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Original Article

Effect of Potting Tube Size on Growth and Development of Ziziphus mauritiana Seedlings

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Tree Nursery.

ABSTRACT

Indigenous tree seedlings play a very critical role in restoration of degraded lands owing to their adaptability and resilience in dryland areas. Development of indigenous seedlings in tree nurseries is therefore an exercise of great essence. This has caused a need for review of practices to improve performance of the seedlings in the nurseries to aid in quality improvement. Tree nurseries have been observed to have varied potting material sizes which would affect seedlings growth and development. Potting material sizes have been observed to have profound effects on water retention, soil fertility and seedling growth parameters. The aim of this study was to evaluate the influence of different potting tube sizes on Z. mauritiana seedlings growth and development in drylands. We evaluated three potting tube sizes; with their varying volumes; 4 x 6 (4683 cm3), 5 x 8 (9216 cm3) and 6 x 9 (22046 cm3). The results showed that potting tube size had a significant effect on the seedlings root collar diameter and height. The seedlings planted in 5 x 8 and 6 x 9 tubes had significantly higher height ($p < 0.05$) than those planted in 4 x 6 cm potting tubes. The means were significantly different at $p < 0.05$). One Way ANOVA revealed that there was a statistically significant difference between the mean heights and RCD of seedlings planted in each of the potting tube sizes; $F(2,237) = 15.82$, $p = 0.00$ and, $F(2,237) = 11.595$, $p = 0.00$ respectively. Tukey's HSD test for multiple comparisons was used to separate the means. Therefore, this study concludes that different potting tube sizes have significant impact on the development of the root collar diameter. Therefore, the use of larger potting tubes (6 x 9) is recommended for raising seedlings to increase growth and development in seedlings.

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INTRODUCTION

Seedlings are small plants with enough potential to grow into mature trees. They are used as food sources by birds, squirrels, and other kinds of animals. These seedlings develop naturally but can also be grown through seeding and germinating, which allows them to sprout faster and increase their chances of survival. Tree seedlings are the future of forests. They help maintain the balance of human-nature relationships, preventing soil erosion and providing fodder for animals. Tree seedlings development is important since seedlings are the main source of biodiversity and remains very central to human lives. We eat food and fruits from trees, we use paper that is made from trees, and medicine that is extracted from the bark of trees (Nature Conservancy, 2020). Animals rest in their shade and breathe their air (Jaenicke, 1999). Moreover, trees are equally an integral part of agricultural landscape and are playing increasingly important roles in income generation for rural households (Jaenicke, 1999). According to Hamilton (2004), trees contribute in terms of health support, financial income, cultural identity and livelihoods security. Trees can be used in many different ways including reducing urban heat island effect and noise, minimizing risks associated with storms and floods as well as reducing soil erosion. Consequently, trees play a major role in the development of urban forestry where they directly and indirectly affect local and regional air quality by influencing urban atmospheric environment (Nowak, 2002).

Development of seedlings begins with the acquisition of viable germplasm or rootstocks that can be germinated or developed through vegetative means (Wolny et al., 2018). Plant growth requirements are a function of seedlings development and vigour (Wolny et al., 2018). All too often, nurseries operate with minimal inputs and outdated techniques, and therefore produce poor seedlings (Jaenicke, 1999). Therefore, to enhance the quality of seedlings produced, nurseries should demonstrate high quality standards that incorporates structured planning and quality control, appropriate substrates and containers, nursery hygiene, and good equipment (Jaenicke, 1999). In dry lands, successful tree growing requires high seedling vigour, among other things (Abera et al., 2018a). Thus, nursery practices have effect on the vigour of the seedlings and accordingly on the success of their transplantation in the field (Abera et al., 2018a). According to Dominguez-Lerena et al. (2006), nursery planting pots have been reported as one of the main factors affecting the successful development of seedlings with large potting pots producing seedlings with long tap roots during the nursery. This notwithstanding, soil mix can greatly influence both the vigour and the water status of the seedlings through its effects on water holding

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capacity, aeration, and nutrition (Abera et al., 2018a). The primary role of any container is to hold a discrete supply of growing medium, which in turn supplies water, air, mineral salts, mineral nutrients, and the physical support of the seedlings (Begum et al., 2021). Thus, to grow seedlings that can support all the physical, environmental, and nutritional upheavals of development require a potting tube that can provide all the supportive necessities for development.

