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Effect of spacing and irrigation regimes on the growth and biomass production of *Faidherbia albida* transplants

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Abstract: The study aimed to examine growth performance of *Faidherbia albida* (Del.) A. Chev. Under field conditions as influenced by different spacing and irrigation regimes. It was conducted in Soba, ten kilometer south of Khartoum (Sudan) in June 2008. The experiment treatments consist of three irrigation regime intervals; 5 days interval; 10 days interval and 15 days interval. In addition, three transplanting spacing was adopted namely: 1x1 m spacing; 1x2 m spacing and 2x3 m spacing. The experimental plot was divided into three parcels (each of about 552 m^2 area) according to irrigation regimes. Each parcel was also divided into three sections (replications) according to the transplanting distances; the experimental design and layout was a Randomized Complete Block Design (RCBD). A three month old *faidherbia albida* transplants (shoot height 20 cm) were planted in the field on 1st August 2008. The number of transplants in each spacing parcel was: 48 seedlings in 1x1 m (144 in the 3 irrigation regimes); 45 seedlings in 1x2 m (135 in the 3 irrigation regimes) and 36 seedlings in 2x3 m (108 in the 3 irrigation regimes), making a total number of 387 seedlings in the field. The seedlings were uniformly irrigated for three months after that, by applying the three specified irrigation regimes. The growth parameters measurements started as from 29th November 2008 (3 month's transplants). Shoot height for all seedlings was measured monthly by using a ruler. The height measurement continued for a period of seven months until 29th June 2009. The seedlings diameters was measured at the ground level (root collar) using a sensitive caliper when the seedlings were harvested for dry weight determination, then a sample (3 seedlings) was dug out from each section, selected randomly, making a total of 27 seedlings. The roots were separated from the shoots at root collar and then the roots and the shoots fresh weights were recorded. The seedlings were oven dried at 80 °C for 24 hours, then the dry weight of shoots and roots were recorded. The result shows that in the irrigation intervals of *F. albida* transplants, shoot height and weight growth were highest for seedlings irrigated every 5 days (84 cm length and 400g weight) respectively; these parameters were lowest for transplants irrigated every 15 days (61 cm length and 91 g weight) respectively, with significant differences. Root dry weight growth was highest for transplants irrigated every 10 days (100 g) and lowest for those irrigated every 5 days (65 g). Plant spacing had direct effect on seedling growth. The height and weight growth increase with increasing spacing between the seedlings in each irrigation regime.
Keywords: *Faidherbia albida;* irrigation; spacing

INTRODUCTION

Faidherbia albida (Del.) A. Chev is a monotypic genus in the legume subfamily Mimosoideae [4], occurs naturally from 270 m below sea level in Israel to 2700 m in Sudan [4], it can thrive under a very wide range of meteorological conditions from desert conditions in southwest Africa where the mean annual rainfall is only 20 mm and the mean annual daily temperature 16.8 °C And in humid tropical conditions in west Africa with mean annual rainfall of 1800 mm and a mean annual temperature of 28 °C [11] its occurrence is generally limited to watercourses where groundwater is present. *Faidherbia albida* occurs on a remarkably wide range of soils. Most characteristically, it colonizes deep sandy clay soils, particularly alluvial deposits along the flood plains of rivers [12, 27, 29]. In Sudan, *F. albida* occurs in various habitats, ranging from alluvial soils of perennial or seasonal water courses, to open savanna woodland and cultivated land. The trees occur singly or gregariously, widespread along rivers and water depressions [10, 26]. It is also found fringing shallow drainage depressions of the *A. Senegal* dominant savanna thorn land on sandy soils to the west of the Nile where it is sporadic in occurrence. The sandy alluvial soils of the Jebel Marra drainage system in western Sudan support the largest population of *F. albida*

