GENETIC VARIATION IN SEED GERMINATION AND GROWTH PERFORMANCE OF 12 *ACACIA NILOTICA* PROVENANCES IN INDIA

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GINWAL, H. S. & GERA, M. 2000. Genetic variation in seed germination and growth performance of 12 *Acacia nilotica* provenances in India. Seed germination behaviour and growth characteristics of 12 different *Acacia nilotica* populations scattered over the natural range in India were studied in a provenance trial. A significant difference between the provenances was observed in respect of seed germination and growth (height, diameter, survival %) of 42 months in the field. Four provenances, i.e. Jabalpur (Madhya Pradesh), Ambala (Haryana), Dholpur (Rajasthan) and Kuthipura (Rajasthan), gave more than 70% germination and also exhibited good growth performance. Seed germination was found to have a strong positive correlation with the growth of field planted seedlings. The possibility of this relationship for the indication of early selection is discussed. None of the traits assessed was related to any of the geographical coordinates of the site (latitude, longitude and altitude). There were fair differences between phenotypic and genotypic coefficients of variability. Both heritability and genetic advance values were fairly high for all characters. Dholpur (Rajasthan) provenance depicted an excellent performance in growth and survival in comparison to others and can be suggested as a potential source for various plantation works in this region. Other good performing provenances are Ambala (Haryana) and Kuthipura (Rajasthan). The relative performance of these provenances was fairly consistent through the years.

Key words : Provenance - variation - seed germination - growth - selection

GINWAL, H. S. & GERA, M. 2000. Perubahan genetik dalam pertumbuhan biji benih dan prestasi pertumbuhan 12 provenans *Acacia nilotica* di India. Tabiat percambahan biji benih dan ciri-ciri pertumbuhan 12 populasi *Acacia nilotica* yang berbeza berselerak di seluruh banjaran semula jadi di India dikaji di provenans percubaan. Terdapat perbezaan yang bererti antara provenans yang dicerap dari segi percambahan biji benih dan pertumbuhan (ketinggian, garis pusat dan % kemandirian) selama 42 bulan di ladang. Empat provenans iaitu Jabalpur (Madhya Pradesh), Ambala (Haryana), Dholpur (Rajasthan) dan Kuthipura (Rajasthan), memberikan lebih daripada 70% percambahan dan juga mempamerkan prestasi pertumbuhan yang baik. Percambahan biji benih didapati mempunyai korelasi positif yang kuat dengan pertumbuhan anak benih yang ditanam di ladang. Kemungkinan kaitan ini untuk menandakan pemilihan awal turut dibincangkan. Tiada satupun ciri-ciri yang ditaksirkan didapati berkaitan dengan mana-mana kesetaraan geografi di tapak tersebut (latitud, longitud dan altitud). Terdapat perbezaan bererti antara pekali fenotip dan pekali genotip bagi

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kebolehubahan. Kedua-dua nilai keterwarisan dan nilai kemajuan genetik adalah tinggi untuk kesemua ciri. Provenans Dholpur (Rajasthan) menunjukkan prestasi yang sangat baik dalam pertumbuhan dan kemandirian berbanding dengan provenans yang lain dan dapat disyorkan sebagai sumber yang berpotensi untuk pelbagai kerja perladangan di kawasan ini. Provenans lain yang menunjukkan prestasi yang baik ialah Ambala (Haryana) dan Kuthipura (Rajasthan). Prestasi provenans tersebut secara relatifnya adalah tetap di sepanjang tahun tersebut.

