Scholars Journal of Agriculture and Veterinary Sciences **e-ISSN 2348–1854**
Sch J Agric Vet Sci 2017; 4(3):91-101 **p-ISSN 2348–8883**
©Scholars Academic and Scientific Publishers (SAS Publishers)
(An International Publisher for Academic and Scientific Resources) DOI: 10.36347/sjavs.2017.v04i03.002

The impact of growing media and container size on the growth and development of *Faidherbia albida* seedlings

Dr. Hakim Araba Ameri[1], Daldoum M.A. Daldoum[2]
[1]Upper Nile University, Faulty of Forestry and Range Science, Juba, South Sudan
[2]Faculty of Forestry, University of Khartoum

***Corresponding Author**
Name: Dr. Hakim Araba Ameri
Email: hakimaraba4@gmail.com

Abstract: The experiment was carried out in the nursery which is located at Soba, 10 km south of Khartoum city (Sudan). Seeds of *Faidherbia albida* were obtained from Nuba Mountains collections, polythene tubes; small (10x20 cm), medium (10x30 cm) and large (20x40 cm) sizes were used in the experiment, filled with sand, silt and sand silt mixture. A total of 432 polythene tubes were used in the experiment; 144 tubes in each size category. 48 bags of each size category were filled with one type of soil; the experimental layout was then arranged in a Randomized Complete Block Design (RCBD). Seeds treated with sulfuric acid were used for this experiment; seeds were sown in May 2008. All cultural practices were done during the first month after germination. In order to collect the growth data, four destructive samples of the seedlings at different growth stages were conducted, In every destructive sampling 4 seedlings were chosen at random from each soil type and container size. The shoot height, root length was measured. Then each part was weighed to obtain fresh and dry weight. These operations were executed successively in June (when seedlings age was 30 days), July, August, and September 2008. The soil types were physically and chemically analyze. The data obtained on the plant growth were analyzed by a PC computer. The final data were subjected to ANOVA test by a SAS program (SAS, 2004). The results have shown that *F. albida* seedling shoot height and weight growth, root length and weight growth increased in large polythene containers and decreased in the smaller containers with significant differences between the different container sizes.
Keywords: *Faidherbia albida,* ANOVA

INTRODUCTION

Faidherbia albida (Del.) A. Chev. in the sub-family *Mimosoideae* of the family *Leguminosae.* [2]. A tree, up to 30 m high, with diameters often up to 2 m [46];. Occurs naturally from 270 m below sea level in Israel to 2700 m in Sudan [2], under a very wide range of meteorological conditions. In southwest Africa it can thrive under desert conditions where the mean annual rainfall is only 20 mm and the mean annual daily temperature 16.8 °C [13]. Whereas in West Africa it can also thrive in humid tropical conditions with mean annual rainfall of 1800 mm and a mean annual temperature of 28 °C [13].

It is found in *a* wide range of soils. Most characteristically, it colonizes deep sandy clay soils, particularly alluvial deposits along the flood plains of rivers [36, 34]. 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 [12]. *Faidherbia albida* is unusual in the African arborescent flora in that it sheds its leaves at the start of the rainy season and is in full leaf during the dry season [47] believes that this habit is fairly consistent and controlled mainly by climatic conditions throughout its range. The wood of *F. albida* is light yellow to white in color and is of good quality, soft and easy to work [6, 49]. The wood is combustible with a calorific value of 4720 kcal kg^{-1} or 19740 kJ kg^{-1} and is easily carbonized with yields of 17% [2]. It makes an average quality charcoal. It can be used for light construction and the tree bole is widely used for the construction of dugout canoes, boats and paddles and the sawn planks for furniture [16, 49]. The branches are used for huts, granaries and sheds. The wood ash is used for soap and as a depilatory [49].

The bark is used to make beehives, saddle stuffing and construction of huts [49]. The old bark of *F. albida* contains 20-29% tannins (2) which are probably the active components that explain the widespread medicinal use of the bark. *Faidherbia albida* produces an excellent, highly nutritious fodder. Both the foliage and the fruits are used as a fodder resource by herdsmen throughout its range in Africa [10, 17, 7, 3]. *Faidherbia albida* has many medicinal properties. Extracts of the bark, gum and roots are the main parts used to treat many ailments. Extracts are used as astringents to treat gastrointestinal disorders, particularly diarrhoea [44, 22, 38, 48, 25]. The ability of *F*. *albida* to grow in areas of very low rainfall is due to its propensity to develop and maintain a root system that keeps in touch with permanent moisture zones in the soil rather than to any physiological attribute that might enable it to regulate water use under stress [2]. *Faidherbia albida* is sensitive to fire [3] and fire-hardy [28] and even as forming part of the fire-climax vegetation of the West African savannas [13]. A Bush fires have been cited as a factor in the decline of the *F. albida* parklands in the Sahelian zone of West Africa- 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 [24]. *Faidherbia albida* is a valuable tree but may be difficult to establish naturally [42] 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. Seedlings grown in containers have many advantages such as better survival rate, easier to plant, immediate growth response benefits, cheaper to produce and plant than bare-root seedlings [24]. There is need to domesticate *Faidherbia albida* by converting them into plantations, hence study their regeneration, growth and development in artificial conditions. The study seeks to determine the regeneration of the species in the nursery as influenced by soil types and polythene bag sizes;