Pure stands occur in belts up to a mile wide, and in places the communities form an almost closed canopy along the Wadis of Kaja and Azum and their major tributaries. The tree is primarily used as a dry season fodder reserve and it is best used in agroforestry; its nitrogen rich leaves which are shed at the beginning of the rainy season serve to significantly improve and fertilize the soil, and thus benefit crop growth [31]. The regeneration potential is enormous but the death of trees caused by the rather careless management is common, leaves and pods are browsed by all livestock. The tree bark is used as medicine [22]. *Faidherbia albida* is tolerant to all soil types including saline soil, in drier areas its main requirement is a high ground water table which must be reached by the tap root before growth [31]. Most *Faidherbia albida* trees growing today are believed to have originated as natural regenerations and it's continuously been cleared for various purposes among which mechanized and traditional farming constitute the main factors [22]. *Faidherbia albida* is a valuable tree but may be difficult to establish naturally [31] because of browsing, drought, fire, cutting and pollarding by man, so that no chance is allowed for the tree to flower and make fruits, seeds and also its initial growth is slow. There is need to domesticate natural tree species by converting them into plantations, hence study their regeneration, growth and development in artificial conditions. Among natural species needed to be domesticated, is *Faidherbia albida*. Few studies have been carried out for this valuable tree species, in term of regeneration and growth patterns. The study seeks to determine the Juvenile tree establishment under field conditions as influenced by different spacing and irrigation regimes

MATERIAL AND METHODS

This experiment was conducted in Soba, south of Khartoum, Sudan (longitude; 30 30 E, Latitiude; 15 30 N), in an area of 0.25 hectares. The average annual temperature in Khartoum is 29.8 °C. Total annual rainfall is about 164 mm. The average annual relative humidity is 21.8% (Khartoum Metrological Station, 2009)

The experiment

The treatments consist of three irrigation regime intervals; 5 days interval; 10 days interval and 15 days interval. In addition, three transplanting spacing: 1x1 m spacing; 1x2 m spacing and 2x3 m spacing. The field was cleaned in June 2008 and then divided into three parcels (each 552 m^2 area) according to irrigation regimes. Each parcel was also divided into three sections (replications) according to the transplanting distances; the experimental design and layout was a Randomized Complete Block Design (RCBD). On 1st August 2008, three month old Faidherbia albida transplants totaling 387 were planted in the field: 48 seedlings in 1x1 m spacing (144 in the 3 irrigation regimes); 45 seedlings in 1x2 m (135 in the 3 irrigation regimes) and 36 seedlings in 2x3 m (108 in the 3 irrigation regimes). The seedlings were uniformly irrigated for three months then applying the three specified irrigation regime.

The height measurement started on 29th November 2008 and was done monthly using a ruler, it continued for a period of seven months until 29th June 2009. The seedlings diameters was measured at root collar using a sensitive caliper after harvesting for dry weight determination for 27 random sample seedling (3 seedling from each section. The roots were separated from the shoots at root collar and then the roots and the shoots fresh weights were recorded. The seedlings were oven dried at 80 °C for 24 hours, then the dry weight of shoots and roots were recorded.

Soil analysis

A soil profile was dug, described and sampled according to the USDA monograph [30]. The samples were taken at four randomly selected sites in the experimental field by using a mechanical auger. In each site samples were collected from the top soil (0-30 cm), sub soil (30-60 cm) and bottom (60-90 cm). Samples of every two similar sites from equal depths were mixed together, thus making a total of 9 samples taken from the field. The soil samples were air dried, crushed and sieved through a 2 mm sieve, and a further sub-sample ground finely to pass through 60 mesh screens for total nitrogen, organic carbon and phosphorus analysis.

The field soil samples were analyzed for the following parameters: 1/ Particle size distribution was obtained by using the modified hydrometer method [8], and the textural classes were assigned according to the American system (30); 2/ Bulk density was determined by the cylinder method; 3/ Water holding capacity was measured by the gravitational method and field capacity and wilting point were outlined; 4/ pH was measured in a 2.5: 1 soil to water suspension using a glass electrode of a pH meter; 5/ Electrical conductivity (ECe) was measured by an electrical conductivity meter in a water extract aliquot of the soils; 6/ Exchangeable elements were extracted by the International Method using Ammonium acetate, then Ca and Mg were determined by titration with versenate [7]. Na and K were determined directly by using an EEC flame photometer on an appropriate dilute portion of the solution extracts; 7/ Nitrogen was determined by micro-kjeldahl method [24]; 8/ Phosphorus determined by spectrophotometer using $NaHCO_3$ method (7); 9/ Organic carbon was obtained by Walkely and Black method [32] and the organic matter equated organic carbon x 1.72. All the chemical determinations were carried out according to the international procedure of plant and soil analyses [17, 23].