Introduction

Acacia nilotica is a fast-growing multipurpose tree species of India that provides high quality wood and other products (Anonymous 1980). It is widely distributed in sub-tropical and tropical Africa from Egypt, Mauritania southwards to southern Africa and in Asia eastwards to India (Dwivedi 1993). In India, it occurs extensively on a wide strip from north to south of the country under varied ecological conditions, though it is widely planted in afforestation programmes in the plains of arid and semi-arid regions. Small-scale farmers value this leguminous species on account of its nitrogen-fixing nature for improving the fertility of soil, good coppicing ability, green manure, fodder, fuel, timber to some extent and excellent characteristics as an agroforestry tree species (Vishwanath & Kaushik 1973). It is a most versatile species for afforestation of the shifting sand dunes, coastal sands, river beds, saline terrains, dry and degraded lands and waste lands where rainfall is scanty and erratic.

In India, *A. nilotica* occurs naturally in extensive areas but a long history of selective fellings and biotic interference has resulted in small discrete populations of the tree. These dwindling natural populations are the basic resource for future breeding programmes and accordingly require conservation. A comprehensive exploration and mapping of natural populations which are disappearing fast need to be undertaken. Provenance testing most probably needs to be expanded to cover as yet untested populations and additional foreign provenances. The significance of genetic variation studies and provenance testing in forest tree improvement is very well recognised (Callaham 1964, Wright 1976). The apparent high phenotypic variability among the populations (Shivkumar & Banerjee 1986, Ginwal *et al.* 1995, 1996, Krishan & Toky 1995) in seed and seedling characteristics of *A. nilotica* indicates the need for a range-wide provenance test to achieve the economic benefits from the selection.

The limited provenance tests conducted up to now provide only preliminary information on variations in seed, germination and seedling characteristics (Mathur *et al.* 1984, Shivkumar & Banerjee 1986, Bagchi & Dobriyal 1990, Bagchi *et al.* 1990, Ginwal *et al.* 1994, 1995, 1996). The detailed information on the adaptability and growth of field planted provenances in *A. nilotica* is very scanty (Shivkumar & Banerjee 1986, Krishan & Toky 1995).

The present study was undertaken to study the pattern and magnitude of genetic variation in seed germination and growth characteristics of 12 *A. nilotica* provenances to identify the best provenance to be utilised for reforestation for maximum productivity and for utilisation in future genetic improvement programmes.

Material and methods

The study was conducted at the Tropical Forest Research Institute, Jabalpur (23° 5'07"– 23° 6'10" N, 79° 59'49"–79° 59'42" E). The area enjoys a semi-arid type of climate with mean annual rainfall of 1350 mm.

The seed collection area (11.00–30.40° N, 72.30–79.57 °E), at altitude of 55 to 450 m, is within the range of its geographical limit in its native land (Table 1). Seeds for the study were collected through a well-coordinated plan. At least 10 parent trees from each populations were randomly selected with at least 100 m distance between any two trees. Open pollinated pods from trees, containing at least 10% pods from each tree were collected and labelled separately. The pods were dried in the sun and seeds were extracted manually.

Table 1. Geographical locations of various provenances of *Acacia nilotica*

Provenance No.	Provenance/Locality	Latitude °N	Longitude °E	Altitude (m)
T1	Panchkula Range Ambala, Haryana	30.40	76.49	250
T2	Faridabad Canal Block Faridabad, Haryana	28.24	77.18	300
T3	Banskantha, Gujrat	24.0	72.30	55
T4	Farm nursery, Kuthipura, Jaipur, Rajasthan	26.53	75.50	390
T5	Agahpur forest block, Bharatpur, Rajasthan	27.14	77.29	225
T6	Dholpur, Rajasthan	26.42	77.54	400
T7	Bikaner, Rajasthan	28.01	73.2	225
T8	Jabalpur, Madhya Pradesh	23.60	79.59	350
T9	Jodhpur, Rajasthan	26.18	73.04	224
T10	Kothputli forest block, Jaipur, Rajasthan	28.42	76.21	450
T11	Ambala, Haryana	30.24	76.38	248
T12	Coimbatore, Tamil Nadu	11.00	76.57	409

The seeds were inoculated with a rhizobium (supplied by the Forest Pathology Division of the Institute) before sowing. Four hundred pretreated seeds (with boiled water) of each provenance were directly sown in polythene bags (20 × 40 cm size @ one seed per bag) containing potting mixture of sand, soil and farmyard manure in the ratio of 1:1:1. The bags were placed on a polythene sheet in a randomised complete block design with three replications in an open ground and watered daily. The number of seeds germinated was recorded daily till the end of the experiment. Germination percentage was calculated on the basis of the original number of seeds sown in the nursery.

