Annals of Arid Zone 48(2): 139-145, 2009

Growth Components at Juvenile Stage and their Relationship with Height at Different Growth Stages in *Acacia albida*

Anjly Pancholy, S.K. Jindal, Manjit Singh and M.P. Rajora
Central Arid Zone Research Institute, Jodhpur 342 003, India

Abstract: Seven accessions of *Acacia albida* sown in nursery in May 1994 were evaluated at 7-month and 8-month old seedling stage in nursery for root and shoot traits. Simultaneously two-month-old seedlings were planted in the field to assess the juvenile-adult correlation by observing it for another twelve years. There were significant differences for collar diameter, root fresh weight, root dry weight, shoot fresh weight, shoot dry weight and total dry biomass per plant at both the stages of the seedlings. During nursery stage, the heritability was low for most of the characters. Expression of relationships was more with age of the plants. The path analysis showed that dry root weight was an important character for dry shoot weight. Shoot length and root-shoot length ratio of the seedlings in the nursery contributed maximum to the height of the plants in the field.

Key words: Growth components, juvenile stage, height, *Acacia. albida*.

Acacia albida Del. also known as *Faidherbia albida* (Del.) A. Chev., native to Africa's dry Savannas and riverine basins, is most valuable plant of the Sahel Zone. Where it grows, the land is favored for growing crops (Anonymous, 1979). In India, it was introduced in 1966 and was recommended for planting in agroforestry systems in Peninsular India in late seventies. Seeds from plus trees from natural stands are presumed to produce genetically superior plants. Positive and significant correlations of parental characteristics like tree height, dbh, seed weight, etc. with their progeny height have been reported in *Pinus sylvestris* in white spruce (Gallis, 1973; Khalil, 1981). Trees are typical of long rotations and delayed reproductive maturity, and therefore long breeding cycles. Maximizing genetic gain per unit time is the ultimate objective of all applied tree improvement programmes (Zobel and Talbert, 1984). Growth and yield are complex characters for which direct selection is difficult. Therefore, a number of associated component characters are analyzed and interrelated at nursery stage. Potential of early selection has been reported by Xie and Ying (1996). To find if selection can be done at nursery stage in *A. albida*, the relationships of traits like shoot length, dry shoot weight and root-shoot length ratio at nursery stage with height of trees in the field were worked out.

Materials and Methods

During 1988, seedlings raised from seed material of seven provenances collected during 1984-1987 from different African countries (viz., Mali, Cameron, Niger and Senegal) by Centre Technique Forestier Tropical at Nogent-sur-Marne, France, were planted in the field. During 1994, flowering and fruiting was observed in 20 trees and these trees were distributed in all the provenances. The seeds from two trees each of these provenantes were collected, pooled and used as source for this study. The seeds of these seven accessions were given names CAZRI-78 (Parent seed source, Mali), CAZRI-79 (Cameroun), CAZRI-81 (Mali), CAZRI-82 (Niger), CAZRI-83 (Niger), CAZRI-84 (Senegal) and CAZRI- 85 (Senegal), and were sown in poly bags containing mixture of soil, FYM and clay (2:1:1) in nursery in the last week of May 1994. Data on nine seedlings at 7-month and 8-month age from each accession were recorded for shoot length, collar diameter, root length, branches per root, root fresh weight, shoot fresh weight and branches per shoot. The shoots and roots were dried in oven at 60°C for 24 h and then weighed. Total dry biomass per plant and the root-shoot length ratio were computed.

In order to assess the field performance, 18 plants, each of about two-month-old seven accessions were planted in field with tree to tree distance of 5 m x 5 m in third week of July 1994 at Central Research Farm of CAZRI, Jodhpur (26°18'N, 73°08'E). The climate of the area is hot, dry summers, sub-humid monsoon and cold, dry winter. The soil is sandy loam with pH 8.1 and low nutrient levels with 0.23% organic carbon, 0.03% nitrogen and 0.02% phosphorus (Dhir, 1984). Data for height were recorded every year during 1994 to 2006 except in 1999 and 2000. Plant-wise nursery data were subjected to analysis of variance and phenotypic and genotypic correlation coefficients were computed as suggested by Al-Jibouri *et al.* (1958). The path coefficient analysis was carried out using phenotypic correlation coefficients taking dry shoot weight as dependent trait as discussed by Dewey and Lu (1959). Simple correlation coefficients were worked out between shoot length, dry shoot weight and root-shoot length ratio of seven-month and eight-month-old seedlings with height of different growth stages of the plants established in the field.

