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Early Growth Performance of Sixteen Populations of *Faidherbia albida* in Semi Arid Baringo District of Kenya

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ABSTRACT

***Faidherbia albida* a leguminous tree species is an important component of the traditional farming systems in the arid and semi arid zones of Africa due to its soil conservation and fertility improvement ability, but its establishment in these areas is often difficult. In semi arid Baringo district of Kenya where the entire annual precipitation occurs in less than one quarter of the year, soil erosion is a serious problem. Therefore planting of fast growing, drought tolerant, nitrogen fixing tree species is an important soil conservation and fertility restoration strategy. In this study a field trial of 16 populations of *F. albida* originating from Eastern, Western and Southern Africa was set up at Noiweit, Kenya in April 1997 to (1) compare the early growth performance among 16 African populations of *F. albida* with the aim of selecting the best for introduction and domestication in this semi arid environment; and (2) to gain insights into *F. albida's* nutrient requirements in the field for better establishment and performance. The experiment was set up as a randomized complete block design (RCBD) with five replicates (blocks). Tree height, stem collar diameter and branch number were assessed six months after transplanting seedlings into the field and the status of soil pH, C, N, P, Na, K, Ca, Mg, Exchangeable acidity, and Particle size distribution were analyzed for each of the five blocks. The populations of Eastern and Southern Africa origin had superior growth, compared to the West African. Overall, the Eastern and Southern African were completely integrated and formed a separate entity from the West African populations. The soil of Noiweit was found to be clay loam in nature, acidic with a pH range of between 4.57 and 5.03, and had adequate levels of K, Mg and Ca. Significant differences (P = 0.05) were observed in the growth of the trees among five replicated blocks. Trees in block two had best overall growth performance conforming with, its comparatively higher total N content. Blocks one, two and three had trees with better growth performance, compared to those in blocks four and five which had stunted growth which could be attributed to soil dispersion caused by the higher exchangeable Na concentrations, pH, exchangeable acidity and Ca concentrations. The Ca: Mg ratios in block one, two and three, were all about 1:2 the lowest acceptable ratio, while block four and five had a ratio of about 1:3 indicating reduced Ca availability to plants in the two blocks. Differences in soil chemical properties (block effects) accounted for 63% of the mean variance component and only about 30% by the seed sources (provenances), emphasizing the importance of these two factors in establishing *F. albida* for soil conservation in this area.**

INTRODUCTION

Faidherbia albida (Del.) A. Chev. a leguminous tree species belonging to the mimosoideae subfamily, is an important agroforestry tree, which has long, been used by farmers throughout arid and semi arid zones of Africa for soil conservation and soil fertility improvement. Its unique reverse phenology of shedding leaves during the rainy season at the time of higher microbial activities in the soil improves the soil structure, stability and permeability and retaining leaves in the dry season provides shade and mulch which reduces evaporation thus conserving the available soil moisture. *F albida* has a remarkable capacity for recycling nutrients from underground to the surface due to its very deep root system (Le Houerou, 1980). The tree also stabilizes sand dunes and prevents soil erosion (Dancette and Poulain 1969). *F. albida* does not compete with inter-planted crops for soil nutrients as it enters a period of physiological rest during the normal crop-growing season (ICRAF, 1989).

Increase in yield from crops grown below the trees has been attributed to increased fertility due to nitrogen fixation, dung from stock browsing and fallen leaves and pods (Radwanski and Wickens, 1967). Under a full canopy (100 - 150 trees ha^{-1}) the trees can provide nutrients equivalent to 300 kg ha^{-1} $year^{-1}$ of nitrogen, 30 kg ha^{-1} $year^{-1}$ of phosphorus and 25 kg ha^{-1} $year^{-1}$ of magnesium (Dancette and Poulain, 1969). Soil water retention was 40% higher under *F. albida* than in open fields (Cook and Grut, 1989). Finger millet (*Eleusine coracana*) grown beneath *F. albida* canopy yielded a 2.5 fold increase in grain and 3.4 fold increase in grain protein (Charreau and Vidal, 1965). Sorghum (*Sorghum bicolor*) doubled in yield and groundnuts (*Arachis hypogaea*) yield increased by 37% (Dancette and Poulain 1969). Giffard (1974) reported a carrying capacity of 20 animal units km^{-1} in *F. albida* dominant Savannah compared with 10 animal units km^{-1} when it is absent.