A review of the literature reveals that small potting tubes have a low water retention rate, and having lower soil fertility than larger potting tubes. According to a study by Kishor and Ram (2019), the container size, media, and interaction thereof had significant influence on length of the primary root, number of secondary roots, fresh root weight, and the dry root weight. The longest primary root (31.07 cm), maximum number of secondary roots (100.72), and fresh root weight (17.55 g) was in the 4200 CC container (polybag 23 cm x 28 cm) which was statistically superior to remaining container sizes (Kishor & Ram, 2019). Another study by Islam et al. (2019) indicated that the longest shoot length (137.5 cm), root length (38.1 cm), and collar diameter (9.5 mm) were highest in T4 treatment which had the largest potting tube size (20 x 25 cm). Studies have shown that soil fertility and water retention are also positively correlated with potting tube size (Islam et al., 2019). A study by Agonafer et al., (2016) found that larger pots retained more water than smaller ones; this has important implications for seedlings development in drylands, where water is scarce. A study by Abera et al. (2018b) showed that larger pots increased root collar diameter and height, while smaller pots led to root-bound seedlings. While this might be desirable for growers in search of a particular aesthetic, it can have negative impacts on the overall health of the seedling by restricting its ability to absorb nutrients from the soil. A study by Hameed et al. (1987) also found that root volume restriction inhibits nutrients uptake, limits oxygen supply, and imbalances growth substances between shoots and roots. Studies have shown that various potting tube sizes affect germination rates as well (Annapurna et al., 2004). Abera et al. (2018a) found that smaller pots had higher germination rates than larger ones, though this could be due to species-specific differences or differences in fertilizers used. In dry lands, the soil quality is usually poor and variable, which limits the growth and development of seedlings. According to a study conducted by Poorter et al. (2012), root collar diameter and height are both significantly impacted by potting tube size. A study from Abera et al. (2018a) also found that water retention was a significant determinant of plant growth rates, with smaller potting tube sizes causing greater water retention and therefore faster plant growth rates, but only up to a certain point—beyond which the plants grew slower due to root bounding.

Ziziphus mauritiana is a much-branched spiny tree or shrub up to 10 m high, with a trunk 40 cm or more in diameter, spreading crown, stipular spines and many drooping branches (Maundu et al., 1999). The tree is widespread in Africa especially in the North, also the Mediterranean to India, and cultivated in tropical and sub-tropical parts of the world. Due to its drought-tolerant characteristics, it has been promoted as a suitable tree for dry land rehabilitation and as an underutilized species (Alam et al., 2018). *Ziziphus mauritiana* was first named as *Ziziphus jujube* in 1789 by Lamarck (Rehder, 1922). However, in India two varieties are recognized; var. hysudrica, which is wild or cultivated with large fruit, and var. fruiticosa, which is a small shrub in the sub-Himalayan tract, with small fruit (Alam et al., 2018). *Ziziphus mauritiana* is a declared noxious weed in three Australian states and is noted as an invasive in parts of southern Africa, and on a number of Pacific and Indian Ocean islands (Alam et al., 2018). In Kenya, *Ziziphus mauritiana* is found in extremely dry areas such as West Pokot, Baringo, and Turkana and in humid areas at the coast. It does well in areas with high

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water table within the agroclimatic zones III-VII(Orwa, 2009). *Ziziphus mauritiana* is used in a spectrum of utilities. The plant has an extensive root system that can be used to aid in the fixation of coastal dune (Barwick et al., 2004). It is also used as a live fence due to its spiny stems and branches that deter livestock. The tree is widely used in livelihood diversification solution in the dryland. In Turkana, the tree is locally known as ekalale (Stave et al., 2006). Its fruits are a major source of food. The fruits are made into a pulp which can be made into a thirst-quenching drink and the seed can be ground as a substitute for sorghum and millet and mixed with figs in honey and stored in large containers for use during times of food scarcity (David & Joep, 2006). Moreover, the people of Turkana have a significant reliance on *Ziziphus mauritiana* due to its reasonably fast-growing characteristics and its all-round use as fruit, fodder, firewood, poles and thorns (David & Joep, 2006). The tree is also used for both medicinal and commercial purposes. Its root decoction is often taken as an abortifacient (Maundu et al., 1999). Among the Swahili, its root infusion is used as a treatment for dysentery, while among the Pokot, it is used to treat tuberculosis and indigestion among the Marakwet. The fruits of *Ziziphus mauritiana* are also sold in the big market centres of Lodwar, Malindi, Kilifi, Mombasa, and Nginyang (Maundu et al., 1999).