MATERIAL AND METHODS

The experiment was carried out in the nursery of Forestry Research Center (FRC) which is located at Soba, 10 km south of Khartoum city (Sudan) (Longitude: 30° 30′ E, Latitude: 15° 30′ N). The topography is flat, with clay soil, and the nursery is protected from all sides by wire fence. To reduce water loss, the seedling beds are built with brick and cement. Seeds of *Faidherbia albida* were supplied by the Forest Research Seed Center (FRSC), from Nuba Mountains collections (Longitude: 24˚ 21˗ E; Latitude: 12˚ 20̅ N); Sand and silt were dug out of the Blue Nile lower terrace and clay from the upper terrace. The polythene tubes of three different sizes were purchased from local market, viz: small (10x20 cm), medium (10x30 cm) and large (20x40 cm) flat dimensions.

About 432 polythene tubes were used in the experiment; these were of three different sizes (small, medium, and large) in equal number (144 tubes) in each size category. The bags were pierced with several holes before filling with the appropriate soil type (48 bags of each size category were filled with one type of soil). Then they were arranged in the brick cemented beds in such a way that each soil type was separated from the other, so as to avoid nutrient leakage and transfer; the experimental layout was then arranged in a Randomized Complete Block Design (RCBD). Seeds treated with sulfuric acid were used for this experiment, since this test proved to be the best for seed dormancy breakage. Three seeds were sown per bag in May 2008. The seed bed was irrigated daily in the morning using flood irrigation. The weeds were cleaned from the bed whenever they appear. The seedlings in each bag were thinned leaving only one seedling in a bag during the first month after germination.

In order to collect the growth data, four destructive samples of the seedlings at different growth stages were conducted as follows: In every destructive sampling 4 seedlings were chosen at random from each soil type and container size. The polythene bags of the sampled plants were cut opened and the roots were carefully washed so as to avoid damage. The shoot height, root length was measured by a ruler to the nearest centimeter; after the seedlings were cut at root collar, separating the shoot from the roots. Then each part was weighed using a sensitive balance to obtain fresh weight, after which they were oven dried at 80 °C for 24 hours, and then the shoots and the roots were reweighed, and the data were recorded. These operations were executed successively in June (when seedlings age was 30 days), July, August, and September 2008.

Soil analysis

The 3 samples of the nursery (sand, clay, and silt) were analyzed for the following parameters: 1/ Particle size distribution was obtained by using the modified hydrometer method [9], and the textural classes were assigned according to the American system [41]; 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 [5]. 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 [32]; 8/ Phosphorus determined by spectrophotometer using $NaHCO_3$ method [5]; 9/ Organic carbon was obtained by Walkely and Black method [44] 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 [30, 21].

STATISTICAL ANALYSIS

The data obtained in both nursery and the field was 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 (SAS, 2004) and the significant levels for the mean separations were assigned according to Duncan's Multiple Range Test ($P \leq 0.05$).

RESULTS

Characterization of the nursery soils

The soils used in the nursery were sand, silt and clay, their physical and chemical properties are shown in (Table 1). The soils used in this study exhibited neutral pH. The sand was poor in exchangeable Ca, Mg but the silt and clay had more or less adequate supply of these nutrients. The clay showed the lowest content of sodium and the silt contained more sodium content than the clay, but the sand had the highest sodium content. All these soils displayed poor organic matter content. Nitrogen content was very poor in sand compared to clay and silt. Phosphorus content in all the soils was poor but better than nitrogen content. Generally the sand used was very poor in nutrient with a porous media, which retained water for short period, only clay and silt were relatively richer than sand in nutrient and had a higher water holding capacity (Table1).

Table 1: Physical and chemical characteristics of soils used in the nursery experiments

Soil type	S.P	M.C (%)	Particles size distribution (%)			B.D (gcm^{-3})	$CaCO_3$ (%)	Ece (dsm^{-1})	pH
			Sand	Silt	Clay				
Sand	22.1	0.4	90.9	9.1	-	1.4	2.4	1.7	7.4
Silt	71.3	4.9	51.7	25.0	23.3	-	5.5	0.8	7.2
Clay	72.5	4.7	20.6	41.2	38.2	1.5	5.3	1.1	7.1

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 type	Soluble cations ($meqL^{-1}$)				O.C (%)	O.M (%)	N (%)	C/N	P (ppm)
	Ca	Mg	K	Na					
Sand	4.5	3.5	0.2	11.2	0.4	0.6	0.01	56	0.40
Silt	5.0	3.5	0.2	1.8	0.9	1.5	0.16	5	0.58
Clay	7.5	4.5	0.3	1.4	0.8	1.3	0.13	6	0.59

The impact of growing media and container size on the growth and development of *Faidherbia albida* seedlings

Shoot height

In the sand medium, shoot height growth of F.albida seedlings in the different containers (small (10x2o), medium (10x30), large 20x40) after two month from sowing was almost identical. The average monthly increment of seedlings growth in these containers was about 3 cm. Seedlings growth in the large containers proceeded steadily upwards until the fourth month (September measurements), with a mean increment of about 8 cm per month. In the medium containers seedling growth rate followed the pattern described for the large containers but at a lower parallel level. While the small containers seedlings growth followed the pattern of growth of seedlings in medium containers but at a lower rate up to the third month from the date of sowing (August). From the third month onwards seedlings growth rate in the small container stabilized at a fixed rate without noticeable increment. At the end of the experiment the seedlings height in large containers was 4 times the seedlings height in the small containers.