Results and Discussion

Mean performance of the seven-month-old seedlings is given in Table 1. There were significant differences among the seven accessions for collar diameter, root fresh weight, root dry weight, stem fresh weight, stem dry weight and total dry biomass per plant. Mean values for seven-month-old seedlings were 28.6 cm for shoot length, 0.28 cm for collar diameter, 1.29 g for dry root weight and 1.14 g for dry shoot weight. When there are no standard accessions/varieties with which comparisons can be made, then grand mean is considered as check. There was no accession, which was significantly better than the grand mean. Under present situation when it is not a common plant of this area, the genotypes having maximum values for the characters required are to be considered for immediate plantation or for inclusion in the breeding programme. For the characters for which there were significant differences among the accessions, the highest values were 0.31 cm for collar diameter for CAZRI-78 (Mali) and CAZRI-79 (Cameroun). Fresh and dry root weights were maximum for CAZRI-82 (Niger), fresh and dry shoot weight and total dry biomass per plant for CAZRI-79 (Cameroun). The other accession which ranked 2nd for dry biomass was CAZRI-82, which had maximum value for root length, fresh root weight, dry root weight and branches per shoot. Root-shoot length ratio, which shows the balanced growth of the plant, was maximum (1.17) for CAZRI-84 (Senegal), but it did not show the highest value for any relative character of total dry biomass. Mean performance of the 8-month-old seedlings is given in Table 2. For most of the characters except root length and secondary branches per root, there were significant differences among the accessions. Though for seven-month-old seedlings, the differences for shoot length, branches/stem and root-shoot length ratio were non-significant, but at later stages of growth these differences among accessions became significant. Though there was not much change in the mean values of the

Table 1. Mean performance of 7-month-old seedlings of different accessions of A. albida

Acc. No.	Shoot length (cm)	Collar diameter (cm)	Root length (cm)	Branches/ root	Fresh root wt. (g)	Dry root wt. (g)	Fresh shoot wt. (g)	Dry shoot wt. (g)	Branches/ shoot	Dry biomass/ plant	R/S length ratio
CAZRI 78	29.2	0.31	23.5	0.56	2.86	1.51	3.39	1.38	6.56	2.89	0.82
CAZRI 79	30.7	0.31	24.4	0.67	3.47	1.75	4.25	1.58	6.11	3.33	0.85
CAZRI 81	35.8	0.29	29.7	0.56	3.19	1.33	3.75	1.49	5.67	2.82	0.91
CAZRI 82	28.1	0.30	30.3	0.56	3.61	1.84	3.27	1.30	7.56	3.14	1.16
CAZRI 83	23.6	0.22	25.4	0.33	1.31	0.56	1.69	0.66	2.89	1.22	1.14
CAZRI 84	23.8	0.23	26.7	0.56	1.58	0.82	1.22	0.63	3.33	1.45	1.17
CAZRI 85	29.0	0.26	26.4	0.56	2.17	1.21	1.89	0.92	4.11	2.12	1.03
Mean	28.6	0.28	26.6	0.54	2.60	1.29	2.78	1.14	5.17	2.42	1.01
C.D. 5%	–	0.05	–	–	1.27	0.68	1.39	0.61	–	1.23	–
C.D. 1%	–	0.07	–	–	1.70	0.90	1.85	0.81	–	1.64	–
GCV	10.60	12.16	2.90	46.93	31.02	31.26	37.94	29.38	21.76	29.48	26.6
PCV	31.86	23.41	27.22	143.90	60.25	63.73	64.91	63.59	80.87	60.97	48.1
h^2 (broad sense)	0.11	0.27	0.01	-0.11	0.27	0.24	0.34	0.21	0.07	0.23	0.3
GA % of mean 5%	7.32	13.00	0.64	-31.5	32.9	31.6	45.7	28.00	12.10	29.40	30.2
GA % of mean 1%	9.38	16.70	0.82	-40.4	42.2	40.5	58.6	35.80	15.40	37.60	38.7

R/S = Root/shoot.

