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Genetic divergence analysis in *Ailanthus excelsa* based on morphological traits

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ABSTRACT

Knowledge about the extent of source variation in relation to growth and fodder yield characters is very useful for improvement of multipurpose tree species (MPTs). The present studies were conducted to assess the variability among 23 progenies of *Ailanthus excelsa* for its further improvement. Morphological and genetic analyses were used to identify the elite progeny and record the variations in different progenies of *A. excelsa*. Significant differences (P > 0.05) were recorded among the progenies of *A. excelsa* for growth and fodder yield characters. Maximum diameter 15.33 and 86.11 mm was recorded in progeny P23 after 6 and 12 months of planting. The genotypic coefficient of variation was much less than the phenotypic coefficient of variation for growth characters, i.e. height, diameter and volume index indicating the influence of environment on growth. Maximum phenotypic coefficient of variation (53.98) and genotypic coefficient of variation (31.16) were observed for volume index. High heritability values for leaf fodder yield (67.00%) and height (64.00%) was observed, while low heritability was observed for height and diameter. The genetic advance as per cent of mean varied from 4.63 to 47 .31 % (leaf fodder). Plant height and diameter after 12 months of planting showed positive correlation with each other and fodder yield. Progeny P23 showed consistency in terms of growth and found superior over others. Non Hierarchical Euclidean cluster analysis (D^2), of 23 progenies grouped the progenies into 4 clusters. The intra and inter-cluster distance indicated the presence of wider genetic distance between *A. excelsa* progenies. Maximum inter-cluster distance between cluster II and IV (3.93) followed by cluster III and IV indicates greater divergence between genotypes belonging to these clusters and an attempt to cross the genotypes in these clusters should bring out desirable gene combinations. Among the growth attributes, volume index contributed maximum to genetic divergence.

Key words: *Ailanthus excelsa,* Genotypic coefficients of variation, Phenotypic coefficients of variation, Progeny

Ailanthus excelsa Roxb, commonly known as Maharukh or Mahaneem, is one of the promising fast growing multipurpose tree species of dry areas due to its adaptation to low rainfalls (400 mm) and high temperature conditions (Seth *et al.* 1962, Bhimaya *et al.* 1963). The role of *A. excelsa* in soil organic carbon improvement along with meeting the diversified needs of farmers, viz. fodder, fuel and timber under agroforestry systems have been found important (Patel *et al.* 2008, Jaimini *et al.* 2006). Moreover, its cultivation with low inputs and in harsh climatic conditions is an additional advantage (Chaturvedi 1956, Gupta 1980 and Kaushik 2012). Tree is native to Sri Lanka, and central, western and southern India, but is also being distributed to other semi-arid and sub-tropical areas (Nadkarni 1976). The tree has been introduced in central Sudan as exotic. It is a moderately salt tolerant species and grows well on dry lands (Dagar 2009). Clayey soils with poor drainage and waterlogged conditions are not suitable for this tree. *A. excelsa* was investigated to prove antibacterial, antifungal, antiviral, antifertility and anticancer (Shrimali *et al.* 2001, Joshi *et al.* 2003, Khaled Rashed *et al.* 2013, Dhanasekaran *et al.* 1993, Ogura *et al.*1977) properties.

The poplar (*Populus deltoids*) and eucalyptus (*Eucalyptus treticornis*) based agrofoestry systems are well established in India under irrigated conditions but in arid and semi-arid regions farmers are hesitating to adopt agroforestry due to lack of fast growing species. *A. excelsa* is also recognized as a valuable tree in semi-arid regions because of its wider adaptability, fast growth and higher tolerance to biotic and abiotic stresses. It is very imperative and also demands of time to identify the fast-growing multipurpose trees. *Ailanthus* is an important species with vide variability, which can exploited for its improvement in different agro-climatic requirements, developing the elite seeds. Hence, it becomes necessary to conduct seed source testing prior to a more intensive breeding work (Sniezko and Stewart 1989). For a successful promotion of large scale plantations there is a need for carefully planned and well directed seed source research. The most successful

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tree improvement programme is that where proper seed sources were used. The loss from using the wrong sources can be great and even disastrous (Zobel and Talbert 1984). *A. excelsa* being cross-pollinated crop offers tremendous scope for selection of high-yielding genotypes to increase the productivity. Therefore, the study was conducted to identify the best performing genotypes of *A. excelsa* from the states of Rajasthan and Haryana.

