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Association of growth related seedling traits in *Acacia senegal* under arid environment of western Rajasthan

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Abstract

Climatic models and predictions indicate increase in aridity world over due to global warming. Arid environments occupy about one third land area of the world. *A. senegal* is the most important dryland resource of western Rajasthan desert ecosystem. The seeds of 13 low and high seed yielding exotic and indigenous provenances were evaluated for diversity and interrelationship among growth related seedling traits targeting establishment and end use of this species. Under the present study most of the growth related seedling traits varied within and amongst provenances. Highly significant correlation of dry biomass per plant of more than 72% with root length (73.3%), collar diameter (72.2%), shoot dry weight (99.7%), root dry weight (95.7%) and seedling length (79.9%) under the present study may be used for early selection. Similarly, highly significant positive correlation of seedling length with seven out of 12 growth related seedling traits validate strong inherent association of these traits under strong genetic control and are amenable for selection. Significant negative correlation in number of nodules per plant with root/shoot length ratio (-57.6%) and no correlation with 10 out of 12 growth related seedling traits tested advocate emphasis on other growth related seedling traits in selection of elite *A. senegal* genotypes for afforestation. The non significant associations suggest that per cent germination was independent of other characters and could be selected separately.

Key words

Arid environment, *Acacia senegal*, Provenances, Seedling traits

Introduction

According to recent perspective climatic models and predictions the aridity shall increase world over under the influence of global warming (Seager *et al.,* 2007; Goa and Giorgi 2008; Solomon *et al.,* 2009). Therefore, it is imperative to develop better understanding of the population biology of predominant arid zone species like *A. senegal* and *P. cineraria* to predict patterns of vegetation change in western Rajasthan. Some of the typical characteristics of tree species in arid environments are dependence on ground water to persist with deep and extended roots below the surface (Miller *et al.,* 2001; Lubczynski, 2009). Consequently, the plants exhibit low fecundity and the population are characterized by low recruitment. Demographically, the stability of long lived plant populations largely depends on survival of adult reproductive individuals (Garcia *et al.,* 2008). Arid environments occupy about one third land area of the total area of the world. Exotic germplasm of *A. senegal* has been adapted in India, Pakistan and Nigeria in arid and semi arid regions under extreme temperatures ranging from sub zero to 48°C.

The climate of western Rajasthan is often characterized by hot and dry summers, sub-humid monsoon and cold dry winters. *A. senegal* and *Prosopis cineraria* are the most important dryland resources of Western Rajasthan desert ecosystem (Tewari *et al.,* 1998; Jindal *et al.,* 2000). *Acacia senegal* (L.) Willd, is highly drought tolerant multipurpose leguminous African tree species that belongs to subgenus *Aculeiferum* (Dondain and Phillips, 1999; Arce and Blanks, 2001). It is an important resource for gum Arabic, fuel wood, re-vegetation, agro-forestry, human food and fodder for livestock (Aoki *et al.,* 2007). It is possible to improve the growth of leguminous trees by identifying elite germplasm naturally capable of fixing symbiotic nitrogen fixation through rhizobia (Singh *et al.,* 2011). Correlation is the biometrical tool which gives the type, nature and degree of association between various traits. Therefore, the knowledge of association of different characters is pre-requisite for any improvement programme (Wani *et al.,* 2012). Unfortunately, due to long life span and rotation period of a given tree species, very less information is available on its genetic improvement. Consequently, growth related attributes such as germination percentage, dry biomass, seedling vigour index, nodulation etc. at early seedling stages often help us in predicting superiority and selection of elite genotypes for different tree improvement (Wani *et al.,* 2012; de Faria *et al.,* 2010; Dumroese *et al.,* 2009; Raddad 2007; Devagiri *et al.,* 2007),

Therefore, selection should be aimed at seed source (genotype) with highest level of susceptibility to root nodulation with rhizobia which could perform well in the initial stage of plantation on poor sites (Devagiri *et al.,* 2007). The objective of the present study was to identify elite germplasm sources of *A. senegal* that have good seed germination capacity and seedling traits suitable for reforestation in arid and semi-arid tracts of western Rajasthan.