In forest nursery practices, the concept of the potting tube size incorporates all the dimensional aspects including volume, height, diameter, and shape (Begum et al., 2021). Potting material size therefore has an effect on the rooting volume of the seedlings. According to Hameed et al. (1987), rooting volume restriction results to reduction of shoot growth and imbalances growth substances between roots and shoots. These aspects pose significant influence to the growth and development of seedlings. It is therefore necessary to standardize optimal size of planting pot for a particular species to obtain a desired seedling size within a time. Moreover, considering the cost of raising seedlings in the dry lands, it is important to have sufficient information about the requisite potting tube size that need to be acquired for raising quality seedlings that can ensure better survival and successful establishment of plantations. This research is important since it will inform which size of potting tube is suitable for raising seedlings thus addressing the problem of poor-quality seedlings commonly realized in nursery seedlings establishment; for instance, if small sized potting seedlings survive and grow as well as larger stock, then nursery costs could be reduced without lowering field performance. The major objectives of this study are to assess the effects of potting tube size on the growth and development of *Ziziphus mauritiana* seedlings. The specific objectives are to determine the effect of potting tube size on the growth rates of seedlings of *Ziziphus mauritiana* and secondly to determine the effect of potting tube size on the development traits of seedlings of *Ziziphus mauritiana.*

MATERIALS AND METHODS

The investigation was carried out during the period January 2022 to April 2022 in the nursery of the Turkana Forestry Research Sub Centre. *Ziziphus mauritiana* (Ekalale) seeds were collected from Loima and were dried in the nursery bed for 3 days. The fruits were broken down and seeds extracted out. 30 Fresh and uniform seeds were sown on 31st January 2022 in three different potting tubes sizes; (4 x 6) dimensions of 24.5 cm x 15.6 cm with a volume of 4683 cm^3, (5 x 8) dimensions of 32.5 cm x 19 cm with a volume of 9216 cm^3, and (6 x 9) with dimensions 38.5 cm x 27 cm and volume of 22046 cm^3 filled up with 5:3:2 ratio of soil mixture (forest soil, manure, and sand) respectively. The seedlings began germinating on day 7 to day 12. The size of the potting tubes represents the treatments. The seedlings were watered twice a day (morning and evening) for eight consecutive weeks using a watering can. The key measurement variables were root collar diameter and the height of the seedlings.

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This study was conducted at the nursery of the Turkana Forestry Research Institute sub-centre. The station is in Lodwar town, Turkana central ward, Turkana County. Turkana County (3.1155° N, 35.6041° E) is an arid and semi-arid county in the north-western part of Kenya (WorldData, 2022). It is characterized by dry and hot climate conditions most of the time. The night time minimum temperature ranges between 24.2 and 26.0 °C and the day time maximum temperature oscillates between 35 and 36.0 °C (Climate-data.org, 2022) The rainfall pattern and distribution are erratic and unreliable both in temporal and spatial. Turkana County has three main rainfall seasons (long rains occur on March-April-May, June-July-August which occurs in Turkana west, Turkana south, Loima and some parts of Turkana east sub-counties. This is influenced by inter-tropical convergence zone (ITCZ) rainfall bearing systems as well as Congo Airmass (CAM) (King et al., 2021). The short rains occur in October-November-December. The soils in Turkana County are mainly sand with alluvial deposits in areas close to the rivers (CIDP, 2018). The vegetation comprises densely populated *Prosopis juliflora* and scattered *Acacia tortilis* along the riverine. Other tree species in the area include *Salvadora persica, Acacia melifera, Acacia senegal*, *Acacia reficiens*, *Acacia nubica*, *Terminalia brownii and Zyziphus Mauritania*. Annual grass species include *Aristida mustabilis* while perennial grasses are mainly *Cenchrus ciliaris*. The forbs in area include *Indigofera spinosa* (Morgan, 1981). The population of Turkana County is 926,976 and the main economic activity of communities living in Turkana County is pastoralism (KNBS, 2019). Agro-pastoralism is also practiced in areas that receive moderately high rainfall and irrigated farming along the river Turkwel (KNBS, 2019).

