

Effect of Mother Plant Management on Propagation of Jojoba Cuttings in Semi-arid Areas of Voi, Kenya

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Abstract

Jojoba (Simmondsia chinensis L.) is a dioecious high value desert shrub growing in the arid areas and produces oil similar to that obtained from sperm whale. However, it's a difficult-to-root plant and rooting is influenced by the management of the mother plant as the source of cuttings. An experiment was set up to determine the effects of mother plant management regimes on the performance of stem cuttings of Jojoba raised in a polythene sheet tunnel using macro-propagation techniques in Voi, Kenya from September 2012 to January 2013. The experimental design was a Randomized Complete Block Design (RCBD) with 8 treatments replicated 3 times. The treatments comprised of management regimes applied on the mother plants prior to the harvesting of cuttings for propagation. These were manure, micro-catchment, irrigation and their combinations. The cuttings were harvested and then dipped in 5000 mgL⁻¹ indole butyric acid (IBA) for 10 seconds before planting in polythene bags where they were left to grow for 5 months. Data was collected on root, shoot and foliage variables and ANOVA was carried out using SAS analysis while the significant means were separated using LSD at $p < 0.05$. Results showed significant differences among the management regimes in all the variables measured with the management regime combinations being more superior while micro catchment alone showed significantly the lowest values in all the variables. However, there were no significant differences between the highest values relative to the control. The latter showed highest values in height and root length among the variables measured while the others were shared among the management regime combinations. This study implies that Jojoba mother plants do not require any special management prior to harvesting of cuttings for propagation.

Key words: Jojoba; management regime; mother plant

INTRODUCTION

Over 80% of Kenya is composed of arid and semi arid lands (ASALs) with only a few crops being grown mainly for subsistence purposes (KARI, 2009). They experience frequent drought leading to crop failure hence overdependence on food relief. In recent years, there has been considerable interest in using ASALs more productively by promoting crops which can tolerate these conditions such as *Jatropha curcas* (Ngethe, 2007) and *Simmondsia chinensis* (Jojoba) (Thagana *et al.*, 2003) which have a potential use for rehabilitation as well as provision of income. Jojoba is a high value shrub and it is a promising cash crop throughout the world. It is a native of Sonoran Desert of USA and Mexico (Gentry, 1958). It grows on coarse, light and medium textured well drained sandy soils with marginal fertility and pH of 5-8 (Undersander *et al.*, 1990). It tolerates low rainfall (220-400 mm per year) and high optimum temperatures of between 27 and 33°C.

Being dioecious, a seeded plantation of Jojoba has high seed variability (Inoti *et al.*, 2015) genetic heterogeneity (Inoti, 2017) and low average yields (Benzioni, 1997). Seed raised seedlings give a ratio of 1:1 (male to female) in the field leading to low production. The recommended ratio is 1:10 (male to female) in order to obtain maximum yields per ha (Undersander *et al.*, 1990) and this can be achieved through vegetative propagation.

Vegetative propagation enables the establishment of plantations with the desired proportion of male to female plants from pre-selected superior clones (Benzioni, 1997). It also creates uniformity, high yields, early bearing and reduced cost of cultural operations (Hogan and Palzkill, 1983). Although jojoba is a difficult to root plant, yet propagation through cuttings is the most commonly used asexual method although with limited success (Palzkill and Feldman, 1993). The events leading to adventitious rooting strongly depend on the mother plant nutritional status, both in terms of minerals and carbohydrates, as well as sink establishment at the cutting base (Da Costa *et al.*, 2013). Similarly, other studies have documented that clones display great variation in rooting ability (Prat *et al.*, 1998; Dick *et al.*, 1999).

Mother plant management in propagation has often received little attention, yet it is a key determinant in rooting of cuttings (Loreti and Morini, 1983; Da Costa *et al.*, 2013; Kester, 2017). Physiological condition is affected by environmental conditions such as light, temperature, water and nutrients. Endogenous auxin, carbohydrate content, mineral nutrients and other biochemical components such as phenolics which act as auxin transport modulators may be affected by environmental factors (Da Costa *et al.*, 2013).

An experiment was set up with the objective to determine the effects of mother plant management regimes on the performance of stem cuttings of Jojoba raised in a polythene sheet tunnel using macro-propagation techniques. This study was aimed at solving the problem of propagation of cuttings in the field for maximum production.

MATERIALS AND METHODS

Site description

The research was conducted in Rukinga Wildlife Works, Maungu, Kenya, where Jojoba bushes have been established. This site is located about 30 km away from Voi, coastal province. It lies in semi arid savannahs with an annual rainfall of 458 mm and an altitude of 892 meters. Soils are moderately fertile with sandy loam and gravel texture and pH of 5-8. Temperatures average at 26⁰C with moderate humidity of 59% (Thagana *et al.*, 2003; TTDP, 2008). The rainfall received during the experimental period was lower than the annual average by 158 mm.