In clay growing medium, *F. albida* seedlings height growth and development in the large container was superior. The seedlings height growth in this container sharply increased between the second and the third month at a rate of 10 cm per month. Thereafter, the growth slowed down. Seedlings height growth in the small containers progressed at the rate of 3 cm per month. There was a great difference in height growth between seedlings in large and medium containers with a magnitude of 10 cm, and seedlings in the small containers with a difference of 20 cm (Fig. 1). In the silt medium, *F. albida* seedlings height growth and development was almost identical in all container sizes up to the third month. From the third month, seedlings growth in the large containers continued with strong vigor. The seedlings in the medium containers followed a pattern of growth at a lower rate compared to those of the large containers. The difference in height growth between the seedlings in the two containers was narrow. The seedlings in the small containers had a lower rate of growth than that of the other container sizes (Fig.1)

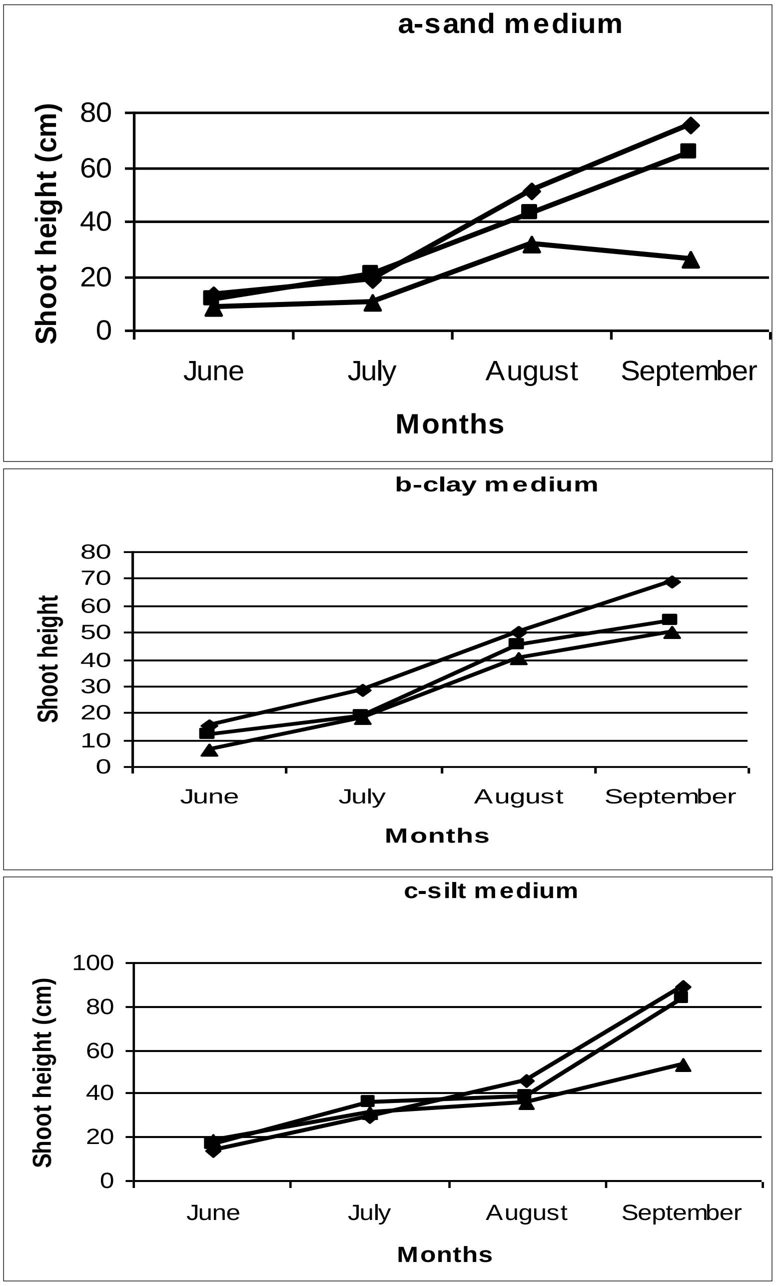

Fig 1: Cumulative shoot growth of *Faidherbia albida* seedlings in the nursery raised in the different polythene bag-sizes: small (▲: 10x20 cm), medium (■: 10x30 cm) and large (♦: 20x40 cm).

Root length

In the sand medium, *F. albida* root length growth in the medium containers proceeded with high rate till the third month from the date of sowing. There was a little decline in the root length growth, afterwards the seedlings root length growth in the large containers proceeded with a higher rate till the third month, then there was a decline up to the fourth month and then it increased at a higher rate. The seedlings root length growth in the small containers was very low till the third month then the growth rate increased where it became closer to seedlings in the large container. (Fig 2)

In the silt medium, root length development was different from first month of seed sowing (first measurement), in the three container sizes. The root length growth rates in all the media were the same and they were parallel to each other. The root length in the large containers was at a higher level, and the root length in the medium containers in middle level and the root length in the small containers at lower level, up to the second month from seed sowing date. A decline happened in the root length growth rate in the large and medium containers while an increased occurred in the small containers, resulting in their coincident in the third month (August). The root length growth in the large containers continued upwards from the third month with an increment of about 15 cm per month.

