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Effects of Irrigation Interval and Planting Spacing on the Establishment and Growth of *Faidherbia albida* (Del.) A. Chev. Transplants in Arid Land Soils*

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Abstract: The study aimed to assess the establishment of *Faidherbia albida* transplants under the effect of irrigation intervals and planting spacing in the field conditions. It consisted of three irrigation intervals of 5, 10 and 15 days and three planting spacings of 1x1 m, 1x2 m, and 2x3 m; and it was conducted in the premises of the Forest Research Center, Khartoum, during May 2008 to June 2009. The results showed that the temporal growth rate of *F. albida* shoot heights was greater in winter (November-February), but it was seriously slowed during the summer period (March-June). The shoot height, diameter and biomass growth of *F. albida* increased with decreasing irrigation intervals; the growth of these parameters was highest in 5 days interval and lowest in 15 days interval. Planting spacings had no direct definite effect on *F. albida* seedlings' growth parameters. Even though, in the longer irrigation intervals, transplants' growth tented to be greater in the wider spacing. Root biomass development seemed to be higher in the longer irrigation interval regimes. There were no significant differences in the foliar nutrient content of the transplants between the different irrigation intervals. The values of mineral elements measured in this study are indicative of moderate nutrient supply for the *F. albida* transplants.

Key words: *Faidherbia albida* establishment; irrigation intervals; panting spacing; dry land soil.

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INTRODUCTION

Artificial regeneration and domestication of natural tree species is becoming more and more indispensable, because there are still many valuable species at wild status, and the natural regeneration conditions are becoming more precarious as ever (FAO 2003; Simons and Leakey 2004). In effect, tree natural regeneration is seriously challenged by many factors, both natural and human induced. Among the natural causes hindering the tree regeneration are prolonged droughts, land degradation and desertification and fires, particularly in Africa. Human causes are many and may include irrational land use (for especially mechanized agriculture and shifting cultivation), overgrazing, fires, clear cutting and over exploitation of trees (Evans 2001a and 2001b; FAO 2003; FAO 2004; Chauhan 2007).

Faidherbia albida (familay: Leguminosae, subfamily: Mimosoideae) is one of the valuable tree species that is still regenerated by natural methods and needs to be domesticated. It is pan African in its distribution, and widely present in the tropical and subtropical regions of the continent and it is found the Middle East. It has been introduced into India, Pakistan, Nepal, Peru, Cyprus, Cape Verde and the Ascension islands. It is present in different areas of Sudan including Darfur, Kordofan and Blue Nile, and preferably in light soils in valleys and along water courses (Wickens 1969; Vogt 1987; Miehe 1988; El Amin 1990; Barnes and Fagg 2003). It is a multipurpose tree rendering many services and goods including timber (both sawn and round), fire wood and charcoal, utensils and implements, fodder (both foliage and pods) and fencing. The services are agroforestry; soil conservation, amelioration and fertility, shade, amenity, bee keeping and honey and medicine (Miehe 1986; Vogt 1987; Saka and Bunderson 1989; Barnes and Fagg 2003). Thus, in view of the obvious benefits drawn from the species, it deserves to be brought under some kind of domestication, particularly that it is becoming more vulnerable under natural conditions due to over exploitation and degradation.

The study aimed at assessing establishment and growth development of juvenile transplants of *F. albida* under field conditions and under effects of variable irrigation intervals regimes and planting spacing.

MATERIALS AND METHODS

Site: The trial plots were located within the premises of the Forestry Research Center, Soba suburb 10 km south of Khartoum city centre (Longitude: 30°30′E, Latitude: 15°30′N). The general climate of the area is semi-arid type and characterized by very low erratic rainfall (164 mm per annum), occurring mostly between July and September. Average annual temperature is about 29.8°C; the hottest months are May-June ($T \approx 42$°C) and the coldest months are December-January ($T \approx 16$ °C). The average annual relative humidity is 21.8%; it drops to about 13% during the hottest winds in March-April and rises to 42% during the wetter period in August (Khartoum Metrological Station data).