MATERIALS AND METHODS

A survey was made during May 2013 for plus tree selection. Four districts of Rajasthan and one district of Haryana were covered during the survey. The healthy and superior phenotypes (trees) were selected as candidate plus trees on the basis of growth, straightness, clear bole height, less branching etc. and further confirmed to plus trees as per check tree method. The plus trees were confirmed after comparing with five codominant trees within a radius of 50-100 m. Thirty plus trees were identified and sufficient quantities of mature pods were collected from these plus trees individually. The seeds were separated from pods manually. The seeds were sown in the polybags filled with mixture of sand, soil and compost in equal proportion during June, 2013. The seedlings were kept in nursery for three months.

The study was conducted at Chaudhary Charan Singh Haryana Agricultural University, Regional Research Station, Bawal, located in the low rainfall zone of the southern Haryana (28.1° N, 76.5° E and 266 m above mean sea level), India. In general, May-June are the hottest (21-46°C), while December-January are the coldest (0 – 15°C) months of the year. The site is characterized by inadequate precipitation (350-550 mm) during monsoon (July – September) and is also quite erratic. The number of rainy days in a year varies between15 to 25. During summer, the maximum temperature reaches as high as 46°C. Whereas, during peak winter months of December and January, the average minimum temperature is recorded around 4-5°C, which at times, reaches below 0°C. Between October and March, weather remains almost dry except occasional light showers. Thereafter, it is quite dry till June. The maximum evapo-transpiration rate of 14 mm/day is recorded in the month of June. The soil of the experimental site was loamy sand in texture (Typic Ustochrept) and the initial $pH_{(1:2)}$ and $EC_{(1:2)}$ were 8.14 and 0.19 dS/m, respectively. The soil was low in organic carbon 0.18%, available N 108 kg/ha, available P 8.34 kg/ha and medium in available K 170 kg/ha

Based on the nursery performance of 30 progenies, 23 progenies were transplanted in the field during October 2013 at a spacing of 5 × 5 m. Fifteen seedlings of each plus trees were planted in randomized block design with three replications. The data on height, diameter and volume index were recorded once in every six months in all the 15 plants in a replication. Leaf fodder yield was recorded after 12 months of planting. Volume index was calculated using the formula given by Hatchell (1985):

$$\text{Volume index} = (\text{Collar diameter})^2 \times \text{Height}$$

Analysis of variance was carried out as per the method suggested by Panse and Sukhatme (1978).

Table 1 Locations of seed collection

Location	District	Latitude (’N)	Longitude (’E)
Gopal pura	Jaipur	26.87	75.81
Paragpura	Jaipur	27.59	76.09
Paragpura	Jaipur	27.60	76.09
Paragpura	Jaipur	27.60	76.09
Nathwala	Jaipur	26.55	75.52
Mundru	Jaipur	26.91	75.78
Bhinda stand	Sikar	27.27	75.61
Dadia Rampura	Sikar	27.34	75.59
Dadia Rampura	Sikar	27.34	75.59
Badhal	Jaipur	27.26	75.47
Bawari	Sikar	27.57	75.12
Bawari	Sikar	27.60	75.15
Bawari	Sikar	27.80	75.50
Khattoo Mor	Sikar	27.36	75.40
Chelasi	Sikar	27.85	75.27
Sevad Bari	Sikar	27.61	74.95
Salasr	Churu	27.70	74.46
Mangluna	Sikar	28.01	74.95
Jajod	Churu	27.74	74.78
Sunwali	Sikar	27.57	75.15
Sunwali	Sikar	27.58	75.14
Baleran	Sikar	27.91	75.13
Churi	Jhunjhunu	27.85	75.08
Churimiyan	Jhunjhunu	27.93	75.10
Mukangarh	Jhunjhunu	27.95	75.21
Jhujhunu	Jhunjhunu	28.10	75.37
Pachari	Jhunjhunu	28.12	75.39
Patikara	Narnaul	28.01	76.15
Menthi	Rewari	28.15	76.38
Menthi	Rewari	28.15	76.38

Genotypic (GCV) and phenotypic coefficients of variations (PCV) were estimated by the formula suggested by Burton (1952) for each character as follows:

$$\text{Genotypic coefficient of variance} = \frac{\sqrt{\sigma^2 g} \times 100}{X} \times 100$$

$$\text{Phenotypic coefficient of variance} = \frac{\sqrt{\sigma^2 p} \times 100}{X}$$

where, X was mean of that particular character.