STATISTICAL ANALYSIS

The data obtained were analyzed by a PC computer and the temporal variation of growth was represented by curves traced on an Excel Spread Sheet. The final data were subjected to ANOVA test by a SAS program (28) and the significant levels for the mean separations were assigned according to Duncan's Multiple Range Test ($P \leq 0.05$)

RESULTS

Characterization of field soils

The profile at a depth of 0-30 cm, the soil color is dark yellowish brown, it is loamy sand; very friable dry with many fine roots, calcareous. In the depth of 30-60 cm the color is dark grayish brown it is firm clay loam, moderate medium angular blocky, slightly sticky very hard dry, moist; few fine and medium vertical tubular pores, presence of roots; calcareous. In the depth 60-108 cm the color is grayish brown to light olive brown it is clay loam, medium angular blocky, sticky wet, slightly plastic, fine vertical tubular pores; roots: few large roots; abundant, fine and medium, soft disseminated carbonate filaments, (gypsic); boundary clear, smooth .

The laboratory analyses of the field soil physical and chemical properties are presented in Table 1. The particle size distribution was predominated by clay 52%, sand 30% and less in silt 16%. The textural class of the soil was clay loam with a bulk density of 1.4 g/cm^3. This soil also contained high carbonate content. The soil had neutral reaction with mean pH value of 7.6. The exchangeable cations were moderately furnished in the surface layer and increased with the soil depth. The N, P and K contents were not very high. Also the organic matter content was very low; the C/N ratios increased with the soil depth.

Table1: Physical and chemical characteristics of the field soil

Soil depth (cm)	S.P	M.C (%)	Particles size distribution (%)			B.D (gcm^{-3})	$CaCO_3$ (%)	Ece (dsm^{-1})	pH
			Sand	Silt	Clay				
0-30	53.8	4.3	37.7	18.0	44.3	1.5	8.2	2.7	7.6
30-60	66.8	5.9	30.5	16.8	52.6	1.4	8.2	6.5	7.6
60-90	70.2	5.9	36.9	12.9	50.1	1.4	8.2	8.4	7.7

S.P: Saturation %; M.C: Moisture Content Percentage; B.D: Bulk Density; ECe: Electrical Conductivity; O.C: Organic Carbon; O.M: Organic Matter.

Table 1: Continued.

Soil depth (cm)	Soluble cations ($meqL^{-1}$)				O.C (%)	O.M (%)	N (%)	C/N	P (ppm)
	Ca	Mg	K	Na					
0-30	10.4	4.1	0.1	20.4	0.4	0.6	0.05	0.1	0.26
30-60	15.5	8.5	0.1	30.0	0.2	0.4	0.02	10	0.25
60-90	14.3	8.0	0.1	70.5	0.2	0.3	0.01	11	0.29

The temporal growth rate of F.albida transplants under different irrigation regimes and spacing

The shoot height growth of *F. albida* transplants which were irrigated every 5 days was identical for plants spaced 1x1 and 1x2 m, up to the fourth month from the date of planting. The shoot height for plants spaced 2x3 m was at a lower rate to the precedent spacing distances up to the fourth month. Generally the height growth of transplants in the three spacing started at a higher rate of about 8 cm per month up to the third month then the growth rate reduced to an average of one centimeter per month. From the fifth month onwards the growth rate was totally reduced for all the transplants in all the spacing up to the end of the monitoring period (Fig. 1).

The shoot height growth of *F. albida* transplants which were irrigated every 10 days was close to each other in 1x2 and 1x1m spacing. The transplants spaced 2x3 m had the higher growth rate with an average of 15 cm per month up to the third month then the growth rate was reduced to 10 cm per month. From the fifth month onwards the growth rate stabilized. The growth rate of transplants spaced 1x1 and 1x2 m progressed rapidly from the start with an average of 10 cm per month, up to the third month, then it stabilized. There was a very big gap in height growth between plants spaced 2x3 m and the other two spacing (Fig. 1).

The shoot height growth of *F. albida* transplants which were irrigated every 15 days started with a rapid rate in spacing 2x3 m with an average rate of 10 cm per month up to the third month, then the growth rate was reduced to 5 cm per month till the fourth month and thereafter the growth stabilized. The growth rate of transplants spaced 1x1 m progressed rapidly with an average rate of 12 cm per month up to the fourth month, then it stabilized. The transplants spaced 1x2 m had an average growth rate of 8 cm per month up to the fourth month then it stabilized. The growth rates of transplants spaced 1x1 and 1x2 m were close to each other. However the transplants spaced at 2x3 m had a higher parallel growth level compared to the other two spacing (Fig.1).