Table 2. Mean performance of 8–month-old seedlings of different accessions of A. albida

Acc. No.	Shoot length (cm)	Collar diameter (cm)	Root length (cm)	Branches/ root	Fresh root wt. (g)	Dry root wt. (g)	Fresh shoot wt. (g)	Dry shoot wt. (g)	Branches /shoot	Dry biomass/ plant (g)	R/S length ratio
CAZRI 78	28.4	0.23	28.9	0.89	2.80	1.37	2.69	1.01	5.11	2.38	1.14
CAZRI 79	32.7	0.33	27.5	1.33	4.36	2.14	3.53	1.88	6.44	4.02	0.83
CAZRI 81	33.5	0.32	24.1	0.33	3.22	1.54	3.80	1.57	7.78	3.11	0.80
CAZRI 82	32.4	0.29	23.1	0.22	2.92	1.49	3.28	1.42	8.00	2.92	0.77
CAZRI 83	25.4	0.25	33.7	0.33	1.94	0.87	2.22	0.84	4.78	1.71	1.44
CAZRI 84	24.8	0.23	28.0	0.56	1.58	0.73	1.86	0.78	3.22	1.52	1.19
CAZRI 85	20.2	0.41	30.1	0.67	1.67	0.74	1.22	0.51	2.22	1.25	1.60
Mean	20.2	0.26	27.9	0.62	2.64	1.27	2.66	1.14	5.37	2.41	1.11
CD 5%	7.3	0.07	–	–	1.41	0.65	1.42	0.55	3.15	1.15	0.42
CD 1%	9.7	0.09	–	–	1.87	0.87	1.89	0.73	4.19	1.53	0.56
GCV	11.4	10.6	12.2	2.90	46.9	31.0	31.3	37.9	29.3	21.8	29.5
PCV	41.4	31.9	23.4	27.2	143.9	60.2	63.7	64.9	63.6	80.9	60.9
h^2 (broad sense)	0.08	0.11	0.27	0.01	-0.11	0.27	0.24	0.34	0.21	0.07	0.23
GA % of mean 5%	6.50	7.32	13.02	0.64	-3.1.5	32.9	31.6	45.7	27.9	12.1	29.4
GA % of mean 1%	8.33	9.38	16.68	0.82	-40.4	42.2	40.5	58.9	35.8	15.5	37.6

characters, but these were less when the seedlings were old by one-month more, because the earlier seedlings were destroyed to record fresh and dry weights. There was not much change in the ranks of the accessions for most of the characters. Phenotypic coefficient of variation (PCV) was more than the genotypic coefficient of variation (GCV) for all the characters in both the ages. In case of 8-month-old seedlings, PCV ranged from 23.4 for root length to 143.9 for fresh root weight. GCV values for fresh and dry shoot and root weights were 31.3, 37.9, 46.9 and 31.0, respectively. Heritability values were low and ranged from 1% for branches/root to 34% for dry shoot weight (Table 2).