Similar rate of root length growth happened in the medium containers with an increment of 10 cm per month. While the root length growth increment in the small containers was only 2 cm per month. (Fig. 2).

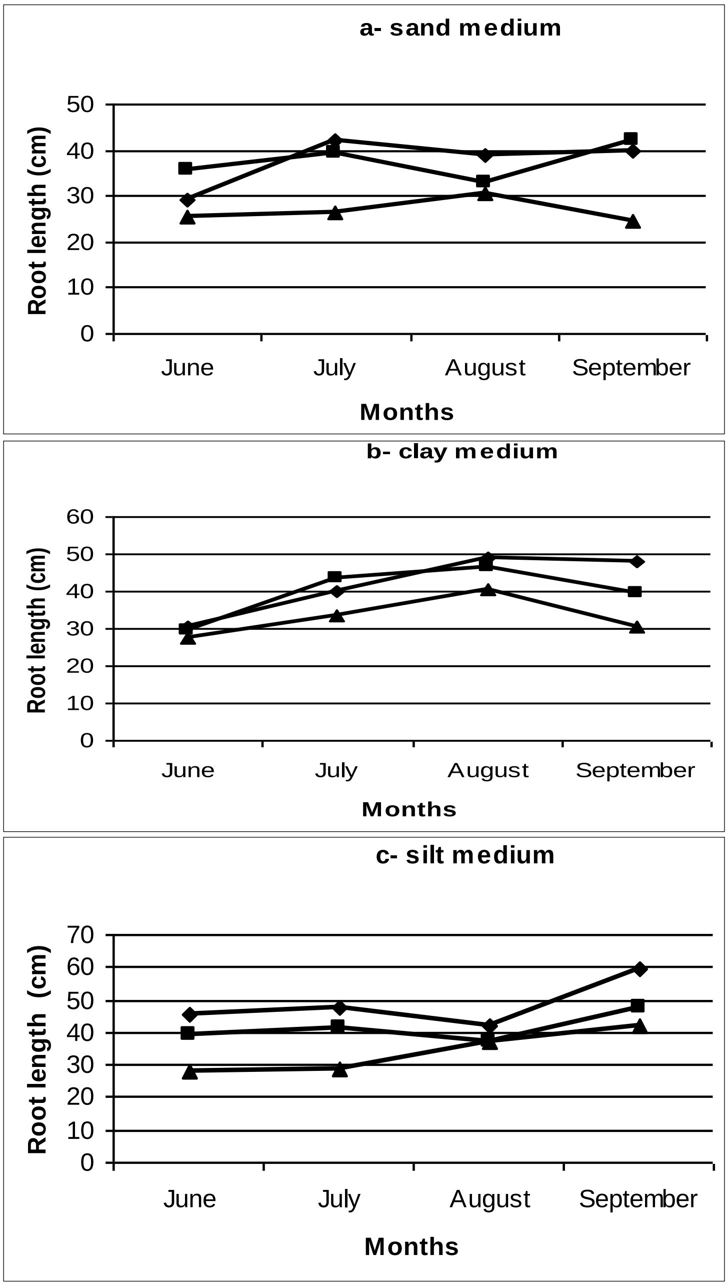

Fig 2: Cumulative root length of *Faidherbia albida* seedlings in the nursery raised in the different polythene bag-sizes: small (▲: 10x20 cm), medium (■: 10x30 cm) and large (♦: 20x40 cm).

Shoot dry weight

In the sand growing medium, *F. albida* shoot dry weight growth in the large and medium containers was almost identical up to the second month from the sowing date without any noticeable differences between them. There was a high increment of about 6 g per month for the shoot dry weight in the large containers (Fig. 3), whereas shoot dry weight in the medium containers was about 2 g per month in the clay medium. *F. albida* shoot dry weight growth rate was almost identical in the large and small containers up to the third month from the sowing date. The growth rate in the large containers was parallel to the other two containers but at a higher rate.