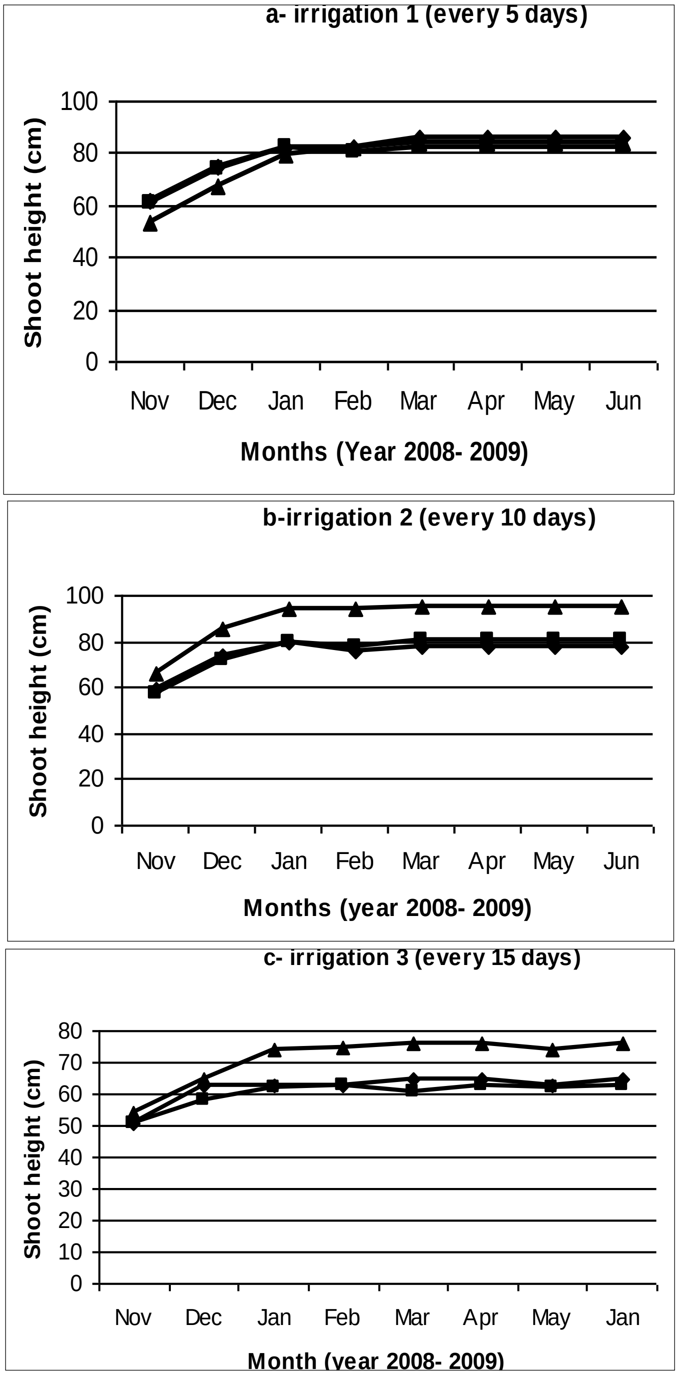

Fig 1: Cumulative shoot growth of *Faidherbia albida* seedlings in the field at different spacing: S1 (♦: 1x1 m), S2 (■: 1x2 m) and S3 (▲: 2x3 m).

Final assessment of *F. albida* transplants on the growth and biomass production as effected by irrigation regimes and spacing

Final observations were taken after seven months from planting date; the measured growth parameters were shoot height, shoot diameter, shoot dry weight, root dry weight, shoot/root dry weight ratio. It was observed that for plants irrigated every 5 days, there were no significant differences between the different spacing (Table2). However, the highest value of shoot height was recorded for transplants spaced 1x1 m (86.2 cm) and the lowest value was recorded for transplants spaced 2x3 m (83.4 cm). For transplants irrigated every 10 days, there were no significant differences in shoot height between all the different spacing. The highest value of shoot height was recorded for transplants spaced 1x2 m (97.5 cm) and the lowest value was recorded for those spaced 1x1 m (77.9 cm). For transplants irrigated every 15 days, there were significant differences in the shoot height between transplants spaced 2x3 m and the other spacing. There were no significant differences in shoot height between transplants spaced 1x2 m and 1x1 m. The highest value of shoot height was recorded for transplants spaced 2x3 m (75.6 cm) and lowest value was recorded for 1x2 m (61.7cm) spacing (Table 2) (Plate 1, 2 and 3).

