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Ideal pot size for raising jojoba nursery seedlings in semi-arid areas of Kenya

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Abstract

An experiment was set up in the dry-lands of Kenya to determine the ideal pot size for raising jojoba seedlings for 6 months during 2012/2013. The experimental design was a RCBD with 5 treatments comprising of different pot sizes replicated 3 times. Data was collected on: survival, plant height, root collar diameter, leaf number, leaf length and width, leaf area, root number and length, fresh root biomass, fresh shoot biomass, total fresh plant biomass and root to shoot ratio. ANOVA was performed using SAS statistical package and Least significant difference (LSD) was used to identify the significant differences among the variable means at $p \leq 0.05$. Results showed that the larger pots had significantly higher growth compared with the smaller ones. However, the longest pot size (7.5 x 30 cm) showed the highest root to shoot ratio (2.0) compared with the largest one (15 x 27.5 cm) which was 1.2. The largest pot size (15 x 27.5 cm) is therefore recommended for use by nurserymen while the smallest pot size (7.5 x 10 cm) is discouraged since it compromises greatly the shoot growth of the young jojoba seedlings.

Keywords: Arid-Lands; Jojoba; Seedlings; Pot Size

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1. Introduction

In recent years, there has been considerable interest in using arid and semi-arid lands (ASALs) which constitute over 80% of Kenya (KARI, 2009) more productively by promoting crops which can tolerate these conditions such as *Jatropha curcas* (Ngethe, 2007) and jojoba (*Simmondsia chinensis)* (Thagana et al., 2004). These are multipurpose crops, and have a potential use for rehabilitation of the environment as well as provision of income to the pastoral communities.

Jojoba is a high value shrub and a promising cash crop for ASALs (Reddy and Chikara, 2010; Ahmad, 2001). It produces high quality oil used in cosmetics, lubricant industry, pharmaceuticals and electronics (Ward, 2003; Undersander et al., 1990).

Deep-rooted, long-lived perennial plants such as jojoba offer promise for agriculture in harsh, arid environments where many conventional crops cannot survive. Such woody plants with their massive root systems can extract moisture from a large volume of desert soil and can persist where herbaceous plants cannot (NRC, 2002).

High quality seedlings are vital for improved field performance and this is based on favourable plant height and root morphology which is rich in fibrous roots (Maltoni et al., 2010). Pot size is one of the main factors in growing high-quality and healthy seedlings (Das, 1992).

Container grown seedlings has become more favored over bare root method in many reforestation projects (Khurram et al., 2017; Lambert et al., 2010; Greer and Diver, 2000) for various reasons. These include: higher field survival, little soil needed for seedlings, out-planting is possible during any time of the year and especially when the soil moisture is enough.

Varying container size alters the rooting volume of the plants, which can greatly affect plant growth (Society of Experimental Biology, 2012; NeSmith and Duval, 1998).

Generally, as pot size increases, also plant leaf area, shoot biomass and root biomass increase as reported by Cantliffe (1993). Shoots and roots are closely interrelated in their growth rates (Tonutti and Giulivo, 1990). Roots depend on foliage for photosynthates while similarly shoots and leaves rely on the roots for water, nutrients and support. The balance between roots and shoots can be upset when the root system is reduced in a small rooting volume resulting to stunted plant growth. Doubling pot size helped seedlings to grow over 40% larger (Society of Experimental Biology, 2012). However, the sizes of the pot used depend on the nursery lifespan and the desired size of the seedlings (Tinus and McDonald, 1979).

2. Materials and methods

2.1. Study site

The trial was set up in Voi, Kenya, where jojoba bushes are established, along longitude 37^0 40’ 60” to 38^0 35’ 25” E and latitude to 3^0 23’ 60” to 3^0 24’ 26” S at an altitude of 892 metres above the sea level (TTDP, 2008).

The area is located in the dry-lands characterized by wooded scattered trees, shrubs and grasses with a bimodal rainfall distribution of 596 mm annually. Temperatures range from 16-37^{0}C with an average of 26^{0}C, sandy loam soil and moderate high humidity (60-80%) (Thagana et al., 2003).

2.2. Experimental design

Experiment was conducted for 6 months from September 2012 to March 2013. Experimental design was RCBD with 5 treatments replicated 3 times. The treatments were composed of different pot sizes based on width and length respectively as follows: 7.5 x 10, 10 x 15, 7.5 x 30, 12.5 x 20 and 15 x 27.5 cm. These were arranged according to volume beginning with the smallest to the largest as follows: 442, 1178, 1325, 2453 and 4857 cm^3. The volume was calculated using the general volume formula of a cylinder which is as follows: $\prod r^2 h$, where $\prod$= Pie (3.14), r= radius and h= height. The potting media was sand and farmyard manure in the ratio 2:1, respectively. Each replicate consisted of 5 rows and each row was made up of a treatment with 10 potted plants. Three plants were randomly sampled per row. Data was collected on: survival, plant height, root collar diameter, leaf number, leaf length and width, leaf area, root number and length, fresh root biomass, fresh shoot biomass, total fresh plant biomass and root to shoot ratio.