Heritability in broad sense was calculated according to the formula suggested by Johnson *et al.* (1955) for each character.

$$\text{Heritability (broad sense) in per cent} = h^2 = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

where $\sigma^2 g$ = Genotypic variance, $\sigma^2 p$ = Phenotypic variance.

Estimates of appropriate variance components were substituted for the parameters to predict the expected genetic gain as suggested by Lush (1949). The expected genetic gain was calculated at 5% selection intensity for each character as:

$$\text{Genetic advance (\%) of mean} = \frac{K.\ \sigma\ p.h^2}{X}$$

where, K = selection differential (2.06), σ p = phenotypic standard deviation h^2 = heritability in broad sense, X = general mean.

The genetic divergence was calculated by using non-hierarchical Euclidian cluster analysis (Spark 1973).

RESULTS AND DISCUSSION

Genetic variability: Significant differences (P > 0.05) were recorded among the progenies of *A. excelsa* for growth characters, viz. plant height, basal diameter, volume index and leaf fodder yield (recorded only after 12 months) after 6 and 12 months of planting in the field (Table 2). The height varied from 32.57 (P28) to 46.23 cm (P 3) after six months of planting, while at the age of 12 months progeny P23 showed maximum height. Maximum diameter was recorded in progeny P23 after 6 and 12 months of planting which was significantly higher than the rest of the progenies. Progeny P23 also showed its superiority over the others and registered highest volume index after 12 months of planting followed by Progeny P 22. The leaf fodder yield was recorded only after 12 months of planting and it varied significantly. The top ranking progeny in terms of leaf fodder yield was P14 followed by P13.

Our study revealed considerable variability for growth, volume index and leaf fodder yield among different progenies of *A. excelsa*. The findings are in agreement with Jat *et al.* (2010) in which they recorded variability for growth in 18 genotypes of *A. excelsa* collected from Rajasthan. Significant differences for growth after different months of planting have also been recorded in progenies of *Melia dubia* (Kumar *et al.* 2013). The recorded variability in growth will be valuable for the conservation of genetic variation, prospects of improvement and assessment of the potential of the locally adapted progeny source.

Table 2 Growth and fodder yield variability in *A. excelsa* after 6 and 12 MAP

Progeny	Plant height (cm)		Diameter (mm)		Volume index (cm^3)		Fodder yield (kg/tree)
	6 MAP	12 MAP	6 MAP	12 MAP	6 MAP	12 MAP	12 MAP
P1	35.61	180.00	8.83	71.11	2776.47	910193.78	1.75
P2	42.30	184.00	10.77	69.55	4906.50	890045.26	1.70
P3	46.23	182.00	13.11	64.00	7945.65	745472.00	1.40
P4	43.44	185.00	11.22	65.66	5468.59	797578.59	0.75
P5	38.44	153.00	13.22	68.39	6718.10	715610.39	1.41
P6	44.11	124.00	11.22	51.77	5552.94	332336.48	1.89
P7	40.55	177.00	9.89	67.55	3966.28	807651.44	2.12
P8	46.00	207.00	10.44	71.44	5013.71	1056460.44	2.00
P9	44.89	198.00	10.44	70.61	4892.72	987182.88	2.92
P11	43.00	213.00	13.88	74.21	8284.14	1173017.43	2.55
P12	42.22	203.00	13.11	68.44	7256.44	950858.82	1.47
P13	44.55	195.00	11.33	76.77	5718.83	1149258.42	3.00
P14	42.66	208.00	11.77	70.72	5909.81	1040274.23	3.17
P15	44.44	200.00	14.11	71.66	8847.65	1027031.12	1.82
P20	41.00	185.00	11.89	70.11	5796.26	909351.24	1.76
P21	43.44	146.00	9.63	61.44	4028.49	551131.55	0.91
P22	36.22	202.00	11.77	79.16	5017.66	1265793.73	2.46
P23	44.22	244.00	15.33	86.11	10392.09	1809243.43	2.11
P26	39.11	195.00	13.67	74.89	7308.44	1093659.86	2.20
P27	44.36	195.00	11.03	60.77	5393.94	720133.62	2.37
P28	32.57	164.00	10.34	63.33	3479.55	657752.98	2.56
P29	39.08	238.00	10.89	61.43	4634.58	898127.49	2.12
P30	34.50	199.00	8.67	61.83	2593.33	760766.83	2.03
Mean	41.43	190.00	11.59	68.74	5734.88	923866.61	2.02
CV	6.37	20.95	12.97	12.51	9.65	8.75	19.66
CD (P>0.05)	4.34	15.42	3.47	3.87	66.51	630.95	0.66