Despite extensive literature in *F. albida* research reports, there is very little, if any, quantitative data on the relationship between soil nutrient availability and *F. albida's* establishment, growth, and biomass production particularly in arid and semi arid environment. Identification of

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Table 1. Collection site data for 16 populations of *F. albida* used in this study.

CI	Code	Population	Country	Zone	Latitude	Longitude	Altitude (m)	Rain (mm)	Temp. °C
OFI	1	Bignona	Senegal	WA	12°45'N	16°25'W	10	1408	26.5
OFI	2	Mana Pools	Zimbabwe	SA	15°45'S	29°20'E	360	628	25.1
OFI	3	Chawanje	Malawi	SA	14°36'S	34°48'E	600	900	24.2
OFI	4	Bolgatanga	Ghana	WA	10°46'N	01°00'W	201	1057	28.2
OFI	5	Mwembe	Tanzania	EA	04°08'S	37°51'E	860	569	23.5
OFI	6	Dumisa	Zimbabwe	SA	22°13'S	31°24'E	280	438	24.7
OFI	7	Debre zeit	Ethiopia	EA	08°43'N	38°59'E	1850	730	--
OFI	8	Pongola river	South Africa	SA	22°20'S	30°03'E	540	340	--
OFI	9	Rama	Ethiopia	EA	14°23'N	38°48'E	1350	742	19.1
OFI	10	Lake Awassa	Ethiopia	EA	07°03'N	38°25'E	1650	961	--
OFI	11	Hoanib river	Namibia	SA	19°15'S	13°23'E	350	98	24.0
CDF	12	Moulvouday	Cameroun	WA	10°23'N	14°50'E	330	815	--
CDF	13	Tera	Niger	WA	14°00'N	00°45'E	240	458	--
CDF	14	Banbora	Burkina Faso	WA	10°34'N	04°46'W	280	800	--
KFI	15	Kainuk	Kenya	EA	01°14'N	35°09'E	500	230	25.0
KFI	16	Tot	Kenya	EA	01°30'N	35°45'E	750	800	21.0

KEY: CI = Collector's Identity; OFI = Oxford Forestry Institute; CDF = Cirad-Foret; KFI = Kenya Forestry Research Institute; WA = West Africa; SA = Southern Africa; EA = East Africa; -- = missing data.

significant site and soil chemical factors associated with growth and productivity of *F. albida* would enable foresters to predict its performance over a range of environments and to focus their research efforts on the impact of a finite number of factors and interactions influencing growth. Quantification of the impact of soil factors would reduce the risk of poor performance or failure in establishment of *F. albida* by allowing avoidance of high-risk sites. The objectives of this study were: (1) to compare the early growth performance among 16 African populations of *F. albida* with the aim of selecting the best for introduction and domestication in this semi arid environment; and (2) to gain insights into *F. albida's* nutrient requirements in the field for better establishment and performance in the semi arid area of Noiweit, Baringo district of Kenya.

MATERIALS AND METHODS

Comparison of Field Growth Performance in 16 Populations of *F. albida* at Noiweit.

Bulked seeds of *F. albida* populations from different geographical regions of Africa were used in this study (Table 1). The samples were representative of the entire natural distribution range of the species in Africa. Noiweit is located at 0°10' N and 36°00' E and at an altitude of 1,500 meters above sea level and was classified as a semi-arid area (Teel, 1984) with mean annual rainfall range between 500 and 800 mm and has an average annual temperature of 21°C.