Genetic advance as percentage of mean was the highest for dry shoot weight (58.9) at 1% level of significance, followed by dry root weight (42.2) and fresh shoot weight (40.5). Low values for shoot length, collar diameter and dry biomass suggested that selection would not be effective for these traits. Johanson *et al.* (1955) reported the heritability estimates along with genetic advance were of more value than the former alone in predicting the effect of selection. Panse (1957) reported that high genetic advance may be expected when heritability is mainly due to additive gene effects. Otherwise low genetic gain would mean that heritability is due to non-additive gene effects (i.e. dominance and epistatis). Dry weights of shoot and root have shown high genetic advance with low heritability showing that variability in these characters might be attributed to additive gene action. There was not much difference in GCV, PCV, h^2 and GA between 7-month and 8-month-old seedlings for dry root weight, fresh shoot weight, dry shoot weight and root-shoot length ratio. Knowledge of the magnitude and sign of genetic correlations among traits effecting yield is important in selection. When strong positive correlations are known to exist for a pair characters selection can be concentrated on the one that is easier to assess. Strong negative relationships among some traits may mean that simultaneous improvement of them is impossible, even if selection indices are used. The genotypic and phenotypic correlation coefficients of total dry biomass with other traits are given in Table 3 and 4. For most of the characters the values of genotypic correlation coefficient were higher than the phenotypic correlation coefficients for both stages of the seedlings. Seedling height, collar diameter, root fresh weight, root dry weight, stem fresh weight and stem dry weight showed positive and significant association with total dry biomass per plant at both stages of the seedlings. Stem dry weight had significant association with shoot length, collar diameter, root fresh weight, root dry weight and

Table 3. Genotypic and phenotypic correlation coefficients of total dry biomass with other traits of 7–month-old seedlings of different accessions of A. albida

Character	Shoot length	Collar diameter	Root length	Branches/ root	Fresh root wt.	Dry root wt.	Fresh shoot wt.	Dry shoot wt.	Branches/ shoot	Dry biomass/ plant	R/S length ratio
Shoot length	–	0.737	0.838	0.265	0.799	0.538	0.833	0.873	0.641	0.711	-0.864
Collar diameter	0.747	–	0.072	0.003	1.034	1.023	0.932	0.996	1.328	1.042	-1.129
Root length	0.199	0.186	–	0.030	0.282	-0.183	-0.090	-0.155	1.159	-0.175	-0.118
Branches/root	-0.014	0.092	-0.037	–	0.075	0.044	0.069	0.027	0.103	0.071	-0.008
Fresh root wt.	0.680	0.785*	0.448	-0.016	–	0.968	0.966	1.005	1.415	1.015	-0.959
Dry root wt.	0.684	0.829*	0.395	-0.047	0.945**	–	0.842	0.882	1.352	0.976	-0.853
Fresh shoot wt.	0.769*	0.843*	0.162	0.040	0.799*	0.807*	–	1.010	1.031	0.946	-1.231
Dry shoot wt.	0.809*	0.858*	0.216	0.028	0.813*	0.834*	0.957**	–	1.026	0.964	-1.326
Branches/ shoot	0.522	0.616	0.062	0.029	0.531	0.611	0.720	0.752	–	1.241	-0.725
Dry biomass/plant	0.775*	0.879*	0.325	-0.012	0.922**	0.963**	0.916**	0.952**	0.707	–	-1.099
R/S length ratio	-0.625	-0.460	0.573	-0.035	-0.259	-0.288	-0.485	-0.458	-0.338	-0.384	–

Above diagonal genotypic correlations; Below diagonal phenotypic correlations; $^*P<0.05$, $^{**}P<0.01$.

Table 4. Genotypic and phenotypic correlation coefficients of total dry biomass with other traits of 8–month-old seedlings of different accessions of A. albida