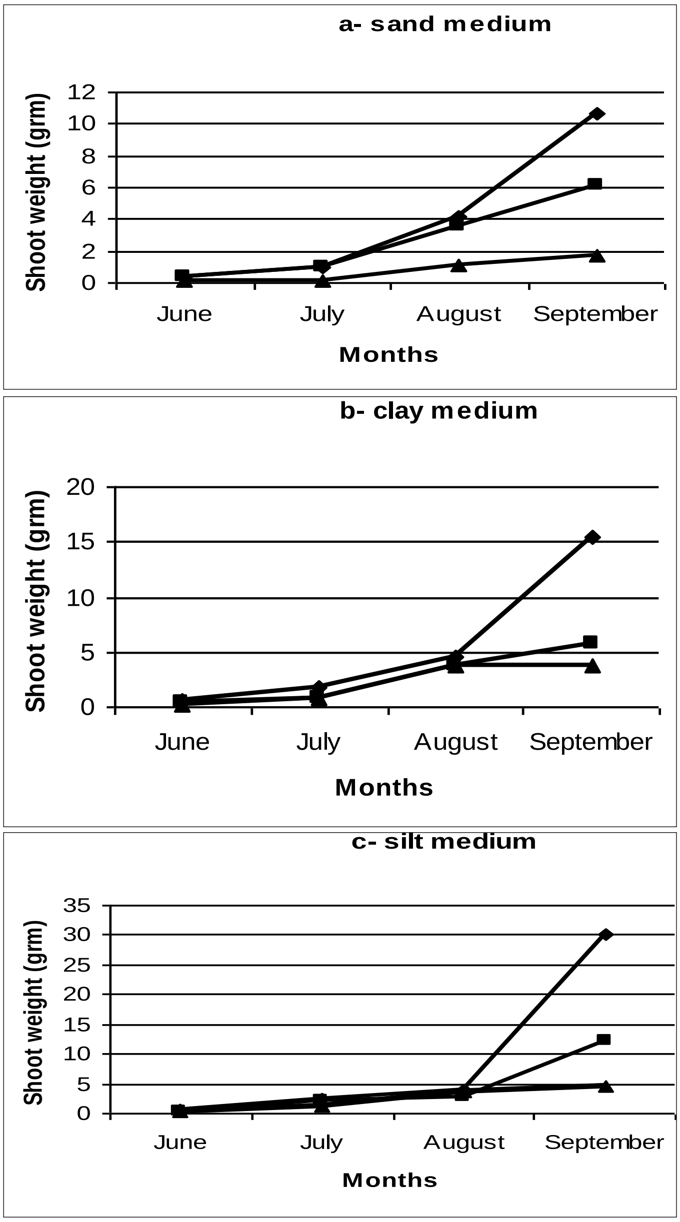

Fig 3: Cumulative shoot dry weight of *Faidherbia albida* seedlings in the nursery raised in the different polythene bag-sizes: small (▲: 10x20 cm), medium (■: 10x30 cm) and large (♦: 20x40 cm).

From the third month onwards there was a clear divergent in weight growth in the three media. The shoot weight growth in the large containers was distinct from the other containers; it was at a higher rate of a progressive buildup, about 12 g per month. The shoot weight growth in the medium containers was comparatively lower; it was about 2 g per month. While the shoot weight growth in the small size containers remained at the same level (Fig. 3).

In the silt growing medium, the pattern of shoot weight growth resembled the pattern of shoot weight growth in the clay medium. Shoot dry weight growth in all the containers was identical up to the third month, after that there was an increase in shoot dry weight in the large containers with an average weight of 25 g per month. Shoot dry weight growth in the medium containers proceeded at a lower rate; it was about 5 g per month. The shoot dry weight growth in the small containers was very low, about one gram per month (Fig.3).

Root dry weight

In the sand medium, *F. albida* root dry weight growth in the medium and large containers went on with almost the same rate until the third month, then there was a divergent. The root dry weight in the large containers increased with an average of 2 g per month, while the root dry weight in the medium containers increased with a lesser rate of about one gram per month. The root dry weight growth in the small containers was the least with an average of 0.5 g per month up to the third month after that the growth rate stabilized with no increment (Fig4).