Table 3 Estimates of genetic parameters for growth traits in *A. excelsa* after 12 months of planting

Characters	Plant height (cm)	Diameter (mm)	Leaf fodder yield (kg)	Volume index
Var Env.	0.160	73.956	0.158	146034
ECV	20.995	12.510	19.667	863316
Var. Geno.	0.018	27.284	0.322	82892343725
GCV	7.052	7.599	28.05	31.16
Var. Pheno.	0.178	101240	0.481	248677323244
PCV	22.109	14.637	34.258	53.98
h2 (Broad Sense)	10.20	26.90	67.00	33.33
Gen. Adv. as per cent of Mean 5%	4.634	8.126	47.313	37.03

The genetic variability parameters, i.e. phenotypic and genotypic coefficient of variation, heritability and genetic advance are presented in Table 3. The estimates of phenotypic coefficient of variation (PCV) were higher than those of genotypic coefficient of variation (GCV) for all the characters. Maximum phenotypic coefficient of variation and genotypic coefficient of variation was observed for volume index. Moderate and high heritability values for leaf fodder yield, height (after six months) were observed, while low heritability was observed for height and diameter after 12 months of planting. The genetic advance as per cent of mean varied from 4.63 (height after 12 month) to 47 .31 % (leaf weight)

The estimates of phenotypic coefficient of variation (PCV) were higher than those of genotypic coefficient of variation (GCV) for all the characters indicating the influence of non-additive gene action and existence of sufficient genetic variations as reported earlier by Kumar *et al.* (2010) in *Eucalyptus tereticornis,* Ali *et al.* (2009) and Kaushik *et al.* (2011) in karanja. The genotypic coefficient of variation was much less than the phenotypic coefficient of variation for growth characters, i.e. height, diameter and volume index after 12 months of planting indicating the influence of environment on growth. GCV alone is no indication of the magnitude of heritable variation. Partitioning of total phenotypic variance (σ 2p) of each trait into heritable (σ 2g) and non-heritable (σ2e) components is helpful in determining the proportion of heritable variation that is exploitable for selection of superior individuals. For this purpose estimates of heritability are necessary. Heritability has an important place in tree improvement programmes as it provides index of the relative strength of heredity versus environment (Dorman 1976). Gains from tree improvement programmes depend on the type and extent of genetic variability.

Johnson *et al.* (1955) reported that heritability estimates along with expected genetic gain are more useful and realistic than the heritability alone in predicting the resultant effect for best genotypes. In the present study, we observed high heritability with high genetic advance in leaf fodder yield followed by volume index, plant height and basal diameter (Table 3) indicating a wide scope for genetic improvement in the species.

Correlations: Plant height after six months showed positive correlation with diameter and height at both the levels (genotypic and phenotypic) after 6 and 12 months except fodder yield, where negative correlation (- 0.127 and -0.025) was recorded. Diameter after six months also showed positive correlation with height and fodder yield except fodder yield at genotypic level (-0.070). However, plant height and diameter after 12 months of planting showed positive correlation with each other and fodder yield (Table 4).The contribution of height and diameter showed positive correlation with each other and fodder production (Table 4). Abarquez *et al.* 2015 also reported positive correlation among height and diameter in mahogany progenies. These results are also in confirmatory with Chavan *et al.* (2011).

Divergence studies: Non Hierarchical Euclidean cluster analysis (D^2), of 23 progenies grouped the progenies into 4 clusters (Table 5). The highest number of nine progenies were included in the cluster II followed by cluster IV (7 progenies) and minimum number of progenies (3) were observed in cluster I. The intra-cluster distances ranged from 1.91 to 4.19 (Table 6) with a maximum value falling in cluster III and minimum intra-cluster distance was found in cluster I. The maximum inter-cluster distance was observed

Table 4 Genotypic and phenotypic matrix between growth traits of *A. excelsa*

Characters		Plant height (cm) after 6 months	Diameter (mm) after 6 months	Plant height (m) after 12 months	Diameter (mm) after 12 months	Fodder yield (kg) after 12 months
Plant height (cm) after 6 month	G		0.337	0.151	0.097	-0.127
	P		0.382	0.091	0.020	-0.025
Diameter (mm) after 6 month	G			0.208	0.564	-0.070
	P			0.430	0.465	0.097
Plant height (m) after 12 month	G				0.365	0.680
	P				0.700	0.272
Diameter (mm) after 12 month	G					0.442
	P					0.230