The four-month old potted seedlings were planted in the field on April 12, 1997, in a randomized complete block design (RCBD) with repeated observations. There were five blocks and in each block, there were 16 experimental units representing each of the populations of *F. albida*. In each unit, there were two seedlings from the same population. In total, there were ten seedlings per population in the whole design at a spacing of 3m x 3m. Height, diameter and branches were assessed six months after transplanting (a total of ten months after planting).

Soil Sampling and Analysis

Soils (0 - 30cm depth) were sampled at three randomly selected sites from each block six months after transplanting the *F. albida* seedlings into the field. In each site samples were collected from topsoil (0 - 15cm depth) and subsoil (15 - 30cm depth). Thus, six soil samples were taken from each block (total of 30 samples for all the five blocks). The soil samples were air-dried, crushed and sieved through a 2mm sieve and a further sub-sample ground finely to pass through a 60-mesh screen for total N, organic C and P analysis.

pH determination

Soil pH was measured in a 2.5:1 soil to water suspension using a glass electrode in a pH meter.

Determination of organic carbon

Organic carbon was estimated by the dichromate oxidation method of Nelson and Sommers (1975).

Determination of total nitrogen percent

Total N was determined by the wet digestion procedure, whereby the ammonium was distilled off and measured by titration with sulfuric acid (the semi micro-Kjeldahl method).

Determination of extractable soil phosphorus

Available P was extracted from soil using the sodium bicarbonate (0.5M $NaHCO_3$; pH 8.5) procedure of Olsen et al. (1954), followed by the P determination in extracts using the colometric ascorbic method described by Murphy and Riley (1962).

Determination of K, Na, Mg and Ca

Exchangeable cations (K, Na, Mg and Ca) were determined by extraction of soils using 1*M* ammonium acetate solution buffered to pH 7.0. Followed by the measurements of Na, K and Ca in the extracts on a flamephotometer and Mg on atomic absorption spectrophotometer.

Determination of exchangeable acidity

Because of pH dependency on Al activities in soils (McLean, 1965) exchangeable acidity (H + Al) was determined titrimerically using unbuffered neutral salt 1M KCl. Thus, the soils were extracted with 1M KCl solution followed by filtration and titration of the aliquots of the extracts using 0.05M NaOH. The amount of this base used was equivalent to the total amount of acidity in the aliquot taken.

Soil particle size analysis

The clay, silt and sand contents of soil samples (particle size) were estimated using the hydrometer method described by Bouyoucos (1962), using the sodium hexametaphosphate solution (calgon) as a soil dispersing agent and making temperature corrections of the solution.

Statistical Analysis

Both plant growth parameters data and soil analysis data were subjected to ANOVA and significant treatment effects separated using Duncan's Multiple Range Test (DMRT) and Least Significant Difference (LSD), using SAS (1991) statistical package. For soil analysis, the five blocks were considered as treatments and the three sampling sites in each block as replications.

Table 2. Analysis of variance for three growth parameters of 16 populations of *F. albida* at Noiweit six months after planting.

		Height (cm)		Diameter (cm)		Branch number	
Sources Of variation	Df	MS	F value	MS	F value	MS	F value
Replication	4	3378.15	10.44*	1.098	12.28*	388.08	4.33*
Population	15	1849.57	5.72*	0.310	3.46*	228.93	2.56*
Error	140	323.51		0.089		89.54	
				Variance Components (%)			
Replication		61		73		55	
Population		33		21		32	
Error		1		6		13	

KEY:MS = mean square, * = significant at P = 0.05.

Table 3. Variation in height, collar diameter and branch number among the 16 populations of *F.albida* six months after planting in Noiweit.