The vegetation is composed of *Prosopis chilensis*, *Acacia seyal* and grasses. The terrain is flat, with a clayey soil (Vertisols). The soil profile is not markedly differentiated and shows the following general features: dark grayish brown to olive brown colour, firm clay loam texture; moderate medium angular blocky, slightly sticky, slightly plastic wet structure, very hard dry consistency, moist humidity, few fine and medium vertical tubular pores, presence of small-medium size roots, calcareous, (gypsic). The particle size distribution is predominately clayey (52%), sandy (30%) and with little silt (16%) (Table 1); hence, the soil textural class is clay loam according to the Soil Survey Division Staff (1993). The soil has a bulk density of medium magnitude (1.4 g/cm^3). It has high calcium carbonate content and neutral reaction with mean pH value of 7.6. Its salinity is slight in the surface and increases to moderate level in the subsurface layers (from 6.5 to 8.4 dsm^{-1}). The soluble cations are moderately furnished in the surface layer and increase with the soil depth, except the K levels which are very low and similar through out the profile. The soil is also poorly furnished in organic matter, N and P.

Table 1. Physicochemical properties of semi-arid soils at Soba suburb, Khartoum State

Soil depth (cm)	Particles size distribution (%)			Bulk density (gcm^{-3})	$CaCO_3$ (%)	Ece (dsm^{-1})	pH
	Sand	Silt	Clay				
0-30	37.7	18.0	44.3	1.5	8.2	2.7	7.6
30-60	30.5	16.8	52.6	1.4	8.2	6.5	7.6
60-90	36.9	12.9	50.1	1.4	8.2	8.4	7.7

Table 1. Continued

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

†OM: Organic matter

Irrigation and spacing trials for establishing *F. albida*: Seeds of *F. albida* were procured from the Forest Seed Center, Khartoum.

Polythene tubes (10x20 cm, flat) were purchased from the local market. *F. albida* seedlings' stock was raised in the Forestry Research Nursery, Soba, by routine silvicultural procedures (May 2008). The irrigation trials consisted of three interval regimes (5, 10 and 15 days). Three transplanting spacing were used; namely, 1x1 m; 1x2 m and 2x3 m. The field was cleaned from trees and grasses by using hoes and machetes and was ploughed by hoes and then divided into three blocks each of about 552 m^2 area. Each block was also divided into three sub-sections (replications) according to the transplanting spacings. Hence, the experimental design and layout was a randomized block design. On 1st August 2008, three months old seedlings of *F. albida* (with average shoot height of 20 cm) were transplanted in the field. The seedling density in each spacing sub-section was 48 seedlings in 1x1 m (with total of 144 seedlings for the 3 irrigation intervals); 45 seedlings in 1x2 m (with total of 135 seedlings for the 3 irrigation intervals) and 36 seedlings in 2x3 m (with total of 108 seedlings for the 3 irrigation intervals) and that summed up to a total of 387 seedlings. The seedlings were uniformly irrigated for three months, after that, by applying the three specified irrigation interval regimes. The plots were regularly cleaned from weeds and other debris; and the dead seedlings were replaced through beating up during the second month of transplantation. Measurements of the growth parameters of the transplants started as from 29 November 2008. Shoot height of the seedlings was measured monthly for a period of seven months, until 29 June 2008. The seedlings were then harvested and their root collar diameter and biomass were determined. Root biomass was determined from 3 excavated transplants from each treatment.

Laboratory determinations: Field soil physicochemical characterization and analysis of the transplants' mineral contents were carried out according to standard methodologies (Page 1982; Klute 1986; Kalra 1998; Pansu and Gautheyrou 2006).

Data analysis: The data were subjected to analyses of variance by a SAS program package (SAS 2004) and mean separations were obtained by Duncan's multiple range test.

RESULTS

The effect of irrigation intervals and spacing on the growth of *F. albida* seedlings under field conditions: The shoot growth of *F. albida* transplants that 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 transplants spaced 2x3 m was at a lower rate to the precedent spacing distances up to the fourth month (Fig. 1a). Generally, the height growth of transplants in the three spacing treatments started with higher growth rate of about 8 cm per month and up to the third month of their field age. Thereafter, the transplants' growth rate slowed down to an average of one centimeter per month. From the fifth month onwards, the growth rate was virtually reduced for all the transplants and in all the spacing trials up to the end of the monitoring period.