2.3. Data analysis

Data was analyzed using one-way analysis of variance (ANOVA) (SAS, 1996) in order to determine differences among the treatment means of the variables under investigation. The significant differences among the means were separated using least significant difference (LSD) at probability level of 5% ($p \leq 0.05$).

3. Results and discussion

3.1. Effect of pot size on survival and plant height of jojoba seedlings

Most of the variables measured showed significant superiority trend which was directly and positively correlated with pot size. The results of this study showed that both survival and plant height increased with increase in pot size. The largest pot size (15x27.5 cm) with a volume of 4857 cm^3 showed the highest survival (90%) and plant height (35.5 cm). These were significantly ($p \leq 0.05$) higher compared with the smallest pot sizes (7.5 x10 cm and 10 x 15 cm) (Table 1).

Studies by Segaw et al. (2016) were not consistent with the current study since plant height was not affected by pot size. However, these studies were based on only 2 pot sizes which had a narrow range of 8 and 10 cm in width while the current study had a wide range from 7.5 to 15 cm in width.

Pot size 12.5 x 20 cm was double the volume size compared with 10 x 15 cm (2453 cm^3 and 1178 cm^3 respectively) and this showed a 56% increase in plant height. This corroborates with earlier findings by the Society of Experimental Biology (2012) who stated that doubling container size resulted into seedlings growing over 40% bigger.

Table 1. Effect of pot size on survival and height growth of jojoba seedlings

Pot size (width x length) cm	Pot volume (cm³)	Survival percent (%)	Plant height (cm)
7.5 x 10	442	36.7c	14.5c
10 x 15	1178	60.0bc	20.5b
7.5 x 30	1325	71.0ab	20.8b
12.5 x 20	2453	86.7ab	32.0a
15 x 27.5	4857	90.0a	35.5a
CV		22.3	12.5
LSD		27.9	5.6

Means followed by different letters in each column are significantly different to each other at ($p \le 0.05$)

3.2. Effect of pot size on shoot growth of jojoba seedlings

The largest pot size showed the highest growth in fresh shoot biomass (17.7 g) and fresh total plant biomass (24.7 g) as well as number of sprouts (3.9). These variables were significantly ($P \le 0.05$) higher compared with all the other smaller pot sizes (7.5 x 10, 10 x 15 and 7.5 x 30 cm) (Table 2).

Similar results were reported by Yadessa and Bekere (2001) who found higher shoot dry weight in larger pots of 10 cm compared with the smaller pot of 8 cm for *Leucaena pallida* seedlings. Small containers causes root restriction hindering water and nutrient uptake leading to reduced plant biomass as a result of lower photosynthetic rate (NeSmith and Duval, 1998).

Table 2. Effect of pot size on shoot growth of jojoba seedlings

Pot size (width x length) (cm)	Pot volume (cm³)	Internode length (mm)	Number of sprouts	Fresh shoot biomass (g)	Fresh total plant biomass (g)
7.5 x 10	442	16.5	0.2c	2.0d	3.0c
10 x 15	1178	15.7	1.4bc	5.8c	9.4b
7.5 x 30	1325	20.0	1.3bc	6.5c	9.7b
12.5 x 20	2453	22.0	2.6ab	9.6b	13.6b
15 x 27.5	4857	23.4	3.9a	17.7a	24.7a
CV		22.9	58.1	20.0	21.3
LSD		8.1	2.0	3.0	4.7

Means followed by different letters in each column are significantly different to each other at ($p \le 0.05$)

The largest pot size showed 8 times higher fresh shoot (17.7 g) and total plant biomass (24.7 g) compared with the smallest pot size (7.5 x 10 cm) (2 g) and (3 g) respectively. These were significantly higher than all the other pot sizes under study. The smallest pot showed a volume of 442 cm^3 which was 11times lower than the largest one (4,857 cm^3). This could be due to large volume of growth media contained in the larger pots leading to a supply of adequate water and nutrient for favourable growth of seedlings. On the other hand, larger pots were least affected by the harsh climatic conditions such as high temperatures and low soil moisture availability prevailing in the study site as compared with the smaller pots. Tinus and McDonald (1979) reported contradictory findings to the present study by stating that small containers resulted to large shoots leading to a high shoot to root ratio.

3.3. Effect of pot size on foliage growth of jojoba seedlings

The largest pot size showed significantly ($P \leq 0.05$) higher number of leaves (67.6) and total leaf area (432.6 cm^2) compared with the smaller pot sizes (7.5 x 10, 10 x 15 and 7.5 x 30 cm) (Table 3). Similarly, the largest pot also showed significantly higher leaf length (37.7 mm), leaf width (19.7 mm) and single leaf area (6.4 cm^2) compared with the smallest pot size which showed 23.7 mm, 11.5 mm and 2.5 cm^2 respectively.