	Heights (cm)			Diameter (cm)			Branch number	
Pop.	**Mean**	**Zone**	**Pop.**	**Mean**	**Zone**	**Pop.**	**Mean**	**Zone**
2	79.1a	SA	3	1.300a	SA	6	31.7a	SA
6	78.0ab	SA	6	1.296a	SA	15	25.9ab	EA
11	74.2ab	SA	2	1.277a	SA	2	24.4abc	SA
15	67.7abc	EA	8	1.237ab	SA	11	23.6abc	SA
5	62.8abcd	EA	9	1.179abc	EA	7	22.2bc	EA
3	62.1abcd	SA	7	1.178abc	EA	8	21.7bc	SA
9	61.7abcd	EA	10	1.112abcd	EA	3	21.5bc	SA
7	61.2abcd	EA	15	1.108abcd	EA	16	19.8bc	EA
8	61.0abcd	SA	11	1.097abcde	SA	10	18.6bc	EA
10	60.0bcde	EA	5	1.041abcde	EA	5	17.3bc	EA
16	59.4bcde	EA	16	0.954bcde	EA	1	17.0bc	WA
13	49.1cdef	WA	1	0.878cde	WA	9	16.8bc	EA
1	45.9def	WA	14	0.870cde	WA	14	16.2bc	WA
12	42.5ef	WA	4	0.854de	WA	12	14.8c	WA
14	39.0f	WA	13	0.852de	WA	13	14.6c	WA
4	32.1f	WA	12	0.791e	WA	4	14.5c	WA
CV	30.75			28.11			47.22	
SD	17.99			0.3			9.46	

KEY: Pop. = Population; CV= Coefficient of variation; SD = Standard deviation. Codes for provenances and abbreviations for zones are given in Table 2. Means followed by the same letter in each column are not significantly different at P = 0.05 (DMRT = Duncan's Multiple Range Test).

RESULTS

Evaluation of Early Growth Performance of F. albida

The six months field performance of *Faidherbia albida* in Noiweit showed that plant height, collar diameter and number of branches were significantly different (P = 0.05) or between populations from different regions in Africa. Sources of origin (provenances) variations accounted fbetween 21% and 33% and the experimental error between 1% and 13% depending on parameter (Table 2).

The three leading populations in height growth were all of Southern African origin (Table 3). The Eastern and Southern African populations were completely integrated with no clear-cut statistical differences among them. The West African populations statistically formed a distinct entity with no significant statistical differences among the populations (Table 3).

Collar diameter showed no significant variation between Eastern and Southern African. However, the four best collar diameter growths were recorded among Southern African populations. The East African populations had intermediate values between Southern and Western African populations except for Hoanib River (Namibia) that was peculiarly grouped with the East African populations. The poorest collar diameter growths were recorded among the West African populations. Although there were no clear-cut statistical differences between the West and the East African populations with regard to collar diameter, the West African populations still form a distinct group with least collar diameter growth relative to the Eastern and Southern African populations (Table 3).

No clear-cut significant difference (P = 0.05) was observed on regional or geographical basis among all the populations with regard to the branch number. Overall, East and Southern African populations were completely integrated, except for Rama (Ethiopia), which was categorized together with the West African populations, which formed a distinct entity.

Variation in Growth Performance of *F. albida* Populations between Replications

There were significant differences (P = 0.05) among the five replicates (blocks). In all the three parameters, between 55% and 73% of the variations were due to replications (Tables 2). With regard to height, block two had the best overall growth, followed by block one. Block three was significantly different from block two but similar to block one. Block four and five were statistically similar and had the poorest overall height growth, they were significantly different from block one, two and three (Table 4). Based on diameter growth for all the populations, block one, two and three were statistically similar, however block two had the best diameter growth, followed by block one and then block three. Block four and five were similar statistically, but significantly different from the first three blocks and had poor diameter growth (Table 4).

Table 4. Variation in height, diameter and branch number among the five blocks at Noiweit.

