African Journal of Biotechnology Vol. 7 (13), pp. 2197-2202, 4 July, 2008
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2008 Academic Journals

Full Length Research Paper

Effect of growing medium on early growth and survival of *Uapaca kirkiana* Müell Arg. seedlings in Malawi

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Accepted 2 May, 2008

The use of appropriate growing medium has been an important factor influencing growth and survival of seedlings in the nursery. Raising *Uapaca kirkiana* rootstocks from seeds has been a challenge as pencil-size stem thickness is required before grafting can be done. An experiment was carried out with the objective of determining an effective growing medium that ensures survival and rapid growth of *U. kirkiana* seedlings. Ten different combinations of sand, forest soil and sawdust amended with four different levels of nitrogen, phosphorus and potash fertilizer were evaluated. The result showed that the growing medium comprising 75% forest soil and 25% sawdust produced the tallest seedlings with larger root collar diameter and higher survival at ten months after planting. Amending the same growing medium with fertilizer improved the root collar diameter of the seedlings. It is concluded that a growing medium comprising 75% forest soil and 25% sawdust and amended with NPK fertilizer was superior in improving *U. kirkiana* seedling growth to attain a suitable diameter for grafting within ten months.

Key words: Forest soil, root collar diameter, seedling mortality, soil aeration.

INTRODUCTION

Uapaca kirkiana Müell Arg. is a highly valued indigenous fruit tree of the Miombo woodlands and the most preferred fruit by communities in southern Africa (Maghembe et al., 1998; Akinnifesi et al., 2006). The fruit can be eaten raw or made into a variety of jams, juices or wines (Saka et al., 2007). The fruit has become important to many people in the rural communities, especially in the arid and semi-arid countries of Africa where maize production has declined due to erratic rainfall, infertile soils and lack of farm inputs (Akinnifesi et al., 2006). The fruit ripen towards the end the dry season (October – December) and is available most of the rainy season (November - February) (Ngulube, 1996). This is the period that many households in southern Africa experience a critical food shortage, and hence many rural communities survive on *U. kirkiana* fruits.

Grafting has been one of the most efficient propagation techniques to achieve early fruit bearing. *U. kirkiana* trees growing in the wild can take 10 - 16 years before bearing fruits, but grafted *U. kirkiana* trees have only taken 2 - 3 years before fruiting (Mng'omba et al., 2007). Currently, up to 80% graft take has been achieved at Makoka Research Station in Malawi, but there has been poor survival and slow growth of the grafted *U. kirkiana* in the field (Akinnifesi et al., 2006). However, there has been a high rate of *U. kirkiana* seedling mortality (Akinnifesi et al., 2008; Sileshi et al., 2007).

Survival of the grafted trees would depend on a number of factors including the quality of rootstocks. Selecting a rootstock with an appropriate diameter is an important factor to match the scion diameter. *U. kirkiana* scion/rootstock alignment has been a problem because the scions are often thicker than the rootstocks (Mng'omba et al., 2007). It is known that proper scion/rootstock alignment intensifies vascular continuity and also enhances rapid healing of the wound. It is expected that a grafted tree with a strong scion/rootstock union would withstand the harsh field conditions. The slow growth of *U. kirkiana* seedlings increases the odd of producing rootstocks with thickness that could match the scion diameter in one season. Observations at Makoka Research Station have

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shown that the growth of *U. kirkiana* seedlings can be slow. The seedlings can take more than a year or two before attaining a graftable size (pencil thick). Generally, seedlings with 10 mm diameter (pencil size) are suitable for grafting (Hartmann et al., 1990). Therefore, management practices that promote rapid growth of *U. kirkiana* seedlings to attain a pencil thick size within a year are needed.

The growth, establishment and survival of seedlings also depend on the quality of a growing medium. There are many commercial growing media used to raise seedlings, but many are expensive and locally unavailable. They have to be imported from elsewhere and this makes them expensive. There is need to establish appropriate and low cost growing media to ensure that the tree seedlings attain a suitable size for grafting within a year. Amending growing media with fertilizer could promote seedling growth, establishment and survival. To our knowledge, the main cause of poor *U. kirkiana* seedling growth and survival in the nursery has not been established (Sileshi et al., 2007). We suspect that this poor seeding performance could be attributed to poor growing medium which comprise solid particles (inorganic particles), air, water, organic matter and micro-organisms. We hypothesize that selecting a proper growing medium and amending it could improve the early growth, establishment and survival of *U. kirkiana* seedlings.