Materials and Methods

Germplasm of *Acacia senegal* provenances representing exotic accessions from Mali, Niger and Senegal were procured from Centre Technique Forestier Tropical (CIFT), Nogent Sur Marne, France. Seedlings of these accessions along with the accessions of Sudan and local collections from Rajasthan were transplanted in 1988 at the Central Research Farm of Central Arid Zone Research Institute, Jodhpur. Seeds of low and high yielding trees of these accessions representing 13 genotypes were collected for the present study. Twenty-five seeds from each genotype were sown in poly bags containing mixture of FYM, clay and sandy soil (1:1:3) in second week of August 2009 in a green house under controlled conditions. Germination was recorded up to 30 days after sowing. After a period of four months the poly bags were removed by cutting vertically and root system was exposed by removing soil and subsequently by washing the exposed roots in running tap water carefully. Data were recorded on surviving seedlings from each genotype for the number of nodules, shoot length, root length, collar diameter, shoot dry weight and root dry weight. Whereas, seedling length, shoot/root length ratio, dry biomass/plant, shoot/root dry weight ratio and seedling vigour index (SVI) were computed for each seedling data. Statistical analysis was carried out to see the association of different growth attributing traits in all the possible combinations of using statistical analysis software (SAS 2011).

Results and Discussion

The genotypes exhibited significant differences both within and among provenances with regard to seed yield, 100-seed weight and percent of nodulating plants. 100-seed weight varied from 3.69 g (genotype 266) of Mali with low seed yield to 9.98 g (genotype 442) from Rajasthan with high seed yield. No correlation was found between low or high seed yielding genotypes with that of seed weight as high seed yielding genotypes like 78, 113, 224, 244 were having less seed weight as compared to low seed yielding genotypes 296 and 407. Raddad (2007) conducted eco-physiological and genetic variations in seedling traits of eight *A. senegal* provenances of Sudan and reported significant differences among provenances in seed weight which ranged from 84-91 g (Clay) and 85-130 g (Sand).

The number of plants showing nodulation for atmospheric nitrogen fixation drastically varied from 0-66.7%. The seedlings of four genotypes viz., 35, 224, 296 and 411 did not show nodulation at all, whereas genotype 442 of Rajasthan exhibited maximum nodulation of 66.7% at seedling stage. Acceptance or rejection of *Rhizobium* by host plant is genetically controlled (Devagiri *et al.,* 2007).

Drastic variation in natural nodulation ranging from 0 to 66.7% among the test genotypes is attributed to the fact that phenotypic variation is determined by genotype and environment interaction and is often expressed in terms of genotypic variation under a given environment (Moles and Westoby, 2004; Cony and Trione, 1998). Jindal *et al.* (2011) revealed the existence of genetic diversity within and among geographical populations viz., Sudan, Niger, Mali, Senegal and India of *A. senegal*. They concluded that the Indian populations exhibited maximum genetic diversity from rest of the African populations.

It is clear from the data that most of the growth related attributes varied amongst test genotypes (Table 1). The maximum shoot length (30.83 cm) was recorded in genotype 407 which was statistically at par with that of genotypes 442 (30.5 cm) and 78 (29.08 cm). Whereas, least shoot length of 18.17 cm was recorded from genotype 244 which was at par with that of genotype 224. Many fold variation were recorded in root length with maximum of 50.17 cm in genotype 442 to minimum of 8.83 cm in genotype 244. The maximum collar diameter of 3.7 mm was recorded in seedlings of genotypes 442 which were at par with that of genotype 407 and 411. Whereas, the minimum collar diameter 1.57 mm was recorded in genotype 244.

Out of 13 genotypes, four genotypes viz., 35, 224, 296 and 411 did not show any nodulation at all, whereas, in rest of the genotypes number of nodules varied from 0.40 to 2.17 nodules per plant under un-inoculated natural growing conditions. The maximum shoot dry weight of 1034 mg was recorded from seedlings of genotypes 442 and the least of 159 mg from genotype 244. Similarly, the maximum and significantly higher root dry weight of 263 mg was recorded from genotype 442 and least root dry weight of 32 mg was recorded in genotype 244.

The longest seedling length of 80.67 cm was recorded in genotype 442 and was significantly higher than all other *A. senegal* genotypes tested. Similarly, the maximum root/shoot length ration of 1.64 was recorded in genotype 442 which was followed by 1.32 in genotype 296. Significantly higher dry biomass per plant of 1297 mg was recorded from genotype 442 which was followed by 1097 mg from genotype 407. Whereas, maximum shoot/root dry weight ratio of 6.71 was obtained from genotype 3, which was at par with genotypes 78, 253 and 244.

Drastic variation in percent germination ranging from 4% in genotype 411 from India to 100% in genotype 68 from Niger was recorded among test genotypes of *A. senegal*. More than 95% germination was recorded in only two genotypes viz., 35 and 68. Maximum SVI of 47.42 was recorded from genotype 35 which was closely followed by genotype 68 and least of 2.44 from genotype 411.