Data collection and Analysis

Seedlings height and root collar diameter data were collected from the study site each week from 16th Feb 2022 to 6th April 2022. For consecutive eight weeks, the heights, and the root collar diameters of 30 seedlings were collected. The heights were measured using a 30 cm ruler and data filled in the data collection sheet. The root collar diameter (RCD) was measured using a 0.1 mm Vernier calliper and the data filled in the data collection sheet. RCD was used since it integrates the entire seedling's morphological response to the environment (Mexal, 1990). Moreover, according to Novikov et al. (2019), root diameter is a seedling attribute that forecasts both survival and growth. Thus, it is the single most useful morphological attribute to measure seedlings performance (Novikov et al., 2019). The weight of the potting tube sizes filled with soil medium was also measured using Original Hanson Round Balance (100 kg). At the end of the data collection, the data collected were statistically analysed using Excel and Analysis of Variance (One Way ANOVA) to check any differences between the means seedlings growth and the potting tube sizes. Since the means were significant, Tukey's HSD was used to test for significance differences between the sample means. The effects of potting tube sizes on the seedling's height and the root collar diameter were performed through SPSS software version 25. Values were represented as significantly different if $p < 0.05$. Charts and graphs were also used to describe the data.

RESULTS AND DISCUSSION

Effect of Potting Tube Size on the Growth Rates of Seedlings of *Ziziphus mauritiana*

The results revealed that larger potting tubes (6 x 9) had the highest mean height (14.954) at ($p = 0.05$) while smaller potting tube had the smallest seedlings mean height (6.71). Consequently, the larger potting tubes (6 x 9) had significantly higher height length (40.5) compared to the smaller potting tube (4 x 6) which had 22.3 (See *Table 1*).

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Table 1: Effect of potting tube size on the height and RCD of *Z. mauritiana*

Pot size	Pot volume (cm^3)	Height Mean	SD	Max	RCD Mean	SD	Max
4 X 6	4683	6.711[a]	6.654	22.3[a]	1.684[a]	1.171	3.02[a]
5 X 8	9216	11.195[b]	9.330	33.0[b]	2.002[b]	1.117	3.56[b]
6 X 9	22046	14.954[ab]	11.272	40.5[ab]	2.504[ab]	0.957	4.3[ab]

Means/Max followed by different letters in each column are significantly different to each other at p < 0.

