observed in the seed characters might be attributed to the genetically variable populations as a result of adaptation to diverse environment throughout their distribution. Variation among the individual trees in a population with respect to seed dimensions (length, width and thickness) and weight were earlier reported in *Pinus strobus* (Demeritt and Hocker, 1974), *Acacia albida* (Sneizko and Stewart, 1989), *Cordia africana* (Loha *et al*., 2006) and *Calophyllum inophyllum* (Hathurusingha *et al.,* 2011). Seed size (length, width and thickness) and weight have controlling influence on seed germination (Dunlap and Barnett, 1983); collar diameter and leaves per plant in *Santalum album* seedlings (Veerendra and Sharma, 1990). Pathak *et al.* (1984) in *Leuceana leucocephala,* Sehgal and Jaswal (1996) in *Grewia optiva*; Singh and Saxena (2009) in *Jatropha curcas* and Divakaraa *et al.* (2010) *in Pongamia pinnata* also confirmed the same.

Generally, larger seeds germinate faster and more completely than the smaller ones due to more endosperm nutrient pool (Kandya, 1978). Hence among the progenies, variation in germination might be ascribed to the significant differences observed in seed dimensions and weight. Our findings also revealed such correlations, as discussed under the association analysis heading. Seed germination, seedling and growth characteristics are interdependent processes and are governed by the genetic set up, environment and seed characters (Pathak *et al*., 1984). Since the seedlings of all the progenies were raised under similar nursery conditions, therefore, variation among the progenies in growth characters might be attributed to genetic differences and the variation observed in seed traits. Growth traits had good positive relationships with seed size and weight (Chauhan and Raina, 1980; Suri, 1984). Hence the variation in the seed traits were well reflected in the form of significant variation among the seed sources in all the growth traits and the correlations may be used for indirect selection in further breeding and conservation programmes.

Variability estimates and genetic parameters for different characters were estimated and expressed in terms of range, mean, standard deviation, coefficient of variation, along with coefficients of variability (phenotypic and genotypic) and it revealed significant dispersion among the progenies for all the traits. These phenotypic differences might be partly due to the genotypic factors and partly due to the environmental effects. The relative magnitude of these components determines the genetic properties for any particular species (Jain, 1982). Such species exhibiting a wide range of variability offers ample scope for undertaking screening for the desired traits and plays a pivotal role in breeding and conservation programmes of the species.

Genetic analysis: The genetic parameters for seed and seedling traits were estimated (Table 3). The estimates

Table 3. Estimates of components of variation for seed and seedling traits in *Grewia optiva*

Trait	Range	Mean	SE(±)	S.D.	C.V	GCV	PCV	h^2B (%)	GA (%)	GG (%)
Germination capacity (%)	37.33-65.33	53.75	5.067	8.06	15.00	11.67	20.07	33.81	7.51	13.97
Germination energy (%)	17.33-45.33	35.16	4.660	6.41	18.23	12.55	26.25	22.92	4.33	12.32
100 Seeds weight (g)	7.07-13.93	10.46	0.447	1.61	15.39	14.79	16.54	80.00	2.85	27.25
Seed length (mm)	5.51-7.2	6.14	0.203	0.39	6.35	5.51	7.94	48.25	0.48	7.82
Seed width (mm)	3.9-5.75	5.08	0.175	0.44	8.66	8.03	10.00	64.55	0.68	13.39
Seedling height (cm)	39.73-72.25	57.84	5.150	10.30	17.81	15.43	21.82	50.00	13.00	22.48
Basal diameter (mm)	3.56-7.34	5.20	0.367	1.06	20.38	19.16	22.73	71.10	1.73	33.27
Root-shoot ratio	0.41-0.55	0.47	0.022	0.04	8.51	6.67	10.46	40.70	0.04	8.51
No. of leaves	38.0-75.3	59.25	5.130	10.76	18.16	15.97	21.90	53.10	14.2	23.97
Leaf area(cm^2)	26.9-53.8	37.60	3.394	6.28	16.70	14.04	21.02	44.60	7.27	19.34