The experiment was concluded at 31 days after sowing. To ascertain the effectiveness of provenances in terms of changes in germination behaviour and to determine the germination value, the final seedling count was considered. Germination value (GV) was determined by multiplying the peak value of germination (PV) with mean daily germination (MDG), i.e. GV = PV × MDG (Czabator 1962). Germination energy was calculated following Ginwal *et al.* (1994) and Willan (1985).

Six-month-old seedlings were planted in the field (pit size 60 × 60 × 60 cm) in August 1992 in a randomised complete block design with three replications. Each provenance constituted a plot with 49-tree (7 × 7) square plot at a spacing of 3 × 3 m. The 25 central trees in each plot of 49 trees constituted the measuring unit. The first assessment was carried out 18 months after planting and subsequently after 30 and 42 months. The traits included for the assessment were total plant height, collar diameter and survival percentage.

The data (considering all three replicates) were subjected to analysis of variance and Duncan's multiple range test using SPSS (Version 6.1) computer program (SPSS Inc. 233 S. Wacker Drive, 11th floor, Chicago, IL 60606-6307). Coefficient of variation (CV%) and linear correlation coefficient among the studied traits and with latitude, longitude and altitude of seed origin of the provenances were calculated as described by Snedecor and Cochran (1967). Genotypic and phenotypic coefficients of variation, heritability, genetic advance and genetic gain were calculated using the method of Kempthorne (1957).

Results

Table 2 lists the mean values of germination percentage, germination value and germination energy of *A. nilotica* provenances along with the statistical significance. The ranges of seed source means were found to be appreciably broad for germination percentage, 25.71–76.00% (T5 and T6); germination value, 0.98–13.25 (T2, T5 and T6); and germination energy, 8.45–31.00 (T2 and T6). Germination started in 4–5 days for all provenances and by 31 days all viable seeds had germinated. Germination greater than 70% was achieved for four provenances only, i.e. T4, T6, T8 and T11. Five provenances, i.e. T1, T2, T3, T5 and T10, gave less than 50% germination. Germination value and germination energy were observed maximum at 13.25 and 31.00 respectively in T6 provenance followed by 12.85 and 30.68, 12.29 and 30.50 in T11 and T4 provenances respectively. Provenances with higher germination also had higher germination value and germination energy. Analysis of variance revealed significant differences in germination percentage among provenances. Coefficient of variation calculated for this trait was 42.54%.

Table 2. Germination parameters of various provenances of *A. nilotica*

Provenance No.	Provenance	Germination %	Germination value	Germination energy
T1	Panchkula Range Ambala, Haryana	30.00 f	1.37	9.99
T2	Faridabad Canal Block Faridabad, Haryana	26.00 f	0.98	8.45
T3	Banskantha, Gujrat	28.57 f	1.74	11.00
T4	Farm nursery, Kuthipura, Jaipur, Rajasthan	72.86 ab	12.29	30.50
T5	Agahpur forest block, Bharatpur, Rajasthan	25.71 f	0.98	8.89
T6	Dholpur, Rajasthan	76.00 a	13.25	31.00
T7	Bikaner, Rajasthan	64.28 d	9.35	26.41
T8	Jabalpur, Madhya Pradesh	71.43 abc	7.18	24.30
T9	Jodhpur, Rajasthan	58.57 e	7.19	23.66
T10	Kothputli forest block, Jaipur, Rajasthan	25.80 f	1.47	9.87
T11	Ambala, Haryana	71.00 bc	12.85	30.68
T12	Coimbatore, Tamil Nadu	68.00 cd	10.22	26.84
F test		***		
CV%		42.54		

Means followed by the same letter(s) do not differ ($p < 0.05$) by Duncan's multiple range test.
*** $p < 0.001$ level of significance.