Shoot height growth of *F. albida* transplants that were irrigated every 10 days was close to each other in 1x1 and 1x2 m spacing treatments. The growth rate of transplants in these trials progressed rapidly from the start with an average increment of 10 cm per month, up to the third month and thereafter the growth occurred at a very low rate. The transplants spaced 2x3 m had higher growth rate with an average increment of 15 cm per month up to the third month, then the transplants' growth slowed down to 10 cm per month. From the fifth month onwards, the growth stabilized at a very low rate. There was a considerable difference in the growth rate of the transplants in 2x3 m spacing and the other two spacing treatments; where growth rate of transplants in 2x3 m spacing occurred at upper parallel echelon to that of the other two spacings (Fig. 1b).

The shoot height growth of *F. albida* transplants that 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 from transplanting date. Then, the growth rate was slowed to 5 cm per month till the fourth month, and thereafter the growth occurred very steadily (Fig. 1c). The growth rate of transplants spaced 1x1 m progressed rapidly with an average rate of 12 cm per month up to the fourth month and followed by a very low fixed growth rate. The transplants spaced 1x2 m had an average growth rate of 8 cm per month up to the fourth month of plantation date then featured with slow steady growth rate. 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 spacings.

Shoot height growth of *F. albida* transplants spaced 1x1 m progressed rapidly when irrigated every 5 days. The average growth rate was 15 cm per month up to the fifth month of plantation date; then, the growth rate slowed to an average of 5 cm per month up to the seventh month, after which the growth stabilized at a low rate (Fig. 2a). The growth rate of transplants irrigated every 10 days also progressed rapidly up to the fourth month with an average increment of 10 cm per month; then, the growth was reduced to an average of 5 cm per month up to the seventh month, after which it stabilized at a fixed slow rate. The growth rate of transplants irrigated every 15 days started rapidly up to the fourth month; then, it was reduced to an average of 3 cm up to the seventh month and then marked with stabilization rate. Generally, the growth pattern was lower in plants irrigated every 15 days, and the growth pattern was higher in transplants irrigated every 5 days.

The shoot height growth rate of *F. albida* transplants spaced 1x2 m was similar in irrigation intervals of 5 and 10 days. The growth rate was lower for transplants irrigated every 15 days. The height growth of transplants irrigated every 5 days progressed rapidly up to the sixth month with an average increment of 11 cm per month; then, it decreased with an average increment of 5 cm per month and followed by a stabilized low rate (Fig. 2b). The growth rate of transplants irrigated every 10 days progressed at a lower rate with 10 cm increment up to the sixth month followed by a decrease to 3 cm up to the ninth month and stabilized thereafter without noticeable increase. The height growth rate of transplants irrigated every 15 days progressed with an average of 5 cm per month up to the eight month and then followed by a stabilized rate towards the end of the monitoring period.

The height growth rate of *F. albida* transplants spaced 2x3 m was in the following order according to the irrigation regime intervals: high in every 10 days, moderate in every 5 days and low in every 15 days (Fig. 2c). The height growth progressed rapidly in transplants irrigated every 10 days with an average increment of 15 cm per month till the sixth month, and then it decreased to 3 cm per month. From the eight month onwards, the growth was stabilized at a fixed rate. The growth of transplants irrigated every 5 days progressed rapidly with an average increment of 8 cm per month up to the sixth month. Then, it was reduced to an average of 4 cm up to the eight month and it stabilized after wards without noticeable increase. The height growth of transplants irrigated every 15 days progressed with a rate of 7 cm per month up to the sixth month then it was reduced and later stabilized at fixed rate.