Height (cm)		Diameter (cm)		Branch number	
Block	Mean	Block	Mean	Block	Mean
2	71.844a	2	1.269a	2	25.375a
1	63.344ab	1	1.163a	1	21.250ab
3	60.696b	3	1.151a	3	19.375b
4	48.250c	4	0.896b	5	17.719b
5	48.031c	5	0.841b	4	16.469b
CV	30.75		28.11		47.22
SD	17.99		0.3		9.46

KEY: Means followed by the same letter in each column are not significantly different at P = 0.05 (DMRT = Duncan's Multiple Range Test); CV= Coefficient of variation; SD = Standard deviation.

Table 5. Variation in soil parameters among the five blocks of the experimental plot in Noiweit six month after planting.

Soil parameter	Block 1	Block 2	Block 3	Block 4	Block 5	LSD
PH (H_2O)	4.57c	4.57c	4.71bc	5.03a	4.97ab	0.28
Organic C %	0.95b	1.03ab	1.13a	1.02ab	0.99b	0.12
Total N %	0.09b	0.21a	0.11b	0.12b	0.12b	0.04
Olsen's P (ppm)	32.50bc	27.50c	57.50a	38.33abc	53.33ab	22.97
Na (cmol kg^{-1})	2.61b	2.32b	2.61b	3.48ab	3.91a	1.30
K (cmol kg^{-1})	6.41abc	5.72c	7.09ab	5.98bc	7.44a	1.32
Ca (cmol kg^{-1})	9.47bc	7.60c	8.93c	11.20ab	13.07a	2.08
Mg (cmol kg^{-1})	4.13ab	3.20b	3.60ab	3.07b	4.53a	1.08
XA (cmol kg^{-1})	1.33a	1.33a	1.33a	1.67a	1.67a	1.56
Sand %	42.72a	41.39a	41.39a	40.72a	41.39a	2.82
Clay %	36.96a	37.51a	36.96a	37.93a	35.51a	4.23
Silt %	20.87a	21.11a	21.65a	21.35a	23.11a	4.89

KEY: XA = Exchangeable acidity; LSD = Least significant difference. Means followed by the same letter in each row are not significantly different at P = 0.05 (LSD).

The highest numbers of branches were observed in block two for all populations, followed by block one, these two blocks were not significantly different (P = 0.05). Block one, three, four and five were statistically similar, however, block four had the least number of branches second to block five. Overall, the performance of the three parameters studied were best in block two followed by block one and three, respectively, and worst in block four and five.

Variation in Soil Properties among Replications (Blocks) in Noiweit

The soil physical and chemical characteristics in different blocks varied with some nutrients although they were similar in other blocks (Table 5). The soils in the experimental plot were strongly acidic and were low in both nitrogen and organic carbon contents, typical of arid and semi arid soils. According to the rating of soils by Tekaglin et al. (1991), it is evident that K, Mg and Ca levels were adequate in Noiweit soil. The soil had very high phosphorous content, which could be due to management factors for example previous burning, and possibly the P status of parent material. Based on particle size distribution, the soil was classified as clay-loam and hence have low water and moisture retention capacities.

DISCUSSION

Effect of Seed Sources (Provenances) on Growth Performance of F. albida at Noiweit

The high inter-population variability as evidenced by the high CV = 30.75 and SD = 17.99, in height was partly due to seed sources. Height was categorized into two well-defined groups; one group consisted entirely of Eastern and Southern African populations and the second group was made up of West African populations. The lack of differentiation among Eastern and Southern African populations could be due to similar climatic and environmental conditions in the two regions. In addition, the Eastern and Southern African populations even though found in semi-arid regions of Africa, do not encounter great climatic extremes in their native habitats and hence do not contain a great amount of genetic variability associated with place of origin (Wright, 1976). On the other hand the West African populations being at the limit of the species distribution, bordering the Sahara desert tends to experience high selection pressure and represent a genetically distinct geographic race (Burley et al., 1986). Stern and Roche (1974) reported that, habitat correlated genetic variation occurs within wide spread species because of natural selection.