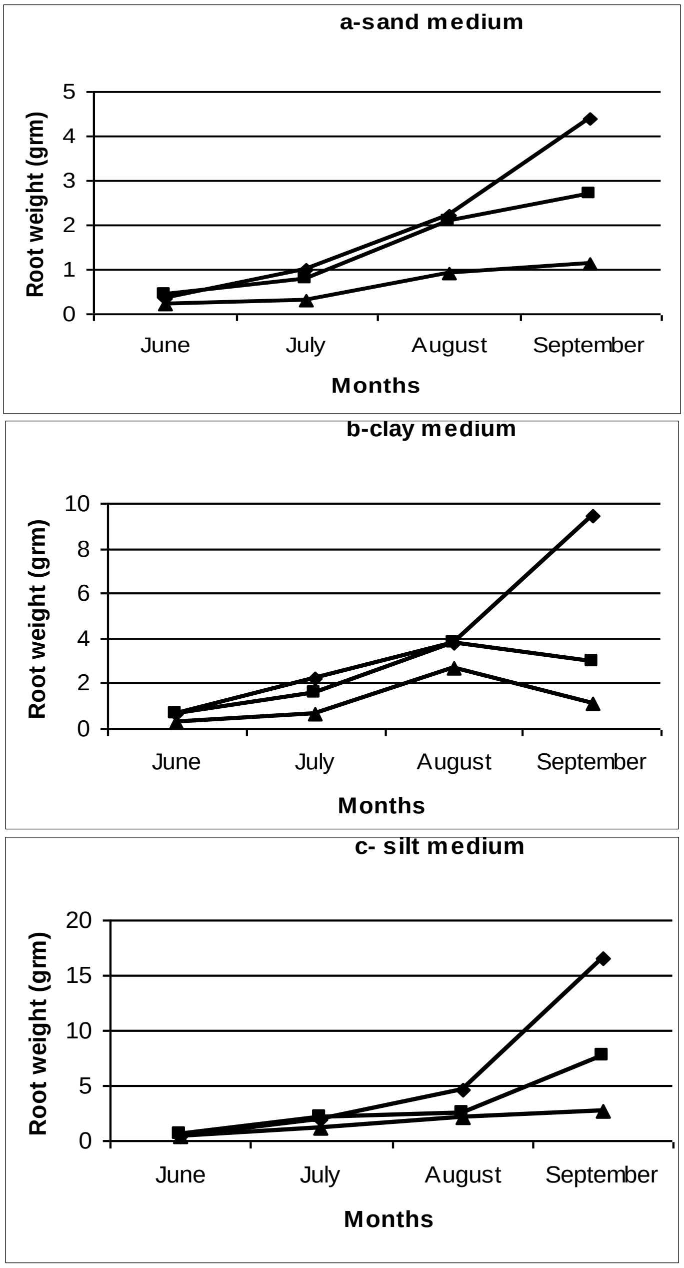

Fig 4: Cumulative root dry weight of *Faidherbia albida* seedlings in the nursery raised in the different polythene bag-sizes: small (▲: 10x20 cm), medium (■: 10x30 cm) and large (♦: 20x40 cm).

In the clay growing medium, root dry matter build up in the large and medium containers was close together up to the third month, after that there was a high increment nearly about 5 g per month in the large containers while in the medium containers the root dry weight stabilized. The root dry weight in the small containers proceeded slowly with a rate of 0.5 g up to the second month then the root dry weight build up proceeded at a lower parallel level to that of medium containers. The average root dry weight increment in the small containers was one gram per month, after the third month there was stabilization in root dry weight growth (Fig. 4).

In the silt medium, *F. albida* root weight growth was identical in the large and medium size containers up to the second month then there was an increase in the dry matter build up in the large containers. The rate of root growth increased sharply from the third month with an average 12 g per month, while the root dry weight growth in the medium containers increased at a rate of 6 g per month. The root weight growth in the small containers was about one gram per month for the whole period of the experiment (Fig. 4).

The effect of growing media and container size on the growth and biomass partitioning of 5 months old *F.albida* seedlings

There were significant differences in the shoot height between the small containers and the other containers, but there were no significant differences between the other two containers. The highest value was recorded for the large containers (77.8 cm) and the lowest value was recorded for the small containers (31.3 cm), (Table 2) (Plates 1, 2, 3). For root length, there were significant differences between root length in the small containers and the other containers, but there were no significant differences between root length in the large and the medium containers. The highest value was recorded for the large containers (49.2 cm) and the lowest value was recorded for the small containers (31.6 cm) (Table 2). For the shoot dry weight, there were significant differences between the large and the other containers, but there were no significant differences between the small and the medium containers. The highest value was recorded for the large containers (18.8 g) and the lowest value was recorded for the small containers (2.1 g) (Table 2).

As for the root dry weight, there were significant differences between the root in the large containers and the medium containers, also there were significant differences between the large and the small containers. There were also significant differences between the medium and the small containers. The highest value was recorded for the large containers (10.1 g) and the lowest value was recorded for the small containers (1.3 g) (Table 2).

Plate 1: Five month old seedlings of *Faidherbia albida* grown in sand medium (shoot height growth was good in the large and the medium polythene bags, and poor in the small bag).

Plate 2: Five month old seedlings of *Faidherbia albida* grown on silt medium (shoot height growth was good in the large and the medium polythene bags, and poor in the small bag).

Plate 3: Five month old seedlings of *Faidherbia albida* on clay medium (shoot height growth was good in the large and the medium polythene bags, and poor in the small bag).

There were significant differences in shoot/root dry weight ratios between the seedlings in the medium and those in the other containers, but there were no significant differences between the large and the small containers. The highest value was recorded for the medium containers (2) and the lowest value was recorded for the small containers (1.4) (Table 2).

Table 2: Growth and biomass analysis of 5 months old seedlings of *F. albida* grown in different polythene bags under Nursery conditions

Polythene bag-sizes	Shoot height (cm)	Root length (cm)	Shoot dry weight (g)	Root dry weight (g)	Shoot/root weight ratio
Small (10x20 cm)	31.1b	31.6b	2.1b	1.3c	1.4b
Medium (10x30 cm)	67.4a	43.0a	8.0b	4.4b	2.0a
large (20x40 cm)	77.8a	49.2a	18.8a	10.1a	1.9b

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

DISCUSSION

Concerning the effects of polythene container sizes on *F. albida* seedling growth, results have shown that shoot height and weight growth, root length and weight growth increased in large polythene containers and decreased in the smaller containers with significant differences between the different container sizes (Table 2). These results are in agreement with the findings of [24, 14, 20, 18] who reported that the shoot, root and total dry weight as well as shoot height increased significantly with increasing container volume. Tilt [38] also found that the northern red oak seedlings biomass was reduced as the volume of the container medium was reduced. *Euonymus juponicu* grown in larger containers had a high mean relative growth rate than those grown in smaller containers [11]. The consensus is that as container size increases, plant growth, leaf area and shoot dry weight are increased [15, 14, 36, 40; 33). In general, as cell size increases transplant leaf area, shoot biomass and root biomass increases [4, 28]. Varying container sizes alters the rooting volume of the plants [28] Shoot and root biomass of *Salvia jamensis* increased linearly with container volume [42]. Plants grown in larger containers are taller than plants grown in smaller containers [51], because they grow faster [42] due to more space and water nutrients [36] grew white spruce seedlings in three different container volumes at three different growing densities and found that shoot height, absolute weight of roots and shoots were clearly superior in the larger containers as found by [19]. The larger containers are recommended when producing seedlings for drier sites where larger root masses are required [34]. Smaller polythene bag (10 X 20 cm), decreases production cost, increases nursery capacity production and it may improve the efficiency of transportation to the field [27]. Moreover, reducing the container size increases the probability for root restriction, and it could predispose plants to drought stress since a significant reservoir of soil water resources goes unexplored [27]. Therefore, when seedlings from small containers are planted in the field they are unable to compensate for evapotranspiration even if they are well watered after transplanting [1].