Experimental design and sampling procedures

The experiment was laid down in a randomized complete block design with 8 treatments replicated 3 times. The treatments were as follows: manure; micro-catchment; irrigation and their combinations as well as the control. These treatments were applied in mature Jojoba bushes grown on a gentle sloping site for 3 years before the cuttings were harvested. Blocking was done according to slope which also accounted for difference in soil fertility and each block constituted a replicate. Water was applied at a rate of 6 litres fortnightly bush⁻¹ while manure was 2.5 kg bush⁻¹. Micro catchment size was 1 m width by 3 m length. Irrigation was applied during the dry season only.

Stem cuttings were obtained from the middle portion of the crown from different management regimes of female bushes as recommended by Aminah (1990) and Palzer (2002). This portion gives cuttings with high carbohydrate to nitrogen ratio which have the best rooting ability (Sadhu, 1989). A total of 12 stem cuttings were randomly harvested from each treatment per replicate, which consisted of 4 bushes each. The stem cuttings were harvested at the dormant stage and each twig consisted of 5 nodes. The cuttings were raised in a polythene sheet tunnel for 5 months from September 2012 to January 2013.

Freshly harvested twigs were then quickly dipped for 10 seconds in IBA at a concentration of 5000 mgL⁻¹ + 15.5, boric acid which were placed in a container. These cuttings were then planted in sand potted polybag containers placed inside a polythene sheet tunnel.

Data summarization and analysis

Three rooted cuttings were randomly sampled per treatment per replicate. The variables measured were: plant height, height of new growth, number of shoots, internode length, leaf length, leaf width, number of leaves, single leaf area, total leaf area, root collar diameter, number of roots, root length and fresh total plant biomass. Data of the variables collected were analyzed using one-way analysis of variance (ANOVA) whereas the significant means were separated by least significant difference (LSD) at $p \leq 0.05$ (SAS, 1996).

RESULTS

Effect of management regimes on the root growth of Jojoba cuttings

Separate application of manure and irrigation treatments did not show any rooting hence no data is available for growth variables as indicated in Table 1. On one hand micro catchment and irrigation combination showed the highest root collar diameter which was significantly higher ($p < 0.01$) compared to micro catchment alone.

Table 1: Effect of management regimes on the root growth of Jojoba cuttings

Management regime	Root collar diameter (mm)	(n) of roots	Root length (cm)
Manure	-	-	-
Micro-catchment	0.7bc	4.3c	10.7bc
Irrigation	-	-	-
Manure and Micro-catchment	2.7a	27.5a	26.9a
Manure and Irrigation	2.7a	16.8ab	29.9a
Micro-catchment and Irrigation	3.0a	23.0a	24.9ab
Manure, Micro-catchment and Irrigation	1.7ab	10.7bc	19.4ab
Control	2.3ab	24.2a	33.1a
CV	60.2	46.9	50.1
LSD	1.7	10.9	15.9
P value	0.0062	0.0002	0.0018

Means with the same letter(s) in each column are not significantly different to each other at $p < 0.05$

On the other hand, manure and micro catchment combination showed the highest number of roots which were significantly ($p < 0.001$) higher than micro catchment alone as well as the combination of manure, micro catchment and irrigation. Micro catchment alone showed the lowest number of roots which were significantly lower than all the irrigation combinations as well as the control. The latter was higher than micro catchment alone by 82%.

The control showed the highest root length which was significantly higher ($p < 0.01$) than micro catchment alone. However, the latter was significantly lower than manure and irrigation combination as well as manure and micro catchment combination.

Effect of management regimes on the shoot growth of Jojoba cuttings

ANOVA results in Table 2 indicate that the highest height was shown by the control which was significantly higher ($p \leq 0.001$) compared to micro catchment and irrigation combination as well as micro catchment alone. On the other hand, micro catchment alone showed significantly the lowest height ($p \leq 0.001$) compared to manure and micro catchment combination, manure and irrigation combination and manure, micro catchment and irrigation combination.