(*) Standard error (SE), Standard Deviation (SD), Coefficient of variation (C.V), Genotypic coefficient of variation (GCV), Phenotypic coefficient of variation (PCV), Heritability (h^2B), genetic advance (GA) and genetic gain (GG)

Table 4. Genotypic and phenotypic correlation for seed and seedling traits among different progenies of *Grewia optiva*

Traits		Germination capacity	Germination energy	100 seed weight	Seed length	Seed width	Seedling height	Basal diameter	Root shoot ratio	Number of leaves
Germination energy	G	0.866**								
	P	0.821**								
100 seed weight	G	0.980**	0.967**							
	P	0.642*	0.551							
Seed length	G	0.737*	0.880**	0.501						
	P	0.394	0.339	0.376						
Seedling height	G	0.388	0.314	0.348	0.450					
	P	0.257	0.242	0.311	0.418					
Seedling height	G	0.824**	0.596	0.597	0.593	0.319				
	P	0.707*	0.550	0.434	0.348	0.205				
Basal diameter	G	-0.172	0.048	-0.098	-0.118	-0.001	-0.067			
	P	-0.066	-0.013	-0.042	-0.059	-0.063	-0.016			
Root shoot ratio	G	0.880**	0.783**	0.729*	-0.672*	0.382	0.950**	-0.004		
	P	0.701*	0.542	0.486	0.311	0.166	0.884**	0.006		
Number of leaves	G	0.900**	0.727*	0.622	0.529	0.146	0.974**	-0.079	0.913**	
	P	0.700*	0.543	0.478	0.300	0.107	0.888**	-0.032	0.832**	
Leaf area	G	0.259	0.365	0.303	0.655	0.263	0.367	0.145	0.378	0.380
	P	0.196	0.142	0.134	0.245	0.165	0.218	0.001	0.231	0.268

*(P<0.05); **(P<0.01)

of PCV were higher than those of GCV for all the traits. Genotypic coefficient of variation was highest for the basal diameter of seedlings (19.16%), while the phenotypic coefficient of variation was exhibited maximum (26.25%) by germination energy. Seed weight showed highest broad sense heritability percentage (80.00%), while the minimum was noted for germination energy (22.92%). Genetic advance was maximum (14.20) for number of leaves per seedling, whereas, the minimum was observed in root-shoot ratio (0.04). Genetic gain was observed maximum in the basal diameter of seedlings (33.27%) whereas the minimum was observed for seed length (7.82%).

Traits which exhibited high heritability followed by high genetic gain could be exploited quiet well in advanced breeding programmes through selection (Gupta *et al*., 2012). Seed size was found highly heritable among seed and seedling characters under investigation. The genotypic coefficient of variation was lower than the phenotypic values, probably due to modifying effect of the environment on the strong inherent association of characters at the genetic level, and reported so by Kaushik *et al*. (2011) in *Pongamia pinnata.* Growth traits in the nursery exhibited varying values with a wide range and high coefficients of variation, indicating thereby the existence of a large range of variation in these traits. Seed size was found highly heritable among seed and seedling characters under investigation. Seedling height could also be used as an early testing trait. This was observed by Ky-Dembele *et al*. (2014) in *Khaya senegalensis*. Seedlings having small shoot dry weight in greenhouse tended to have average or below average volume growth in field tests. This method may also be applied in *Grewia optiva* progenies to eliminate slow growing seedlings.