Figure 1: Histogram comparing Heights in various potting tube sizes

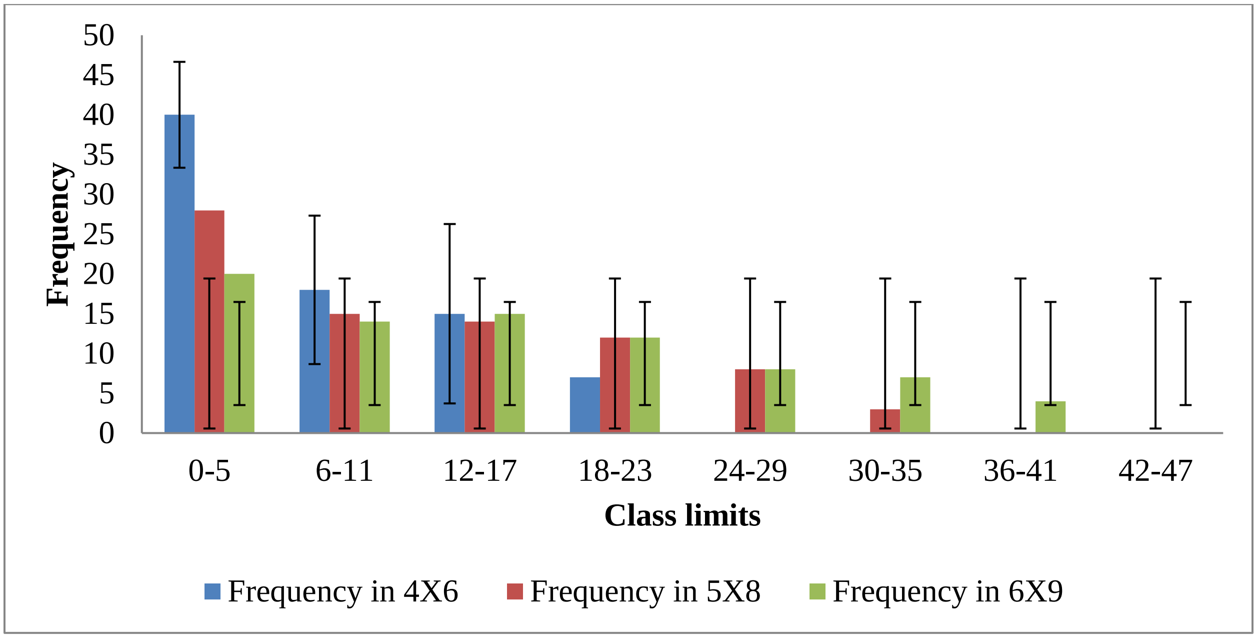
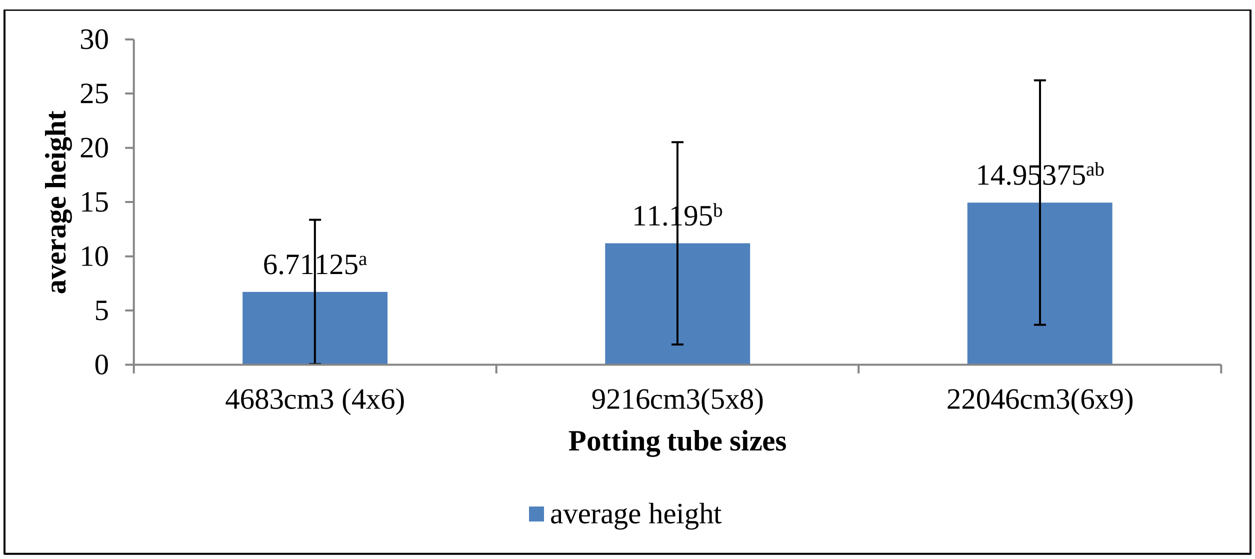


Figure 2: Comparison of average height of seedlings in different potting tube sizes



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According to the One Way ANOVA conducted, the means were significantly different at $p < 0.05$; for the mean heights $F_{(2,237)} = 15.82$, P = 0.00 (see *Table 6*). We therefore reject the null hypothesis that all the population means are equal. This concludes that potting tube sizes have a significant effect on the height growth of seedlings. Using the partial eta squared, the measure of association between the height of the seedlings and the potting tube size was determined to be 0.118 (see *Table 2*). This indicates a large effect (Richardson, 2011).

Table 2: Measures of associations output

	Eta	Eta Squared
height of tree * pot size	.343	.118
root collar diameter * pot size	.299	.089

Table 3: Potting tube weights filled with soil (kg)

4 x 6	5 x 8	6 x 9
0.4	1.7	3.0
0.5	1.5	3.0
0.4	1.5	3.0
0.5	2.0	3.1
0.5	1.6	3.4
0.5	2.0	3.0
0.5	1.6	3.5
0.5	1.7	3.1
0.5	1.9	3.2
0.5	1.7	3.0

Table 4: Mean and SD of the potting tube weights

	4 x 6	5 x 8	6 x 9
Mean	0.48	1.72	3.13
Standard Deviation	0.042	0.187	0.183

The results of this study indicated that plant height and root collar diameter RCD increased with the increase in potting tube size. This was consistent with the results of the study conducted by Cantliffe (1993) which indicated that as container size increases, the plant leaf area increases, shoot biomass and root biomass also increases. Consequently, according to Nesmith & Duval (1998), root and shoot growth, biomass accumulation and partitioning, photosynthesis, leaf chlorophyll content, plant water relations, nutrient uptake, respiration, flowering, and yield are all affected by root restriction and potting tube size. Adequate soil volume in roots ensures there is water, fertility, and the physical rooting environment of the seedlings. A similar study by Agonafer et al. (2016) indicated that smaller pot size had a higher fresh shoot weight ($p = 0.0025$) while large pot size had significantly higher root to shoot ratio ($p = 0.03$) of *Cajanus cajan*. This study also found that by increasing the potting tube size volume to 22046 (6 x 9), the average growth rate increased by 50.19%. This data was consistent with an earlier study conducted by Kinyua (2017) which