Table 5 Clustering for genetic divergence in growth traits of *A. excelsa*

Clusters	No. of progenies in cluster	Progenies
Cluster I	3	1,23, 28
Cluster II	9	2, 30, 7, 8, 20, 29, 9 , 13, 14
Cluster III	4	11, 26,22, 23
Cluster IV	7	4, 21,6, 12, 15, 3, 5

Table 6 Intra and inter-cluster distances for growth traits in *A. excelsa*

Clusters	Cluster I	Cluster II	Cluster III	Cluster IV
Cluster I	1.91	2.12	2.44	2.74
Cluster II		3.16	3.03	3.93
Cluster III			4.19	3.13
Cluster IV				3.81

may be due to environmental factors and thus, suggests that selection of parents for hybridization within cluster should be based on genetic diversity rather than geographic diversity. Maximum inter-cluster distance between cluster II and IV followed by cluster III and IV indicates greater divergence between genotypes belonging to these clusters and an attempt to cross the genotypes in these clusters should bring out desirable gene combinations. The lowest inter-cluster distance observed between clusters I and II suggested that progenies from these clusters were not genetically much diverse and thus, selection of parents from these clusters should be avoided. It is therefore desirable for the tree breeder to select those clusters which are having more inter-cluster distance. Thus, it may be suggested that the crosses between clusters II and IV may result sufficient segregation and further progeny selection may help in the improvement of species. Therefore, the progenies belonging to these clusters could be taken as parents for a successful hybridization program.

It is revealed that one progeny P23 showed consistency in terms of growth, however the progenies P22, P13, P14 proved superior in terms of growth, volume index or leaf fodder yield. The variability study indicated that volume index, registered highest phenotypic coefficients of variances (PCV) and genotypic coefficients of variances (GCV). The estimates of phenotypic coefficient of variation (PCV) were higher than those of genotypic coefficient of variation (GCV) for all the characters indicating the influence of non-additive gene action. The application of D^2 clustering technique grouped the 23 progenies into 4 clusters. The intra and inter-cluster distance indicated the presence of wider genetic distance between *A. excelsa* progenies. Maximum inter-cluster distance between cluster II and IV (3.93) followed by cluster III and IV indicates greater divergence between genotypes belonging to these clusters and an attempt to cross the genotypes in these clusters should bring out desirable gene combinations. Among the growth attributes volume index contributed maximum to genetic divergence.

Table 7 Cluster mean values for growth traits in *A. excelsa*

Clusters	Plant height (cm) after 6 months	Diameter (mm) after 6 months	Plant height (m) after 12 months	Diameter (mm) after 12 months	Fresh leaf weight (kg) after 12 months	Volume index after 12 months	Volume index after 12 months
Cluster I	34.23	9.28	182.00	65.43	2.12	5549.37	1125730.00
Cluster II	42.83	10.94	199.00	68.78	2.36	4825.78	944346.50
Cluster III	40.64	13.67	214.00	78.60	2.33	7750.58	1335429.00
Cluster IV	43.19	12.23	171.00	64.49	1.38	6545.41	731431.30
Mean	41.44	11.59	191.00	68.74	2.02	6167.79	1034234.00

between cluster II and IV (3.93) followed by IV and III and minimum was between clusters I and II (2.12). The cluster mean also varied among different cluster groups for growth and leaf fodder yield traits (Table 7). The highest cluster mean for height and diameter was recorded in cluster III, while cluster II recorded maximum leaf fodder yield after 12 months of planting.

The D^2 statistic, which is based on several characters, is one of the powerful tools to assess the relative contribution of different component traits to the total diversity to quantify the degree of divergence between populations, to understand the trend of evolution and choose genetically diverse parents for obtaining desirable recombination. There was considerable variation among the cluster means for the characters studied, indicating the divergent nature of the clusters formed. The clustering pattern revealed that trees from different geographic regions were grouped together in a cluster and as trees from the same geographical area were placed in different clusters. This suggested that geographical diversity did not go hand in hand with genetic diversity. This was inline with results obtained earlier through D^2 analysis by Kaushik *et al.* (2007) in *Jatropha curcas*. The trees that originated in one region had been distributed into different clusters.

Maximum intra-cluster distance shown by cluster III indicates wide divergence with in cluster itself which

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