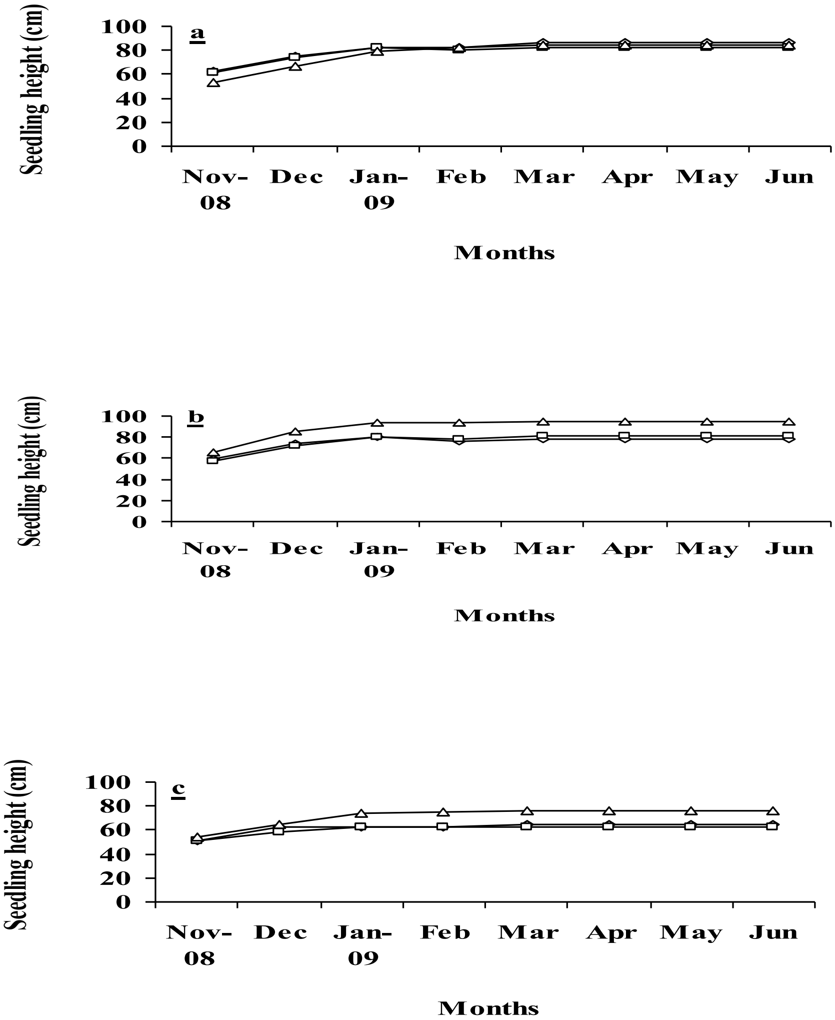

Fig. 1. Cumulative shoot growth of 14 months old *Faidherbia albida* transplants under various irrigation intervals (a: 5 days; b: 10 days and c: 15 days) and planting spacings (◊: 1x1 m; □: 1x2 m and Δ: 2x3 m) in semi-arid land soils.