At 18 months after field planting, significant differences were detected among provenances in height ($p < 0.001$) and root collar diameter ($p < 0.01$); however, no significant difference in survival was observed (Table 3). Coefficient of variation indicated a considerable variation among provenances. The provenance T4 attained a maximum of 175.89 cm height growth whereas provenances T5 and T11 were only 96.81 and 97.23 cm tall respectively. The provenances which showed the fastest height growth, i.e. T4, T7, T8 and T12, also displayed better growths in root collar diameter.

At 30 months, one more provenance, i.e. T6, was included in the above category of the fastest growing provenances. Provenances differed significantly from each other in respect of height ($p < 0.01$), collar diameter and survival ($p < 0.001$). The coefficients of variation observed for these traits were considerably high, i.e. 14.84, 21.67, 25.23% for height, diameter and survival respectively. The fastest growing provenances also had comparatively higher root collar diameter and survival. Percentage survival was observed maximum at 80.94% in T6 provenance and minimum at 35.36% in T5 provenance.

Table 3. Growth performance of various provenances of *A. nilotica*

Provenance No.	Age: 18 months			Age: 30 months			Age: 42 months		
	Height (cm)	Collar dia. (cm)	Survival (%)	Height (cm)	Collar dia. (cm)	Survival (%)	Height (cm)	Collar dia. (cm)	Survival (%)
T1	114.78 bc	1.18 c	64.62	132.85 bc	1.51 cde	37.39 d	165.90 b	2.10 b	12.53 f
T2	126.96 bc	1.37 bc	88.43	135.20 bc	1.80 b	70.46 ab	159.00 b	2.26 b	62.55 ab
T3	120.38 bc	1.14 c	72.79	125.70 bc	1.62 bcde	58.48 bc	165.46 b	2.28 b	43.46 bcde
T4	175.89 a	1.85 ab	61.22	193.60 a	2.46 a	48.62 cd	231.20 a	3.24 a	53.36 abcd
T5	96.81 c	1.02 c	68.98	109.47 c	1.68 bcd	35.36 d	164.95 b	2.10 b	32.41 def
T6	116.05 bc	1.92 a	97.28	157.87 b	2.63 a	80.94 a	238.26 a	3.33 a	70.70 a
T7	135.34 b	1.07 c	66.78	148.30 b	1.47 de	64.04 abc	175.40 b	2.22 b	56.83 abc
T8	130.01 bc	1.12 c	57.82	148.64 b	1.51 cde	51.36 bcd	171.50 b	2.23 b	46.03 bcd
T9	107.75 bc	1.05 c	66.66	132.12 bc	1.66 bcd	59.13 bc	164.56 b	2.08 b	36.13 cde
T10	110.50 bc	1.17 c	54.42	125.50 bc	1.70 bc	37.84 d	133.14 b	2.05 b	23.03 ef
T11	97.23 c	1.11 c	48.71	139.00 bc	1.41 e	57.80 bc	189.83 ab	2.35 b	55.93 abc
T12	137.95 b	1.47 abc	79.59	143.40 bc	1.80 b	52.37 bcd	174.20 b	2.54 b	42.35 bcde
F value	4.55***	3.66**	2.19 (ns)	3.99**	32.38***	5.54***	2.84*	3.64***	6.21***
CV%	17.57	23.83	20.25	14.84	21.67	25.23	16.69	18.18	37.57

Means followed by the same letter(s) do not differ ($p < 0.05$) by Duncan's multiple range test.
Significance levels *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, ns - not significant.