Under the present study most of the growth related seedling traits varied among test genotypes within and amongst provenances and were in corroboration with earlier reports. The effect of natural variations on growth related seedling traits such as nodulation (Diabate *et al.,* 2005; Raddad, 2007; de Faria *et al.,* 2010), seed germination and seedling traits (Singh *et al.,* 2011), morphological and biomass traits (Wani *et al.,* 2012) and seed source (Devagiri *et al.,* 2007) among provenances have been reported in leguminous trees.

For most of the growth related attributes, genotype 442 of *A. senegal* was recorded with maximum values but due to meager germination did not show high seedling vigour index. Poor germination in tropical tree species is mainly due to exogenous seed dormancy. A number of researchers have investigated methods for breaking seed dormancy and to improve seed germination such as effect of seed scarification and gibberellic acid treatment on seed emergence in *Lupinus diffuses* (Dehagan *et al.,* 2003), scarification and growing media on seed germination of *Crotalaria pamilalort* (Linding and Lara-Carbera, 2004), acid scarification and warm water treatments on germination of *Capparis sponsa* (Soleiman *et al.,* 2008), breaking *Setaria parviflora* seed dormancy by nitrates (Fedrico and Mollard 2009) and treatments for breaking seed dormancy of *Prosopis koelziana* and *Prosopis juliflora* (Zare *et al.,* 2011). Scarification treatment had been reported to be necessary to break seed dormancy in species of *Acacia* and *Prosopis* (Vilela and Ravetta, 2001; Sarr *et al.,* 2005; Zare *et al.,* 2011). Correspondingly, our earlier experimentations have also demonstrated that germination percentage can be significantly enhanced from 20 to 90% in control treatment by seed scarification with sulfuric acid (98%) for 15 min (Singh *et al.,* 2011).

An overview of the data exhibits significant (at 5% level of significance) to highly significant (at 1% level of significance) correlation of different growth related seedling traits with each other. Dry biomass per plant, which is the most important growth related seedling trait, exhibited highly significant correlation of more than 72% with root length, collar diameter, shoot dry weight, root dry weight and seedling length. Interestingly, more than 68% significant positive correlation of the number of nodules was recorded with shoot/root dry weight ratio and significant negative correlation with root/shoot length ratio (Table 2).

In general highly significant correlations were observed amongst inter-dependent traits such as shoot length with traits like collar diameter, shoot dry weight and seedling length. Similarly highly significant correlations of root length was observed with characters like root dry weight, seedling length, root shoot length ratio and dry biomass per plant.

There was no correlation of percent germination with other growth related seedling traits tested. This is evidenced from

Table 1 : Seedling growth related attributes of 13 genotypes of *A. senegal*

Genotype	1	2	3	4	5	6	7	8	9	10	11	12
3	27.95	10.45	2.49	1.60	454	70	38.40	0.38	524	6.71	60	23.04
35	28.60	20.80	2.76	0.00	589	129	49.40	0.73	718	4.62	96	47.42
68	23.23	15.19	2.31	1.60	353	74	38.42	0.65	427	4.84	100	38.42
78	29.08	11.83	3.00	2.17	418	70	40.92	0.41	488	6.02	24	9.82
113	20.88	13.00	2.40	1.50	310	75	33.88	0.62	385	4.19	16	5.42
224	19.40	22.60	2.04	0.00	281	71	42.00	1.17	352	4.00	32	13.44
235	24.20	10.30	2.88	1.00	384	75	34.50	0.43	458	5.20	24	8.28
244	18.17	8.83	1.57	0.67	159	32	27.00	0.49	191	5.32	12	3.24
266	27.20	17.00	2.58	0.40	421	96	44.20	0.62	517	4.38	16	7.07
296	27.50	36.30	2.42	0.00	527	189	63.80	1.32	717	2.81	28	17.86
407	30.83	31.50	3.18	1.17	901	196	62.33	1.02	1097	4.60	28	17.45
411	28.50	32.50	3.10	0.00	233	58	61.00	1.15	291	4.03	4	2.44
442	30.50	50.17	3.70	0.67	1034	263	80.67	1.64	1297	3.93	16	12.91
CD 5%	1.96	4.09	0.68	0.60	79.6	21.1	15.88	0.17	84	1.78		

1: Shoot length (cm); 2: Root length (cm); 3: Collar diameter (mm); 4: Number of nodules; 5: Shoot dry weight (mg); 6: Root dry weight (mg); 7: Seedling length; 8: Root/shoot length ratio; 9: Dry biomass/ plant; 10: Shoot/root dry weight ratio ;11: Germination (%); 12: Seedling vigour Index (SVI)