Performance of seedlings in large containers had the highest increase in growth of stem, root and other plant parameters of the seedlings. This is confirmed by [31], who reported that larger container seedlings of black spruce had better stem growth than smaller container stocks. Larger seedlings survive better because they have more fibrous roots, which have a greater ability to extract water from the soil [8]. On the other hand, the large (container) sizes occupy much space in the nursery beds. In addition, it holds more growing media and the process of filling, transportation, and post planting operations were time consuming. In addition, planting seedlings with larger roots will reduce the rate of planting by hand as large roots requires a bigger hole and pruning operations for avoiding root coiling. On the other hand, small roots can be planted in small holes are quicker to make than deep holes.

Although, large polythene size produces seedlings with the highest increase in shoot, root, leaves, nodules and other plant parameter, however, in most cases, its usage is impractical since the seedlings will be more expensive to grow and plant. Whereas, its usage may be practical in the situation of unfavourable condition, i.e. water-stress, as the large root systems from large containers suffer less post-plant shock than plants with small root systems [46]. The root pruning will promote more natural and improved lateral root development and therefore better mechanical stability and wind firmness of plantation trees [23]. Performance of seedlings in medium containers (15 X 20 cm), was much better than that in the small containers, and it had satisfactory growth that comparable to seedlings in large containers On the other hand, the length of the root was consistent with the height of polythene length, thus the seedling was not predisposed to root coiling and might not require any pruning operations during out-planting process. Relatively, the usage of medium polythene bag (15 X 20 cm), optimizes production cost, increases nursery capacity production and improves the efficiency of transportation to the field. It is recommended for seedling production since it reconciles between having vigorous seedling stock with optimum production cost.

REFERENCES

1. Aloni B, Daie J, Karni L. Water relations, photosynthesis and assimilate partitioning in leaves of pepper (Capsicum annuum) transplants: Effect of water stress after transplanting. Journal of Horticultural Science. 1991 Jan 1; 66(1):75-80.
2. Barnes RD, Fagg CW. Faidherbia albida monograph and annotated bibliography.
3. Baumer M. Notes on trees and shrubs in arid and semi-arid regions. Food & Agriculture Org.; 1983.
4. Cantliffe DJ. Pre-and postharvest practices for improved vegetable transplant quality. HortTechnology. 1993 Oct 1;3(4):415-8.
5. Chapman HD, Pratt PF. Methods of Analysis for Soils, Plants and Waters. Priced Publication 4034. Division of Agriculture Sciences. University of California, Berkeley. 1961.
6. Daldoum DM, Ameri HA. The Impact of some Soil Types and Container Sizes on Growth and Development of Faidherbia albida Seedlings in the Nursery Site.
7. Graham GA. A Farming Systems Research Bibliography of Kansas State University's Vertical File Materials: Revised. Resources on Developing Countries, Farrell Library, Kansas State University; 1986.
8. South D, Mitchell B. Survival of the fittest: pine seedling survival increased by machine planting large seedlings. Highlights of Agricultural Research. 1999; 46(2).
9. Day PR. Particle fractionation and particle-size analysis. Methods of soil analysis. Part 1. Physical and mineralogical properties, including statistics of measurement and sampling. 1965 Jan(methodsofsoilana):545-67.
10. Delwaulle JC. Species, techniques and problems of semi-arid zones (the Sahel).
11. Dubik SP, Krizek DT, Stimart DP, McIntosh MS. Growth analysis of spreading euonymus subjected to root restriction. Journal of plant nutrition. 1992 Apr 1; 15(4):469-86.
12. El Amin HM. Trees and shrubs of the Sudan. Ithaca press; 1990.
13. FAGG C, BARNES R. African acacias: study and assembly of the genetic resources. ODA Forestry Research Scheme final report.
14. Funk, D.T.; Roth, P.l. and Clemer, M. L. (1980). The influence of container type and potting medium on growth of black walnut seedlings. North Central Forest Experimental Station. Forest service. USDA. Research note NC-253.
15. Funk DT. Pot size, pot shape, and soil mix all influence black walnut seedling growth. Plant Propagator. 1971; 17(1):10-4.
16. Seaward BR, Carter DT, Banks PF. The Zimbabwe Bulletin of Forestry Research.
17. Fortman L. The tree tenure factor in agroforestry with particular reference to Africa. Agroforestry systems. 1985 Dec 1; 2(4):229-51.
18. Jaenicke H. Good tree nursery practices: practical guidelines for research nurseries. World Agroforestry Centre; 1999.
19. Karlsson I, Kovats M. Effects of rooting medium, container size, cover and planting time on container-grown Douglas fir seedlings. Research notes. 1974.
20. Kinghorn JM. Principles and concepts in container planting. InProceedings of the North American Containerized Forest Tree Seedling Symposium. Great Plains Agricultural Council, Denver, Colorado 1974 Aug 26 (pp. 8-18).
21. Klute A, Dirksen C. Hydraulic conductivity and diffusivity: laboratory methods. Methods of soil analysis: part 1—physical and mineralogical methods. 1986 Jan (methodsofsoilan1):687-734.
22. Kokwaro JO. Medicinal plants of east Africa.