The performance of provenances in respect of height, collar diameter and survival varied significantly at age after 42 months after field planting with T6 provenance outranking the rest. Although T4, T7, T8, T11 and T12 provenances maintained their superiority over the others, the T6 provenance appeared as the most promising indicating maximum height (238.26 cm), collar diameter (3.33 cm) and excellent field survival (70.70%) at this age. Considerable variations among provenances for height, collar diameters and survival were noticed, i.e. 16.69, 18.18, 37.57% respectively.

Variation for all the studied traits was non-clinal as none of the studied traits was found to bear any significant correlation with any of the geographic coordinates, i.e. latitude, longitude and altitude. Seed germination percentage was found to have significant positive relationship ($p < 0.05$) with tree height, root collar diameter and field survival (Table 4). This relationship also appeared significant at 18 months and 30 months growth (except survival). Tree height at 42 months was observed to have significant positive relationship with collar diameter ($p < 0.001$) and survival $p < 0.01$). It also revealed significant relationship with the height ($p < 0.001$) and collar diameter ($p < 0.001$) of the previous period (at 30 months). The tree heights at 18 months and 30 months appear to have a significant relationship with their collar diameters but did not indicate a significant relationship with the field survivals. A highly significant relationship ($p < 0.001$) was seen in collar diameter between trees from the provenances of any two age groups.

Discussion

Variations in *A. nilotica* provenances with respect to seed germination and seedling growth could be due to the fact that this species grows over a wide range of rainfall, temperature and soil types in India (Dwivedi 1993, Ginwal *et al.* 1996). Populations must have experienced marked differences in selective pressure. The differences observed for these traits could be genetic in nature as has been also emphasised by Arya *et al.* (1995) and Vakshasya *et al.* (1992). The coefficient of variation for germination percentage indicates that the provenances are highly variable for this trait suggesting a good scope of selection at this stage. However, the statistical analysis of seed germination and seedling growth traits using Duncan's multiple range test shows that for most characters, seed sources do not fall in separate groups. This indicates that the variations are gregarious and could be due to the fact that the provenances selected were evenly distributed over the wide range of this species.

There were a few provenances (T4, T6, T8, T11) which performed very well in the germination experiment. Because of the greater germination value and germination energy of these provenances, they can be considered more vigorous than the others. Since germination energy is a measure of speed of germination, it gives an idea of the vigour of the seed and of the seedling which it produces (Willan 1985). The interest in germination energy is based on the theory that only

Table 4. Correlation coefficient (*r*) among the various studied traits of *A. nilotica* provenances

Character	Germination percentage	Height			Collar diameter			Survival		
		18 months	30 months	42 months	18 months	30 months	42 months	18 months	30 months	42 months
Germination percentage	1.000									
Height										
18 months	0.331*	1.000								
30 months	0.579***	0.564***	1.000							
42 months	0.544***	0.410*	0.619***	1.000						
Collar diameter										
18 months	0.369*	0.486**	0.622***	0.696***	1.000					
30 months	0.336*	0.365*	0.515***	0.622***	0.732***	1.000				
42 months	0.494**	0.491**	0.666***	0.907***	0.890***	0.732***	1.000			
Survival										
18 months	0.017	0.095	0.088	0.146	0.372*	0.321	0.222	1.000		
30 months	0.277	0.142	0.324	0.321	0.332*	0.240	0.339*	0.321	1.000	
42 months	0.502**	0.252	0.532***	0.457**	0.444**	0.391*	0.520***	0.457**	0.675***	1.000

Significance levels * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

those seeds which germinate rapidly and vigorously under favourable conditions are likely to be capable of producing vigorous seedlings in field conditions, whereas weak or delayed germination is often fatal (Aldhous 1972). Results of the present study strongly support this hypothesis as the provenances having higher seed germination also had better field performance. Germination value which is a further expression of germination energy has been used as an integrated measure of seed quality in *Terminalia ivorensis* by Okoro (1976) and *Pinus kesia* by Costales and Veracion (1978).