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indicated a 56% increase in the plant heights when seedlings height were compared to the pot volumes. Similar results were also found by Society for Experimental Biology (2012) which indicated that doubling plant pot sizes makes plant grow over 40% larger. According to Nesmith & Duval (1998), small containers causes root restriction hindering water and nutrient uptake leading to reduced plant biomass as a result of lower photosynthetic rate.

Figure 3: Comparison of average RCD of seedlings in different potting tube sizes

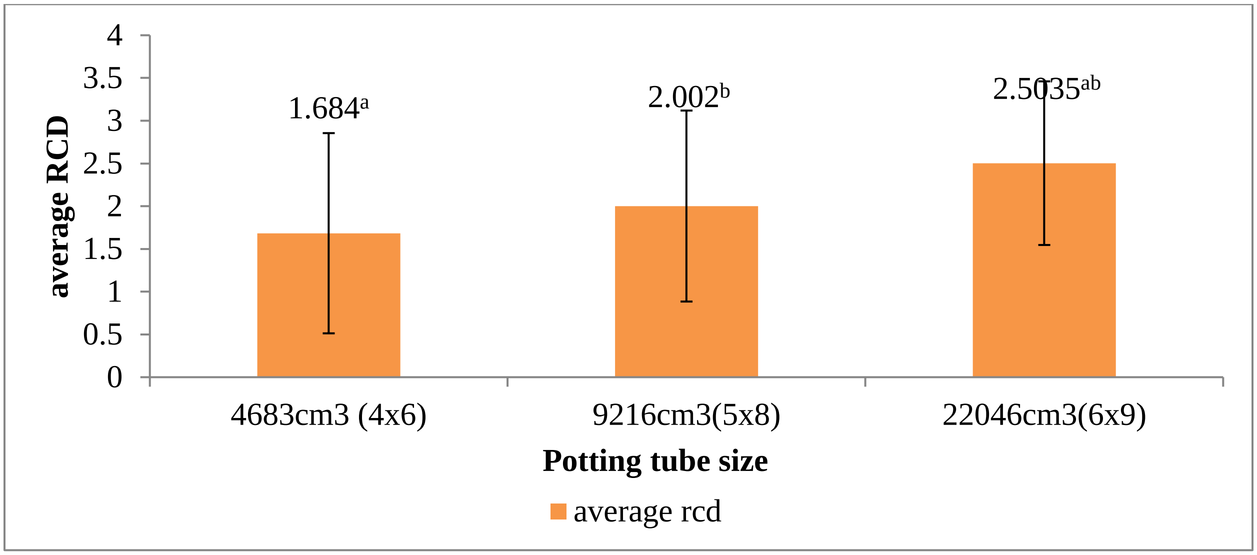

Figure 4: *Z. mauritiana* seedlings growth in 8 weeks

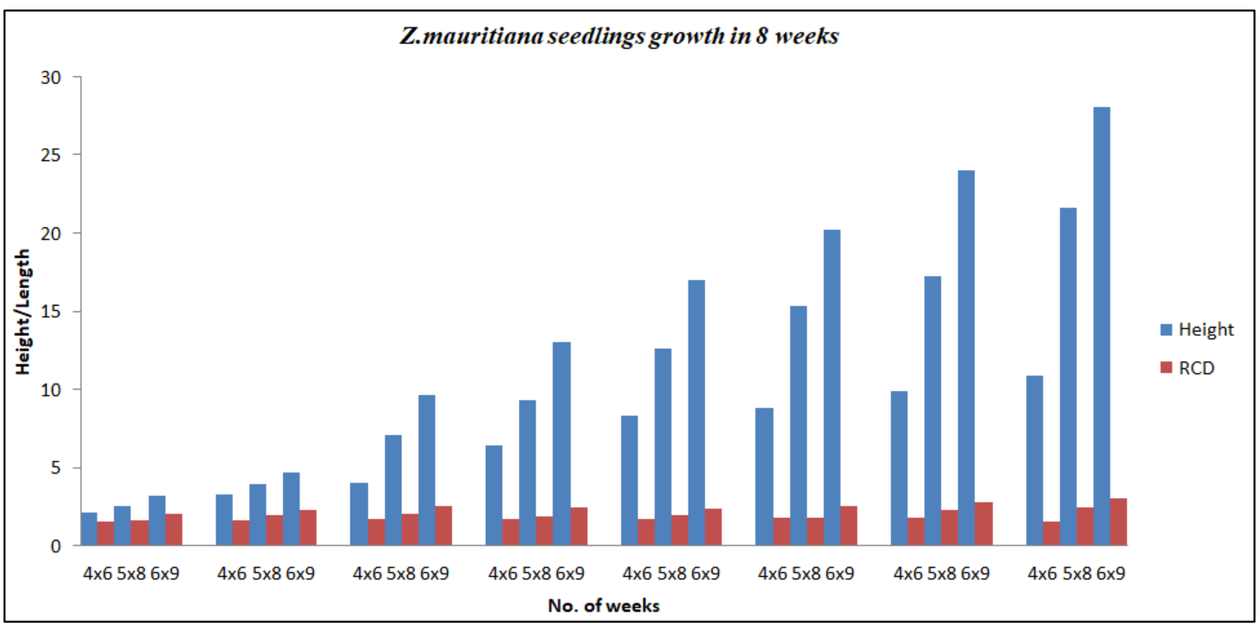

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Table 5: Tukey HSD between mean comparison

Multiple Comparisons			
Tukey HSD			
Dependent Variable	**(I) pot size**	**(J) pot size**	**Sig.**
root collar diameter	4 x 6	5 x 8	0.155
		6 x 9	0.00
	5 x 8	6 x 9	0.011
height of tree	4 x 6	5 x 8	0.007
		6 x 9	0.00
	5 x 8	6 x 9	0.03
**. The mean difference is significant at the 0.05 level.*			

Table 6: One Way ANOVA output

	df	F	Sig
Height of seedlings*pot size	2	15.816	0.000
Root collar diameter*pot size	2	11.595	0.000

The results revealed that smaller potting tube sizes (4 x 6) had significantly lower RCD mean of 1.684 compared to the larger potting tube sizes 5 x 8 (2.00) and 6 x 9 (2.504); the means were significantly different at $p < 0.05$ (see *Table 1*). For the mean RCD, $F_{(2,237)} = 11.595$, $p = 0.00$. Therefore, we reject the null hypothesis that all the population means are equal. This therefore implies that different potting tube sizes have significant impact on the development of the root collar diameter. To understand how strong is the effect of potting tube size on the root collar diameter, effect size was determined using the partial eta squared as indicated in *Table 2* above. The measure of association between the root collar diameter and potting tube size was 0.089. This indicated a medium effect (Richardson, 2011)