Association analysis: Genotypic and phenotypic correlations for seed and seedling traits among different progenies of *Grewia optiva* were worked out (Table 4). Germination capacity was highly correlated with germination energy both at genotypic and phenotypic levels (0.8666 and 0.821, respectively). Similarly highly significant correlation was noticed between root-shoot ratio and seedling height (0.950 and 0.884, respectively) and with number of leaves (0.913 and 0.832, respectively). Number of leaves also showed such correlations with seedling height (0.974 and 0.888, respectively). At genotypic level, germination capacity was noted of having highly significant positive correlation with 100 seed weight (0.980), seedling height (0.824), root-shoot ratio (0.880) and number of leaves (0.900) while at phenotypic level, only significant positive correlation was found. Germination energy exhibited highly significant positive correlation with 100 seed weight (0.0.967), seed length (0.880) and root shoot ratio (0.783) at genotypic level. Number of leaves had only significant positive correlation at genotypic level with germination energy (0.727).

Many significant and positive and negative correlations were observed in the present studies among the various seed and seedling traits, emphasize on the utilization of such correlations in undertaking indirect selection for desired traits in the species. Such type of correlation was found either at genotypic level or phenotypic level or at both the levels among the different progenies. Similar kind of results was observed earlier by Srivastava (1995) in *Bauhinia variegata,* Manga and Sen (1998) in *Prosopis cineraria*, Neelannavar and Chavan (2009) in *Albizia lebbek* and Divakaraa *et al.* (2010) *in Pongamia pinnata.*

Principal component analysis: The first three principal components of seed and seedling traits in the thirty-five progenies of *Grewia optiva* were analyzed (Table 5). In the first (›$_1$ = 5.276), second (›$_2$ = 1.174) and third (›$_3$ = 1.039) principal components, the largest absolute loading were germination capacity (0.924), seed width (0.656) and root shoot ratio (0.914). Some components paid negative contribution, as revealed from the Table 5. Highest loading for each trait was underlined. Total variability explained by these three components was 74.892 percent for seed and seedling traits in the thirty-five progenies of *Grewia optiva*.

Table 5. PCA Analysis of seed and seedling traits in *Grewia optiva*

Trait	Component		
	1	2	3
Germination capacity (%)	0.924	-0.136	-0.104
Germination energy (%)	0.813	-0.020	-0.030
100 Seeds weight (g)	0.784	-0.006	-0.129
Seed length (mm)	0.676	0.480	-0.117
Seed width (mm)	0.410	0.656	-0.189
Seedling height (cm)	0.877	-0.237	0.113
Basal diameter (mm)	0.874	-0.320	0.122
Root-shoot ratio	-0.068	0.114	0.914
Number of leaves	0.902	-0.191	0.131
Leaf area (cm^2)	0.412	0.536	0.283
Eigen value (›)	5.276	1.174	1.039
Percentage of Variance	52.756	11.743	10.393
Cumulative % of variance	52.756	64.499	74.892

The results of principal component analysis revealed three components out of ten which had eigen vectors greater than unity, which explained 74.892 percent of total variation. Others were dropped, according to Kaiser (1958). The first component accounted for 52.756 percent variability, specifically germination capacity, number of leaves, seedling height, basal diameter, germination energy, seed weight and seed length. Second component explained 11.743 percent variation, especially through seed width and leaf area. Root shoot ratio was the chief factor of 10.393 percent variation from the third component. Pezzotti *et al*. (1994) on *Dactylis glomerata,* Tunctaner (2002) in willow, Mayor *et al.* (2004) on *Arachis hypogeae* and Bhat *et al*. (2016) in *Pinus roxburghii,* also used PCA analysis for working out of variability.

Conclusion

The estimates computed for seed and seedling traits exhibited high variability among all the progenies. This facilitates selecting a genetically broad based population, serving for conservation of genetic diversity in long term genetic improvement programme. Higher variability estimates were aided by high heritability and genetic advance. Utilization of correlations might play immense role in undertaking indirect selection for desired traits in the species**.** Progenies SI-3 (Deothal), SO-6 (Amberkothi), HA-1 (Bharari), SI-5 (Deyoltikkeri) and CH-5 (Rajpura) excelled all other progenies. The variability found could be exploited in tree improvement programmes through selection and breeding approaches for development of advanced generations for the production of higher quality planting stock (seed), which is the need of the hour.

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