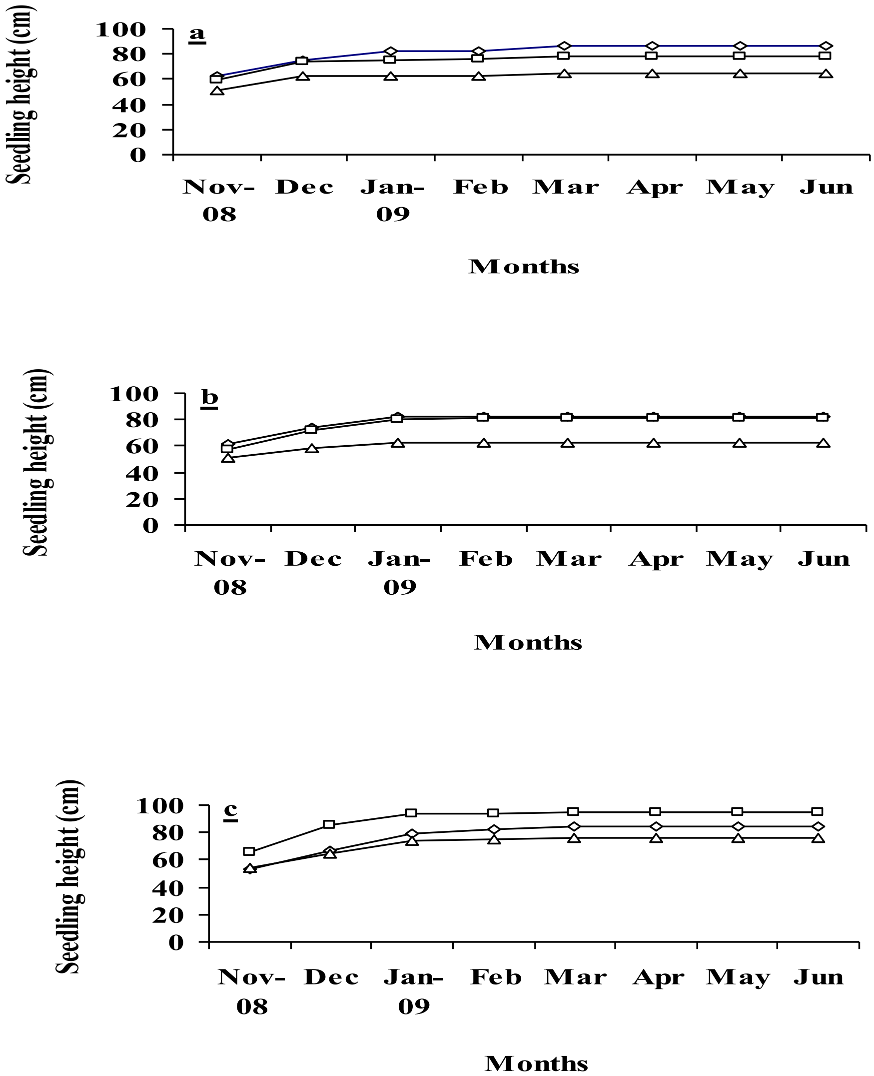

Fig. 2. Cumulative shoot growth of 14 months old *Faidherbia albida* transplants under various planting spacings (a: 1x1 m; b: 1x2 m and c: 2x3 m) and irrigation intervals (◊: 5 days; □: 10 days and Δ: 15 days) in semi-arid land soils.

Effect of irrigation intervals and spacing on the growth and biomass production of *F. albida* transplants under field conditions: These analyses belong to the last observations, which were taken after seven months from planting date. For plants irrigated every 5 days, there were no significant differences between the different spacings and for all the monitored parameters (Table 2). However, the highest value of shoot height (86.3 cm) was recorded for transplants spaced 1x1 m and the lowest value (83.4 cm) for the ones spaced 2x3 m. The shoot diameters increased in proportion with the increasing spacing distances between the transplants. Growth parameters of transplants irrigated every 10 days showed no significant differences between all the different spacing treatments. The highest shoot height (97.5 cm) and mass (283.3 g.) were recorded for transplants spaced 1x2 m. Shoot diameter values were very close to each other in the various spacings. For transplants irrigated every 15 days, there were significant differences in the shoot height and mass between transplants spaced 2x3 m and the other spacings. The highest values of shoot height and mass were registered for the 2x3 m spacing treatment. On the other hand, shoot diameter values of the transplants were not significantly different between the various spacing treatments.

For transplants irrigated every 5 days and every 10 days, there were 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 spacings. Values of root mass were highest for transplants irrigated every 10 days and exceeded those irrigated for 5 and 15 days by a factor of 1.5 on the average.

The analysis of foliar nutrient contents of transplants irrigated by various interval regimes showed that there were no significant differences between the intervals and for all the elements (Table 3). The values of each nutrient element of the transplants were very close in the different irrigation intervals, viz, 5, 10 and 15 days intervals.

Table 2. Growth parameter values of 14 months old transplants of *F. albida* grown at different irrigation intervals and spacings in a semi-arid land soils

Irrigation intervals	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		
	S2 (1x2)	84.5a	20.3a	400.0a	65.1a	3.6a
	S3 (2x3)	83.4a	21.5a	361.1a		
Every 10 days	S1 (1x1)	77.9a	17.1a	237.5a		
	S2 (1x2)	97.5a	19.1a	283.3a	100.1a	2.5a
	S3 (2x3)	80.6a	18.7a	244.4a		
Every 15 days	S1 (1x1)	65.2b	19.7a	91.6b		
	S2 (1x2)	61.7b	16.5a	150.0b	68.3a	2.7a
	S3 (2x3)	75.6a	16.8a	238.8a		

Means followed by the same letter (s) in the column and for each irrigation interval are not significantly different at P = 0.05.

Table 3. Foliage nutrient content of 14 months old transplants of *F. albida* grown at different irrigation intervals in a semi-arid land soils

Irrigation intervals	OC‡ (%)	OM† (%)	N (%)	C/N	P (%)	Ca (%)	Mg (%)	Na (%)	K (%)
5 days	51.53a	88.63a	1.46a	26.4	0.36a	1.32a	0.47a	0.30a	1.14a
10 days	52.19a	89.76a	1.44a	27.1	0.34a	1.22a	0.47a	0.19a	1.11a
15 days	52.72a	80.67a	1.11a	35.3	0.31a	1.15a	0.39a	0.15a	1.07a