Table 2: Effect of management regimes on the shoot growth of Jojoba cuttings

Management regime	Height (cm)	Height of new growth (cm)	Internode length (mm)	Total fresh plant biomass (g)
Manure	-	-	-	-
Micro-catchment	3.7cd	2.7bc	10bc	0.7cd
Irrigation	-	-	-	-
Manure and Micro-catchment	14.5ab	10.1a	28.3a	3.8a
Manure and Irrigation	13.9ab	10.7a	20.7ab	2.7ab
Micro-catchment and Irrigation	9.2bc	7.7ab	21.3ab	3.3ab
Manure, Micro-catchment and Irrigation	12.4ab	8.8a	18.0ab	2.0bc
Control	17.6a	9.0a	26.3a	3.2ab
CV	50	56	51.1	48
LSD	7.8	6	14	1.7
P value	0.0010	0.0045	0.0026	0.0005

Means with the same letter(s) in each column are not significantly different to each other at $p < 0.01$

Manure and irrigation combination showed significantly highest ($p < 0.01$) height of new growth compared to micro catchment alone. Micro catchment alone showed significantly lower height of new growth compared to all the other management regime combinations including the control except micro catchment and irrigation combination.

Manure and micro catchment combination showed the highest internode length and total fresh plant biomass. However, the highest internode length was only significantly superior ($p < 0.01$) to micro catchment alone while the latter was also significantly lower than the control by 62%. On the other hand, the highest total fresh plant biomass was significantly higher compared to micro catchment alone and the combination of manure, micro catchment and irrigation. Similarly, the lowest total fresh plant biomass was showed by micro catchment alone which was significantly lower than all the other management regime combinations including the control except manure, micro catchment and irrigation combination.

Effect of management regimes on the foliage growth of Jojoba cuttings

Manure and micro catchment combination showed the highest leaf length, leaf width and single leaf area compared to the other management regimes (Table 3). On the other hand, the highest leaf width was significantly higher than micro catchment alone as well as the combination of manure, micro catchment and irrigation. The highest single leaf area was significantly higher than micro catchment alone and the combinations of micro catchment and irrigation as well as manure, micro catchment and irrigation.

Table 3: Effect of management regimes on the foliage growth of Jojoba cuttings

Management regime	Leaf length (mm)	Leaf width (mm)	Number of leaves	Single leaf area (cm ²)	Total leaf area (cm ²)
Manure	-	-	-	-	-
Micro-catchment	10.3bc	5.7cd	2.3c	0.9cd	6.3cd
Irrigation	-	-	-	-	-
Manure and Micro-catchment	34.8a	17.3a	14.7ab	3.9a	64.1a
Manure and Irrigation	31.3a	13.2ab	22.0a	3.0ab	64.7a
Micro-catchment and Irrigation	27.3ab	11.3abc	11.3b	2.1bc	23.4cd
Manure, Micro-catchment and Irrigation	25.5ab	8.7bc	12.2b	1.9bc	34.1abc
Control	30.4a	12.2abc	15.2ab	2.7ab	41.2ab
CV	48.9	48	51.7	51.5	64
LSD	17.1	7.2	8.8	1.6	32.7
P value	0.0016	0.0011	0.0006	0.0012	0.0022

Means with the same letter(s) in each column are not significantly different to each other at $p < 0.01$

Manure and irrigation combination showed the highest number of leaves which were significantly superior ($p < 0.001$) compared to all the other management regimes except manure and micro catchment combination and the control. Manure and irrigation combination showed the highest total leaf area which was significantly higher than micro catchment and irrigation combination as well as micro catchment alone. The latter was also significantly lower than manure and micro catchment combination and the control by 90% and 83%, respectively. Although ANOVA results of root, shoot and foliage growth variables showed significant differences ($p < 0.01$) among the treatments, there were no significant differences between the highest values relative to the control.

DISCUSSION

Despite the importance of the mother plant management to rooting of cuttings (Da Costa *et al.*, 2013), the findings of the present study were contradictory showing that there is no need for mother plant management. This implies that propagation of Jojoba cuttings does not need any special prior management regime on the mother plants. Da Costa *et al.* (2013) reported that adventitious rooting in cuttings is a multifactorial response leading to new roots at the base and establishment of an autonomous plant.

The most plausible explanation for this study on the low performance of management regimes is that application of manure alone without enough water through irrigation could have resulted to toxicity to the mature Jojoba bushes hence poor quality of the cuttings. There were isolated cases of partial and total death of the bushes with manure application. This experiment was conducted in 2012 during a period of severe drought, since the rainfall received was 34% below average compared to the long term annual rainfall (458 mm) for the region. The optimum rainfall for Jojoba is between 500-600

mm (rainfall plus irrigation). Yermanos (1979) also recommended supplemental irrigation for areas where rainfall does not exceed 400 mm yr⁻¹. The supplemental irrigation in the current study was 6 litres bush⁻¹ per fortnight which was not adequate for a drought year and this could explain the low performance of irrigation in this study.