Character	Shoot length	Collar diameter	Root length	Branches/ root	Fresh root wt.	Dry root wt.	Fresh shoot wt.	Dry shoot wt.	Branches/ shoot	Dry biomass/ plant	R/S length ratio
Shoot length	–	1.008	-2.073	-0.127	0.937	0.943	1.122	1.009	1.112	0.979	-1.091
Collar diameter	0.714	–	-1.882	0.372	0.932	0.922	1.030	1.026	0.949	0.977	-1.049
Root length	-0.041	0.035	–	-0.688	-1.791	-1.795	-1.999	-1.691	-2.068	-1.732	1.473
Branches/root	0.141	0.169	0.244	–	2.685	2.749	-0.118	1.444	-1.887	2.115	-0.645
Fresh root wt.	0.681	0.782*	0.226	0.284	–	1.007	0.926	0.995	0.802	1.005	-0.994
Dry root wt.	0.711	0.790*	0.162	0.217	0.977**	–	0.938	0.985	0.814	0.996	-0.996
Fresh shoot wt.	0.751	0.729	-0.010	0.155	0.756*	0.750	–	0.984	1.049	0.964	-1.129
Dry shoot wt.	0.805*	0.859*	-0.048	0.187	0.851*	0.873*	0.883**	–	0.915	0.996	-1.037
Branches/ shoot	0.653	0.703	-0.025	-0.092	0.614	0.656	0.768*	0.729	–	0.867	-1.089
Dry biomass/ plant	0.780*	0.849*	0.066	0.209	0.949**	0.972**	0.839*	0.963**	0.714	–	-1.020
R/S length ratio	-0.687***	-0.449	0.675***	0.052	-0.330	-0.381	-0.504	-0.558	-0.468	-0.479	–

Above diagonal genotypic correlations; Blow diagonal phenotypic correlations; $^*P<0.05$, $^{**}P<0.01$, *** $P<0.10$.

Table 5. Phenotypic path using dry shoot weight as dependant trait

Character	Shoot length	Collar diameter	Root length	Branches/ root	Fresh root wt.	Dry root wt.	Fresh shoot wt.	Branches/ shoot
7-month								
Shoot length	0.152	0.114	0.030	-0.002	0.104	0.104	0.117	0.079
Collar diameter	0.055	0.074	0.014	0.007	0.058	0.061	0.063	0.046
Root length	0.007	0.006	0.033	-0.001	0.015	0.013	0.005	0.002
Branches/root	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	0.000
Fresh root wt.	0.010	0.012	0.007	0.000	0.015	0.015	0.012	0.008
Dry root wt.	0.045	0.054	0.026	-0.003	0.062	0.065	0.053	0.039
Fresh shoot wt.	0.467	0.513	0.098	0.024	0.486	0.490	0.608	0.437
Dry shoot wt.	0.073	0.086	0.009	0.004	0.074	0.085	0.100	0.139
'r' with dry shoot weight	0.809	0.858	0.216	0.028	0.813	0.834	0.957	0.752
Partial R^2	0.123	0.064	0.007	0.000	0.013	0.054	0.582	0.104
8-month								
Shoot length	0.097	0.069	-0.004	0.014	0.066	0.069	0.072	0.063
Collar diameter	0.198	0.278	0.009	0.047	0.217	0.219	0.203	0.195
Root length	0.004	-0.003	-0.095	-0.023	-0.021	-0.015	0.001	0.002
Branches/root	0.003	0.004	0.006	0.024	0.007	0.005	0.004	-0.002
Fresh root wt.	-0.159	-0.182	-0.053	-0.066	-0.233	-0.227	-0.176	-0.143
Dry root wt.	0.396	0.439	0.090	0.121	0.544	0.557	0.418	0.365
Fresh shoot wt.	0.311	0.302	-0.004	0.064	0.313	0.311	0.414	0.318
Branches per shoot	-0.045	0.049	0.002	0.006	-0.043	-0.046	-0.053	-0.069
'r' with dry shoot weight	0.805	0.859	-0.048	0.187	0.851	0.873	0.883	0.729
Partial R^2	0.078	0.239	0.005	0.005	-0.198	0.486	0.366	-0.051

Diagonal values are direct effects.

stem fresh weight for both stages of the seedlings. Root length, root secondary branches and stem branches had no significant association with any of the traits for both stages of the seedlings except stem branches with stem fresh weight at 8-month of seedling growth. Root-shoot length ratio, an important trait for the balanced growth of the plant, showed positive association only with root length. Shoot length had maximum variation, which was common with root/ shoot length ratio, was 39% (7-month-old seedlings) and it increased to 47% (8-month-old seedlings). The next important trait was root length, which had 32% common variance (7-month-old seedlings), which increased to 45% (8-month-old seedlings).