Means followed by the same letter (s) in the column and for each irrigation interval are not significantly different at P = 0.05. ‡OC: Organic carbon. †OM: Organic matter

DISCUSSION

The shoot growth of *F. albida* transplants was very rapid during the six months from the planting date (1st August 2008), which coincided with part of autumn and winter, but after that and during the summer period the growth was greatly slowed in all the irrigation frequency ranges including the shortest interval regime of every 5 days. A plausible explanation for this phenomenon could be that the transplants were subjected to some kind of stress from the excessive heat and desiccation from the dry summer wind pulses (Parson 2003; Brink 2007; TNAU AGRITECH PORTAL 2008; Allotment Blogger 2011); even though, the species is known to thrive and foliate in summer (Wickens 1969; El Amin 1990). Another, cause for this effect might be linked to the edaphic factor of the field, which is a heavy saline clay soil, and that does not allow transplants to penetrate the soil freely and develop a good root system; and also the heavy clay hinders free and deep percolation of water. It is worth to mention that the natural proliferation habitats of the species consist of light deep soils like the alluvial soils in valleys and along the water courses (El Amin 1990; Vogt 1995).

The average values of growth parameters of *F. albida* transplants, monitored in this study, increased with decreasing irrigation intervals irrespective of the planting spacings. Therefore, the shoot height, diameter and biomass were 84.7 cm, 20.6 mm and 356.5 g, respectively in 5 days' irrigation interval, and 85.3 cm, 18.3 mm and 255.1 g, respectively in 10 days' irrigation interval, and 67.5 cm, 17.7 mm and 160.1 g, respectively, in 15 days' irrigation interval. However, root biomass tented to be higher in the longer irrigation intervals, i.e., contrary to the development of the former parameters. The decline in the *F. albida* transplants height and biomass as the irrigation frequencies decrease is in line with what have been reported by Kozlowski (1971) and Duryea (1984) who reported that with the decrease of soil water content, shoot growth is retarded and thus plants developing under adverse soil water conditions are often stunted and dwarf (Levitt 1972; Duryea 1984). Mean height and diameter of acacia seedlings, therefore, was reduced in water stress and consequently stem biomass. Reduction in height and diameter growth of acacias due to water stress has been also observed in previous studies of Pokhrival *et al*. (1997) for *Acacia nilotica* and Awodola (1991) for *Acacia seyal* and

F. albida. The observed increase in root biomass as irrigation frequencies were reduced is supported by what have been reported by Kozlowski and Pallrdy (1997) and Levitt (1972) that decrease in soil moisture could cause a greater increase in the root growth than the shoot and hence greater biomass production.

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 distance between them is simply a result of exploiting the available below-ground resources (water and nutrients) by less number of transplants. Loutfy El-Juhany and Ibrahim Aref (1999) 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 (Evans 2001a and 2001b; Burley *et al.* 2004)). Corollary, the shoot/root dry weight ratios of *F. albida* transplants were affected by irrigation interval and spacing. When the water supply was limiting, allocation of assimilates tend to be modified in favour of root growth and leads to increased root biomass and consequently root to shoot ratio increases (Hsiao and Acevedo 1974; Ibrahim 1995). Although growth of both roots and shoots decreases under drought conditions, the root/shoot ratio generally increases (Kozlowski and Pallardy 1997). This is true because above ground growth is affected more severely than below ground growth (Bongarten and Teskey 1987; Wilson 1988). Joly *et al.* (1989) 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 (1995) for *Acacia farnesiana* and with others for different woody species (Ayoub and Grace 1992; Ibrahim 1995).

Foliar nitrogen uptake is expected to be the seedlings characteristic that is most reliably correlated with available soil nitrogen, and it is expected to influence the dry matter yields (Saka and Bunderson 1989). However, the role of other nutrients, particularly the phosphorus availability, can not be ruled out in determining the growth and dry matter yield of the seedlings (Kraske and Fernandez 1990).

In conclusion, the establishment and growth of *F. albida* transplants are best with the increase of irrigation frequencies (regimes of 5 and 10 days intervals). Even, though, when the establishment of the transplants becomes certain and no fear subsequent death is warranted, then the irrigation intervals can be increased to 15 days or even longer. Wider planting spacings are to be favored as they allow juvenile transplants to benefit from the growth resources in the wider spaces and have better establishment.

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