The correlation matrix (Table 4) reveals that in *A. nilotica* seed germination percentage may be an important trait for the selection of seed sources for raising stock for bulk commercial plantations. The high correlations between seed germination percentage and plant height, collar diameter and survival show that seed source selection can be done at the laboratory/nursery level to obtain maximum productivity. Strong correlations between growth traits of young seedlings with those of older trees suggest a good basis for predicting the performance of mature trees from that of juvenile ones. These relationships would be very helpful in the early selection of the provenances, as has also been confirmed by Gupta *et al.* (1991) in the provenance trial of *A. nilotica*. Most of the studied traits have strong positive correlations with one another; this suggests that such characters can be used to the advantage of the breeder and simultaneous improvement of the character can be brought about easily.

The success or failure of tree breeding depends largely on the extent of variability in the base population which is measured by different population parameters including genotypic and phenotypic variations and genotypic and phenotypic coefficients of variation (Subramanian *et al.* 1995). In the present study there were considerable differences between the genotypic and phenotypic coefficients of variation for all the characters (Table 5). This indicates that these characters are sensitive to environmental changes (Subramanian *et al.* 1995). The genotypic coefficients of variation are comparatively lower than the phenotypic coefficients of variation for all the studied traits. This has also been reported by Rathinam *et al.* (1982) for height and girth, and Subramanian *et al.* (1995) for height, girth and clear bole length.

The heritability values for the studied traits are fairly high (Table 5). Heritability in broad sense may give useful indication about the relative value of selection of the material at hand, but to arrive at a more reliable conclusion, heritability and genetic advance should be considered jointly (Subramanian *et al.* 1995). The genetic gains at the age of 42 months indicate that there was a fair relationship between phenotype and genotype and a considerable variability for the studied characters in the material. Seed germination, collar diameter and survival registered higher values of genetic gain in comparison to height, although the latter is also fairly good. It is suggested that selection to improve the genetic pattern of these characters will be effective in the present material.

Table 5. Estimates of genetic variables as determined from measurements of various studied traits

Parameter	Germination percentage	Height	Collar diameter	Survival
General means ($\bar{x}$)	51.52	177.78	2.39	44.61
Error variance (σ^2E)	51.52	928.50	0.1564	135.168
Genotypic variance (σ^2G)	478.06	571.50	0.1377	234.97
Phenotypic variance (σ^2P)	529.58	1500.00	0.294	370.14
Genotypic coefficient of variance (GCV)	42.43	13.44	15.52	34.36
Phenotypic coefficient of variance (PCV)	44.66	21.78	22.68	43.12
Heritability (h^2) %	90.27	38.10	46.83	63.48
Genetic advance	42.76	30.39	0.522	25.16
Genetic gain (GA as % of mean)	82.00	17.09	21.84	56.39

Values calculated for measurements at age of 42 months.

In view of the high heritability of germination percentage, which has been also reported by Khalil (1978), and its significant relationship with juvenile height and collar diameter growth which is maintained up to the last measurement, i.e. 42 months, there is a good indication that the provenances which are superior in seed quality are also superior in growth and survival. Such relationship can be explored for the early detection of superior provenances. This confirms the earlier conclusion that provenances with fast, juvenile growth rates maintain their superiority until a later developmental stage (Khalil 1981, Nienstaedt 1981). Thus, seed germination characteristics, as they are under genetic control (Whittington 1973, Isik 1986, Arya *et al.* 1995), can be included among the criteria for the selection of fast-growing / superior provenances.

The present investigation clearly shows the presence of considerable genetic differences in seed germination, seedling survival and growth of various provenances of *A. nilotica.* At this stage we are able to recommend two provenances, i.e. T4 (Farm nursery, Kuthipura, Jaipur, Rajasthan) and T6 (Dholpur, Rajasthan), for large scale afforestation / planting programmes in this region, and also for further genetic improvement programmes in this species.

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