The most outstanding result was the superior height growth of the three Southern African populations of Mana Pools (Zimbabwe), Dumisa (Zimbabwe) and Hoanib River (Namibia). The early fast height growth of Southern African populations increases their importance for agroforestry and soil conservation in the East African region, since populations with faster growth habit can shorten establishment period and protect the soil from excessive soil erosion (Sun et al., 1995).

About collar diameter, there was no clear-cut statistical differentiation between the Eastern and Southern African populations, although the Southern African populations had bigger diameter, followed by East African populations with intermediate values and West African had the least. This suggests that the pattern of genetic differentiation among the populations was continues (Riemenschneider and McMahon, 1993) and seems to confirm the clinal pattern of variation observed in seed and seedling traits (Dangasuk et al, 1997). Height and diameter had been found to have high habitability values in young *Acacia auriculiformis* (Bernard, 1996) and young *F. albida* (IRBET-CTFT, 1989) and therefore may form good parameters for early selection criteria for improvement of *F. albida, as* well as for selection of populations of *F. albida* for soil conservation program in the semi arid Baringo district, where soil erosion is a serious problem due to the few days of heavy precipitation in a year and the scanty vegetation cover.

About the branch number, the two common groups of Eastern and Southern African and West African populations were also evident in the DMRT analysis. The result of this study is in agreement with Otegbeye and Samarawira (1992) that faster growing trees invariably have more room for branch development than slower growing trees.

Effects of Soil Properties on Early Growth of *F. albida* Among the Five Blocks

There were significant differences in the six months performance of *F. albida* trees among the five blocks in the experimental plot, which could be due to local variation in physical and chemical properties of the soil. Variability in soil physical and chemical properties within short distances (10 to 15 m) based on the properties of parent rocks in Baringo district had been reported by Bryan (1994). Spatial variability in growth rate of crops and trees over distances of only 5 to 20 m is wide spread in the Sahelian zone of West Africa which is thought to be due to pre-existing variability in soil physical and chemical properties (Scott-Wendt et al., 1989; Manu et al., 1990; Geiger and Manu, 1991). Blocks used for provenance trials are usually so large that field micro-variability is normally present hence increasing intra-plot error and obviating effective analysis of variance (Vandenbelt, 1992).

The exceptionally superior growth performance of the trees in block two could be attributed to the comparatively highest total Nitrogen availability in that block (McLaren and Cameroun, 1990). Dunham (1991) reported soils being more acidic under *F. albida* in Mana Pools compared to open areas, contrary to previous studies, which indicated the opposite. If confirmed, then the species could be considered to have preference for acidic soils, which could be a probable explanation for the comparatively better performance of the species in block, one and two which had the greatest soil acidity in this study.

The stunted growth of trees observed in block four and five could be due to soil dispersion caused by their relatively higher exchangeable sodium concentration (Courtney and Trudgill, 1976; Landon, 1991). Alternatively, it could be due to the higher concentration of exchangeable acidity in block four and five relative to the other three blocks (Geiger et al., 1992). The Ca^{2+}:Mg^{2+} ratios in block one, two and three were all about 1:2, the lowest acceptable ratio, while both block four and five had the same ratio of about 1:3 indicating reduced calcium availability even when exchangeable calcium in the two blocks indicated high levels (Rowell, 1994), which could be another reason for the significantly poor tree growth in the two blocks. The significantly higher concentration of calcium in block four and five might have resulted into the significantly higher pH values in the two blocks relative to the other three blocks, due to calcium liming ability (Courtney and Trudgill, 1976).

F. albida is successful in sandy alluvium and sandy clay in the West African Sahel (Fagg, 1992) and on alluvial soil in Eastern and Southern Africa (Joly, 1992). The soil in Noiweit is predominantly clay loam and hence the present trial need to be maintained and monitored for sometimes in order to come up with firm conclusions and recommendations on the growth performance of *F. albida*, as well as its importance for soil conservation in this type of soil.

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