Management techniques applied to the mother plants can exert positive effects on the rooting potential of cuttings (Loreti and Morini, 1983). The ability to root also depends on the endogenous balance of carbohydrates, auxins and rooting co-factors according to Sadhu (1989) who reported that endogenous auxin accumulation helps to initiate rooting and this varies with species and season. Season of harvesting the cuttings has been ranked higher than variation within Jojoba plants in initiating rooting (Low and Hackett, 1981). However, this was not investigated by this study. Rooting hormone such as IBA promotes rooting during periods of high rooting potential but can have no effect or become slightly inhibitory during periods of low rooting potential (Low and Hackett, 1981). These findings corroborate with this study since IBA was not effective in promoting rooting.

Ability to root is also affected by the physiological condition of the stock plant (Low and Hackett, 1981), cultural factors (Foster *et al.*, 1984) and maturation (Ozel *et al.*, 2006). The cuttings in the present study were obtained from old bushes which were over 25 years hence the inability to root effectively. Earlier works by Paton *et al.* (1970) and Zhou, (2002) stated that the ability of cuttings to form roots tends to decrease with the age of the mother plant due to increase in rooting inhibitors. Cultural practices such as pruning, fertilizing and watering during the dry season can encourage sprouting of shoots for cuttings (Longman, 1993).

The superior performance of the control, in this study, corroborates with a study by Undersander *et al.*, (1990) who stated that manuring is not necessary for mature bushes since addition of nitrogen (N) and phosphorous (P) does not show any improvement in vegetative growth and yields (Hussein *et al.*, 2013; Osman and AboHassan, 2013). This is also consistent with work by Benzioni and Ventura, (1998) who reported that low P had no effect on shoot growth or chlorophyll concentration. Recent work by Kessler, (2017) reported that high carbon to nitrogen allows high carbohydrate storage resulting to healthier rooted cuttings. Similarly, calcium is needed to produce thicker stems and cell walls which translate into stronger cuttings. On the other hand, since Jojoba can thrive under marginal nutrient soils ((Undersander *et al.*, 1990; CJP, 2007), it is likely that the inherent soil fertility in the study site was adequate for normal growth hence no further addition of nutrients was necessary.

The events leading to adventitious rooting strongly depend on the mother plant nutritional status, both in terms of minerals and carbohydrates, as well as sink establishment at the cutting base (Da Costa *et al.*, 2013). High levels of amino acid build up were observed under canopies of Jojoba bushes (Burman *et al.*, 2002), due to nutrient recycling.

The negative effect of the micro catchments in this study can best be explained by low rainfall received during the year (300 mm) of the experiment making runoff harvesting less effective. In addition, creation of micro catchments opened the soil surface to more water loss from the soil as compared to minimal disturbance for the control as earlier

reported by Al-Kaisi *et al.*, (2000). The authors showed that soil surface disturbance through tillage causes moisture loss. Every soil disturbance on the top 5 cm depth causes soil moisture loss of 6 mm. Schiffner (2012) stated that soil moisture storage efficiencies of 40-60% in ASALs are achieved when tillage is minimized or eliminated. Under dry conditions, it is recommended to scrap small weeds on the surface without disturbing the soil too deeply (Al-Kaisi *et al.*, 2000). After a long dry spell, highly disturbed soils dry faster.

This study noted low performance of irrigation applied singly. This phenomenon can best be explained by the little water added through irrigation (6 litres per fortnight) which was inadequate to sustain the water requirements of a mature Jojoba bush for normal growth especially under harsh drought conditions. On average 1-2 litres of irrigation water plant⁻¹ day⁻¹ is recommended for Jojoba (CJP, 2007). Little water application under high temperatures during drought can lead to scorching of the lateral roots at the top soil layer where 80% of the lateral roots are found.

On the other hand, manure and irrigation combination showed superior growth performance in most of the variables measured though not significant relative to the control. Manure supplies nutrients which are made available to plants through irrigation water. This phenomenon agrees with studies by (Sadhu, 1989) who observed that high carbohydrate to N ratio in stock plants favour rooting in cuttings. High accumulation of carbohydrate and starch at the rooting zone was associated with improved rooting in *Eucalyptus globulus* (Ruedell *et al.*, 2013) and *Tectona grandis* cuttings (Husen and Pal, 2007).

Feldman, (1982) has emphasized the importance of mineral nutrients such as P and trace elements namely, boron, zinc and molybdenum in stimulating rooting. Heterogeneity of Jojoba population leads to lack of significant positive response to nutrient addition (Al-Soqeer, 2010). Further investigations are necessary to determine the effect of mineral nutrition on Jojoba mother plant propagation since the present study shows improved performance which however was not significantly different relative to the control.

CONCLUSION AND RECOMMENDATIONS

Different management regimes on Jojoba mother plants before propagation did not show significant differences relative to the control. This study therefore recommends no special management regime required for Jojoba mother plants before harvesting of cuttings. However, further research is recommended on use of young mother plants which are well watered through irrigation and/or adequate rainfall as well as improved mineral nutrition.

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