Partitioning of phenotypic correlation coefficient of stem dry weight with its related traits showed that the direct effects were of the same significance as of correlation coefficients for both stages of the seedlings, except with root fresh weight for eight-month old seedlings (Table 5). Maximum values on direct effects were of shoot fresh weight followed by height for 7-month-old seedlings, and root dry weight followed by shoot fresh weight for 8-month-old seedlings. Root dry weight through which most of the characters were contributing was an important character for dry shoot weight when the seedlings were 8-month-old. Partial R^2 values showed that 58.2% of the variation in dry shoot weight was due to fresh shoot weight in 7-month-old seedlings, and it decreased to 36.6% in 8-month-old seedlings. Variation due to dry root weight for dry shoot weight was less in 7-month-old seedlings, but in 8-month-old seedlings it was the major component.

Rainfall data and correlation coefficients of shoot length, dry shoot weight and root-shoot length ratio of 7-month and 8-month-old seedlings in nursery with different growth stages of plants in the field are given in Table 6. Shoot length and

Table 6. Correlation coefficients of shoot length, dry shoot weight and root-shoot length ratio of 7-month and 8-month-old seedlings in nursery with different growth stages of plants in the field

Year	Rainfall (mm)	No. of rainy days	Age of plants (in field) (month)	Shoot length (in nursery)		Dry shoot wt./ plant		Root-shoot lenth ratio	
				7-month	8-month	7-month	8-month	7-month	8-month
1994	595.5	36	7	0.698**	0.563*	0.453	0.474	-0.428	0.424
1995	339.6	17	19	0.524	0.327	0.333	0.473	-0.472	-0.342
1996	627.6	26	31	0.448	0.035	0.237	0.279	-0.451	-0.073
1997	440.0	29	43	0.161	-0.411	-0.155	-0.159	-0.176	0.359
1998	478.2	23	55	0.011	-0.433	-0.252	-0.163	-0.035	0.372
2001	437.2	22	91	-0.146	-0.684**	-0.486	-0.474	0.195	0.588*
2002	50.6	7	103	-0.126	-0.674**	-0.467	-0.461	0.212	0.575*
2003	419.7	26	115	-0.142	-0.673**	-0.495	0.475	0.258	0.562*
2004	220.4	16	127	-0.189	-0.693**	-0.541	-0.504	0.312	0.577*
2005	257.1	15	139	-0.141	-0.626*	-0.490	-0.422	0.308	0.516
2006	270.4	20	151	-0.117	-0.597*	-0.457	-0.412	0.349	0.451

*P<0.20, **P<0.010.

dry shoot weight of 7-month and 8-month-old seedlings had a positive association with plant height up to third year of growth, and these relationships became negative with increase in their magnitude with age of the plants in the field. But, Tuttle *et al.* (1987) reported that loblolly pine seedlings planted during drought year showed that height at the time of planting was inversely related to the total seedling height during the first two seasons permitting shorter seedlings at planting to reach the same height as taller ones by age two. Root-shoot length ratio of 7-month- old seedlings had negative relationship up to fifth year of growth and later on this relationship became positive. But in case of seedlings of 8-month-old, this relationship was negative up to third year of growth only. After fifth year these relationships were significant at P<0.20/P<0.10. Positive and increase in the magnitude of the correlation of root-shoot length ratio with height of the established plants in the field showed that the genotypes having more root length than the shoot length will perform better in the field. Though there were no significant relationships (P<0.05), but there was change in sign and magnitude of the relationship with the age of the plants. Under such situations squared correlations are interpreted because the correlation coefficient is misleading in suggesting the existence of more covariation than exists, and this problem gets worse as the correlation approaches zero. R^2 values showed that up to 48.0% of the variation in height of the plants in the field was due to shoot length and 34.6% due to root-shoot length ratio in 8-month-old seedlings.

The findings of this paper of juvenile-adult relationship in *Acacia albida* need confirmation under different agro-ecological conditions.

Acknowledgements

The authors thank the authorities of NBPGR, New Delhi, and Centre Technique Forestier Tropical at Nogent-sur-Marne Cedex, France, for providing the seed material of different provenances of *Acacia albida*.

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