For transplants irrigated every 5 days and every 10 days, there was no significant differences in the shoot dry weight between all the different spacing (Table 2). On the other hand, for plants irrigated every 15 days, there were significant differences in shoot dry weight between transplants spaced 2x3 m and the other spacing. There were no significant differences in root collar diameter, root dry weight and shoot/root weight ratio between all the different spacing in all irrigation regimes (Table 2).

Table 2: Growth and biomass analysis of 5 months old transplants of *F. albida* grown at different irrigation regimes and spacing under field conditions

Irrigation regimes	Spacing (m)	Shoot height (cm)	Diameter (mm)	Shoot dry weight (g)	Root dry weight (g)	Shoot/Root weight Ratio
Every 5 days	S1 (1x1)	86.3a	19.9a	308.3a	65.1a	3.6a
	S2 (1x2)	84.5a	20.3a	400.0a		
	S3 (2x3)	83.4a	21.5a	361.1a		
Every 10 days	S1 (1x1)	77.9a	17.1a	237.5a	100.1a	2.5a
	S2 (1x2)	97.5a	19.1a	283.3a		
	S3 (2x3)	80.6a	18.7a	244.4a		
Every 15 days	S1 (1x1)	65.2b	19.7a	91.6b	68.3a	2.7a
	S2 (1x2)	61.7b	16.5a	150.0b		
	S3 (2x3)	75.6a	16.8a	238.8a		

Means followed by the same letter (s) in the column are not significant different at $p \geq 0.05$ (Duncan Multiple Range Test).

Plate1: *Faidherbia albida* juvenile transplants spaced at 1x1 m in the field (5 months old)

Plate 2: *Faidherbia albida* juvenile transplants spaced at 1x2 m in the field (5 months old).

Plate 3: *Faidherbia albida* juvenile transplants spaced at 2x3 m in the field (5 months old)

DISCUSSION

The experimental result shows that *Faidherbia albida* transplants, shoot height and weight growth were highest for seedlings irrigated every 5 days (84 cm length and 400g weight) respectively; these parameters were lowest for transplants irrigated every 15 days (61 cm length and 91 g weight) respectively, with significant differences $p \geq 0.05$. Root dry weight growth was highest for transplants irrigated every 10 days (100 g) and lowest for those irrigated every 5 days (65 g) (Table 2). The decline in the *F. albida* transplants height and weight as the irrigation frequencies decreases are in line with what have been reported by [9,18, 19] who observed that with the decrease of soil water content, shoot growth is retarded, and thus plants developing under adverse soil water condition are often stunted and dwarf [9, 20, 21]. Mean height and diameter of acacia seedlings, therefore was reduced in water stress and consequently stem dry weight. Reduction in height and diameter growth of acacias due to water stress has been observed in previous studies of Pokhrival *et al.;* [25] for *Acacia nilotica* and Awodola [2] for *Faidherbia albida* and *Acacia seyal*. The observed increase in root dry weight as irrigation frequencies were reduced is supported by what have been reported by Kozlowski [18], that when soil moisture decreases, that could cause a greater increase in the root than the shoot [20].

Plant spacing had direct effect on seedling growth. The height and weight growth increase with increasing spacing between the seedlings in each irrigation regime. Increasing stem diameter and height of *F. albida* transplants with increasing the distance between them is simply a result of exploiting the available below ground resources (water and nutrient) by less number of transplants. Aref *et al.;* [1] found similar result with Leucaena stand experiment in Saudi Arabia in which spacing between rows and plants influenced seedling growth. Increasing spacing would also increase biomass of branches, leaves and main roots of trees [3]. Corollary, the shoot/root dry weight ratios of *F. albida* transplants were affected by irrigation regimes and spacing. When the water supply is limiting allocation of assimilates tend to be modified in favor of root growth and leads to increase root dry weight and consequently the root to shoot ratio increases [13, 14]. Although, growth of both roots and shoots decreases under drought conditions the root/shoot ratio generally increases [19]. This is true because above ground growth is affected more severely than below ground growth [6, 33]. Joly *et al.;* [15] considered this as an adaptation that restricts transpiration surface area and increases water absorption from the soil. This finding concurs with the results of Barrose and Barbose [5] for A*cacia farnesiana* and with others for different woody species.

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