23. Kooistra CM. An overview of copper pruned Lodgepole pine in plantations. InProceedings of the Forest Nursery Association of British Columbia Conference in Prince George, BC 1991 Sep 24 (pp. 106-110).
24. Landis TD. The container tree nursery manual. Agriculture handbook (USA). 1989.
25. Miehe S. Acacia albida and other multipurpose trees on the Fur farmlands in the Jebel Marra highlands, Western Darfur, Sudan. Agroforestry systems. 1986 Jun 1; 4(2):89-119.
26. Saleem M, Ahmad M, Ahmad A. Chemistry of the medicinal plants of genus Acacia. Hamdard Med. 1998;41:63-7.
27. NeSmith DS. Transplant age influences summer squash growth and yield. HortScience. 1993 Jun 1; 28(6):618-20.
28. NeSmith DS, Duval JR. The effect of container size. HortTechnology. 1998 Oct 1; 8(4):495-8.
29. Oboho, E.G. Using forestry to improve living conditions of the Sokoto State dwellers. Presented at the launching of the Biological Sciences Association Magazine (*Bioscope*) 1984: 1-16.
30. Page AL. Methods of soil analysis: chemical and microbiological proerpteis. Amen Society of Agronomy; 1982.
31. Paterson J. Growing environment and container type finluence field performance of black spruce container stock. New For. 1997; 13: 329-339.
32. Pearson D. (1970). The chemical analysis of foods. J and A. Chrchill, 140, Gloacester Place, London.
33. Richard MP. Effect of nursery media particle size distribution on container-grown woody ornamental production (Doctoral dissertation, Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Master of Science in The Department of Horticulture by Michael Paul Richard BS, Louisiana State University).
34. Riley L.E, Dumroese R.K, Landis T.D. National proceedings: forest and conservation nursery associations. Dept. of Agriculture, Forest Service, Rocky Mountain Research Station, 2006: 160.
35. Vandenbeldt RJ, editor. Faidherbia albida in the West African semi-arid tropics: proceedings of a workshop, 22-26 Apr 1991, Niamey, Niger. World Agroforestry Centre; 1992.
36. Scarratt JB. Container size affects dimensions of white spruce, jack pine planting stock. Tree Planters' Notes. 1972.
37. Sturmheit P. Alley cropping in southern Zambia: the potential of alley cropping in Mazabuka district. 1989.
38. Sturmheit P. Alley cropping in southern Zambia: the potential of alley cropping in Mazabuka district. 1989.
39. Timberlake J. Handbook of Botswana acacias. Gaborone: Division of Land Utilisation, Ministry of Agriculture 120p. Illus., maps.. Icones, Maps. Geog. 1980;5.
40. Tonutti P, Giulivo C. Effect of available soil volume on growth of young kiwi plants (1). InI International Symposium on Kiwifruit 282 1987 Oct 14 (pp. 283-290).
41. USDA soil Survey monograph (1975). A basic system of soil classification for making and interpreting soil surveys, USDA.
42. Van Iersel M. Root restriction effects on growth and development of salvia (Salvia splendens). HortScience. 1997 Dec 1; 32(7):1186-90.
43. Vogt K. A field worker's guide to the identification, propagation and uses of common trees and shrubs of dryland Sudan. 1996.
44. Walkley A, Black IA. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil science. 1934 Jan 1; 37(1):29-38.
45. Watt, J.M. and Breyer-Brandwijk, M.G., 1962. The Medicinal and Poisonous Plants of Southern and Eastern Africa being an Account of their Medicinal and other Uses, Chemical Composition, Pharmacological Effects and Toxicology in Man and Animal. The Medicinal and Poisonous Plants of Southern and Eastern Africa being an Account of their Medicinal and other Uses, Chemical Composition, Pharmacological Effects and Toxicology in Man and Animal., (Edn 2).
46. Weston LA, Zandstra BH. Effect of root container size and location of production on growth and yield of tomato transplants. Journal of the American Society for Horticultural Science (USA). 1986.
47. White F, Angus A. Forest flora of Northern Rhodesia. Forest flora of Northern Rhodesia. 1962.
48. Wickens GE. A study of Acacia albida Del. (Mimosoideae). Kew Bulletin. 1969 Jan 1:181-202.
49. Le Houerou HN. Browse in Africa: the current state of knowledge. ILCA; 1980.
50. Wickens GE. Role of Acacia species in the rural economy of dry Africa and the Near East. Food & Agriculture Org.; 1995.
51. Wu Y, Mishima K, Fujii E, Nakayama K, Yabuuchi H, Ogawa G, Kawamura T. Studies on the growth character of Osmanthus aurantiacus Nakai in containers with varied volume and shape. Technical Bulletin of Faculty of Horticulture-Chiba University (Japan). 1998.