Table 2 : Correlation coefficient of growth related seedling traits in *A. senegal*

	1	2	3	4	5	6	7	8	9	10	11	12
1	1.000	0.535	0.841**	0.037	0.714**	0.621*	0.718**	0.297	0.702*	-0.002	0.051	0.219
2		1.000	0.611*	-0.475	0.693*	0.842**	0.972**	0.958**	0.733**	-0.683*	-0.219	-0.001
3			1.000	0.083	0.735**	0.635*	0.736**	0.414	0.722**	-0.096	-0.143	0.005
4				1.000	0.017	-0.207	-0.381	-0.576*	-0.031	0.686*	0.131	-0.011
5					1.000	0.931**	0.769**	0.535	0.997**	-0.187	0.061	0.263
6						1.000	0.866**	0.734**	0.957**	-0.493	-0.039	0.192
7							1.000	0.871**	0.799**	-0.563	-0.166	0.060
8								1.000	0.584*	-0.781**	-0.233	-0.039
9									1.000	-0.255	0.040	0.251
10										1.000	0.235	0.076
11											1.000	0.961**
12												1.000

*Significant at 5%, ** Significant at 1%; 1: Shoot length (cm); 2: Root length (cm); 3: Collar diameter (mm); 4: Number of nodules; 5: Shoot dry weight (mg); 6: Root dry weight (mg); 7: Seedling length; 8: Root/Shoot length ratio; 9: Dry biomass/ plant; 10: Shoot/root dry weight ratio; 11: Germination (%); 12: Seedling vigour Index (SVI)

the fact that genotype 86 with low 100-seed weight resulted in cent percent germination and on the contrary genotypes 411 and 442 with significantly higher seed weight exhibited very low percent germination of 4 and 16%, respectively. Most of the previous evidence suggests no relationship between seed mass and percentage of seedling emergence (Jones et al 1994; Eriksson, 1997; Chen *et al.,* 2002). The non significant associations advocate that percent germination is independent of other characters and could be selected separately. A negative and non-significant correlation of root dry weight with shoot root dry weight ratio among test genotypes of *A. senegal* was recorded. The earlier findings of Manga and Sen (1998) in *Prosopis cineraria* are in consistency with the present findings. In contrast experiments have also shown that seedlings from large seeds are more tolerant to several hazards encountered during establishment, including competition from established vegetation, deep shade, defoliation, mineral nutrient shortage, drought and burial under soil or litter (Leishman *et al*., 2000; Westoby *et al*., 2002).

Acacia species appear to be suitable for forestation of dry lands and degraded soil; they have a reputation for moderate to high tolerance to water stress and for biomass production even under extreme drought conditions and spells (Raddad *et al.,* 2005). Consequently, there should be clear differences in growth parameters and biomass gain strategies among populations when they are grown under similar conditions, and such differences could possibly be observed at an early developmental stage. Among the growth characters, highly significant correlation of dry biomass per plant of more than 72% with root length, collar diameter, shoot dry weight, root dry weight and seedling length under present study may possibly be used for early selection. Earlier Devagiri *et al.* (2007) also reported that collar diameter showed highly significant positive correlation with seedling dry weight followed by plant height and root length. Raddad (2007) suggested greater variations among groups than within them would result in higher genetic gain.

Highly significant positive correlation of seedling length with seven out of 12 growth related seedling traits viz., shoot length, root length, collar diameter, shoot dry weight, root dry weight, root shoot length ratio and dry biomass per plant were recorded. Similarly, Wani *et al.* (2012) reported positive and significant correlation of seedling height with collar diameter, leaf area, shoot fresh weight and root dry weight. Shoot dry weight and root dry weight showed positive and significant correlation with seedling biomass under different environments. This suggests that there exits a strong inherent association between these characters. Therefore, these traits seem to be under strong genetic control and are quite amenable for selection.

A significant positive correlation of number of nodules with shoot/root dry weight ratio across provenances under the present investigation indicates that selection may be aimed at seed source (genotype) with highest level of susceptibility to root nodulation with rhizobia which could perform well in the initial stage of plantation at poor sites (Devagiri *et al.,* 2007).

Significant negative correlation of the number of nodules per plant with root/shoot length ratio and no correlation with 10 out of 12 growth related seedling traits tested advocates emphasis on other growth related seedling traits exhibiting strong inherent association in selection of elite *A. senegal* genotypes for afforestation.

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