Table 3. Effect of pot size on foliage growth of jojoba seedlings

Pot size (width x length) (cm)	Pot volume (cm^3)	Number of leaves	Leaf length (mm)	Leaf width (mm)	Single leaf area (cm^2)	Total leaf area (cm^2)
7.5 x 10	442	14.8c	23.7c	11.5b	2.5b	39.6c
10 x 15	1178	27.7c	30.0bc	16.4a	4.4ab	125.4c
7.5 x 30	1325	28.3bc	36.4ab	17.3a	5.8a	154.4bc
12.5 x 20	2453	48.2ab	37.8a	18.1a	5.7a	265.5ab
15 x 27.5	4857	67.6a	37.7a	19.7a	6.4a	432.6a
CV		29.4	12.6	15.4	24.5	44.4
LSD		20.0	7.6	4.7	2.2	120.2

Means followed by different letters in each column are significantly different to each other at ($p \leq 0.05$)

Similar results were reported by NeSmith et al. (1992) who found that decreased rooting volume in bell pepper led to a reduction in leaf area due to smaller and fewer leaves per plant with a consequent decline in leaf photosynthetic rate coupled with reduced chlorophyll content.

3.4. Effects of pot size on root growth jojoba seedlings

The largest pot size showed significantly ($p \leq 0.05$) the highest root collar diameter (5.2 mm), root length (42 cm) and fresh root biomass (7 g) compared with all the other smaller pot sizes (Table 4). Recent findings by Segaw et al. (2016) reported similar results on *Sesbania sesban* for root length and fresh root biomass and preferred the use of larger pot size compared to the smaller one.

However, highest root: shoot ratio based on length was showed by the smallest pot size (1.6) which was significantly higher compared with the largest pot size (1.2). These results contradict those by Segaw et al. (2016) who reported that larger pots showed higher root: shoot ratio in *Cajanus cajan and Sesbania sesban*. On the other hand, the longest pot (7.5 x 30 cm) showed the highest root: shoot ratio (2.0) which was significantly higher compared with 10 x 15, 12.5 x 20 cm and largest pot size. This can be explained by the fact that jojoba being a desert shrub has developed special root morphological adaptations for survival in very dry environments.

Table 4. Effect of pot size on the root growth of jojoba seedlings

Pot size (width x length) cm	Pot volume (cm^3)	Root collar diameter (mm)	Number of roots	Root length (cm)	Fresh root biomass (g)	Root : shoot ratio (L)	Root: shoot ratio (wt)
7.5 x 10	442	2.8b	54.8	23.3c	1.0c	1.6ab	0.8
10 x 15	1178	3.3b	55.2	30.5bc	3.7b	1.5bc	0.7
7.5 x 30	1325	3.4b	33.1	40.8ab	3.2bc	2.0a	0.5
12.5 x 20	2453	4.0b	60.0	40.0ab	4.0b	1.3bc	0.4
15 x 27.5	4857	5.2a	52.0	42.0a	7.0a	1.2c	0.4
CV		16.9	36.7	16.0	36.0	15.8	49.1
LSD		2.2	34.4	10.3	2.5	0.4	0.5

Means followed by different letters in each column are significantly different to each other at ($p \leq 0.05$)

The length of roots for the large pot was also similar to those of 7.5x30 cm. This showed that the larger containers are more favorable for jojoba seedlings since they allow sufficient growth of roots since jojoba has a tendency for faster root growth compared to shoot elongation. This was confirmed further by significant root: shoot ratio in terms of length shown by the longest pot.

Similar studies by Mariotti et al. (2015) and Vaknin et al. (2009) showed that seedlings raised in bigger pots produced the largest seedlings. Plant size can influence out planting performance especially in xeric sites where long rooted seedlings in large containers perform better (Mariotti et al., 2015; Pinto et al., 2011; Tinus and McDonald, 1979). Balanced bigger seedlings achieve higher survival especially in arid environments (Villar-Salvador et al. 2010).

The higher root to shoot ratio and root weight tend to perform better, as large root system supply the water and nutrient requirements of their relatively small shoot (West, 2006) and it is considered a desirable character in arid lands (Villar-Salvador et al., 2010). Shoot and root development of walnut seedlings was more limited by pot diameter than depth (Mariotti et al., 2015), however this was not investigated by the current research. Seedlings with large roots suffer little post-transplant shock and also come into production earlier compared with small root systems (Weston and Zandstra, 1986).

4. Conclusion

Jojoba seedlings grow best in large pot sizes leading to higher survival and shortening the nursery period to attain 30 cm in plant height. However, small pots should be discouraged since they lead to stunted growth of seedlings which can result to low survival in the field.

Based on the findings, the largest pot size (15x27.5 cm) is recommended for use by nurserymen for raising jojoba seedlings while the smallest pot size (7.5x10 cm) is disregarded since it compromises greatly the shoot growth of the young seedlings. On the other hand, the other medium pot sizes (10x15), (12.5x20) and (7.5x30) cm can be used sparingly depending on the availability of the materials and labor. Use of large pots is also recommended for raising other deep rooted seedlings in arid areas, since deep rooted nature is a phraetophytic adaptation for arid plants. However, further research is needed to determine the most ideal pot size for jojoba in terms of length, width and volume of soil.

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