The largest pot size showed the highest root collar diameter 4.3 mm compared to all other pot sizes as indicated in *Table 1*. According to Agonafer et al. (2016), similar results on *Sesbania sesban* preferred the use of larger pot sizes compared to the smaller ones. According to a study conducted by Hameed et al. (1987), confining root growth to small containers substantially reduced shoot and root growth and increased the proportion of total dry matter present in the stems. These were due to drought stress (Hameed et al., 1987). These results corroborated with those studied by Nishizawa & Saito (1998) which indicated a gradual decrease in length of leaves with progressively smaller volume containers, irrespective of leaf position.

CONCLUSION AND RECOMMENDATIONS

From the above results, it can be deduced that potting tube size has a significant effect on the growth and development traits of *Ziziphus mauritiana* seedlings. The mean height and root collar diameter of the seedlings consistently ranked highest in those raised in potting tube size 6 x 9, followed by 5 x 8 and finally by 4 x 6. It is clear that a large potting tube size is a good and efficient for seedlings development since it holds large amount of soil mixture and water retention which has a high effect on the growth and development of seedlings. From our study, we can conclude that seedlings planted in large potting tubes obtain the highest growth performance. Thus, a good and efficient potting tube size has a significant effect on the growth and development on *Ziziphus mauritiana* seedlings. Since the study area experiences acute rainfall, using the larger potting tube (6 x 9) would be advantageous. This is because, as the container height and diameter increases, the amount of media pore space increases thus increasing both the media water holding capacity and aeration.

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