Factors such as aeration, mineral nutrient and moisture content of the growing medium could affect the growth, survival and establishment of seedlings (Villagra and Cavagnaro, 2006). A good growing medium must be well-aerated with a balanced mineral nutrients and good soil moisture retention. For *U. kirkiana* trees, the best growth performance has been on well-drained sandy loam or gravely soils (Ngulube, 1996). At Makoka, a combination of forest soil and sand (1:1 v/v) has been used, but this has proved unsuccessful for the growth and survival of *U. kirkiana* seedlings. The objective of this study was to determine an effective growing medium that promotes growth, establishment and survival of *U. kirkiana* seedlings for rootstocks.

MATERIALS AND METHODS

Site description

Makoka Research Station lies 1029 m above sea level, latitude 15° 30' S and longitude 35° 15' E. It has an annual rainfall between 560 and 1600 mm and temperature varies between 16 and 32°C. The rainfall for this site is unimodal and falls between November and April (Akinnifesi et al., 2004).

Growing medium composition

U. kirkiana seeds collected from Phalombe in Malawi were first sown in sand and forest soil for six months. They were then planted in pots (430 x 280 mm) containing ten different combinations of forest soil, sand and sawdust in March 2000. The different compositions of the growing medium evaluated were as follows: (i) 25% sand and 75% forest soil; (ii) 50% sand and 50% forest soil; (iii) 75% sand and 25% forest soil; (iv) 50% forest soil and 50% sawdust; (v) 75% forest soil and 25% sawdust; (vi) 33.33% sand, 33.33% forest soil and 33.33% sawdust; (vii) 25% sand, 25% forest soil and 50% sawdust; (viii) 25% sand, 50% forest soil and 25% sawdust; (ix) 50% sand, 25% forest soil and 25% sawdust; or (x) 100% forest soil.

The forest soils were used as the source of mycorrhizae since *U. kirkiana* seedlings do not easily survive on farmland deficient of its natural forest soil which contains mycorrhizal inocula (Högberg, 1982; Mwamba, 1995). Therefore, mycorrhizal inoculum was supplied to all the growing media used, and hence it was not a limiting factor to the growth and survival of *U. kirkiana* seedlings. Water application to the seedlings was done during the morning hours using a watering can every time that the growing media in the pots appeared dry.

Soil chemical analysis

A chemical analysis of the overall growing media was carried out at the onset of the experiment before the first fertiliser application. The forest soil was randomly collected from the top 0 - 20 cm soil depth and bulked from ten points using the Edelman soil augers. Sub-samples were processed and analyzed following routine procedures described by Anderson and Ingram (1993). The soil chemical properties were pH (H_2O) (5.62), extractable P (38.3 mg/kg) and potassium (1.39 cmol/kg). In addition, the soil texture contained 46% sand, 46% clay and 8 % silt.

Fertilizer amendment

Three months after planting *U. kirkiana* seedlings, fertilizer was applied to each pot at the rate of either (i) 0 g N, P and K, (ii) 1.25 g N, 2.5 g P_2O_5 and 0.75 g K_2O, (iii) 2.5 g N, 5.0 g P_2O_5 and 1.50 g K_2O, or (iv) 3.75 g N, 7.5 g P_2O_5 and 2.25 g K_2O. This was the first application and the second fertiliser application was done after eight weeks and at the same rate. The sources of fertiliser used were Urea for nitrogen (46% N), Triple Supper Phosphate for phosphorus (46% P_2O_5) and Potassium Sulphate (60% K_2O) for potash.

Experimental design and management

The experiment was laid out as a randomised block design in a factorial arrangement (10 levels of growing medium and four levels of fertiliser) and with three replicates. Seedling survival, height and root collar diameter data were recorded every month up to 12 months. This was to find a suitable seedling thickness (pencil thick) for grafting of seedlings within a shortest time period (one year). Seedlings were thinned to one per pot and hand weeding was done where necessary.

Statistical data analysis

The data collected were subjected to analysis of variance (ANOVA) using SAS package (version 9.1) (1999). LSD ($P < 0.05$) test was used for mean separation.

RESULTS

Nutrient properties of soil media

The data presented in Table 1 shows that the highest potash content was obtained from the growing medium

Table 1. Soil chemical analysis of the ten growing media used to raise *U. kirkiana* seedlings in the pots at Makoka nursery.

Growing medium*	Total N (mg/Kg)	Phosphorus (mg/Kg)	Potash (cmol/Kg)
M1	11.59	25.6	0.49
M2	18.38	21.2	0.34
M3	5.98	17.2	0.27
M4	11.48	28.4	0.62
M5	14.05	24.0	0.83
M6	8.47	20.0	0.46
M7	7.9	22.4	0.51
M8	7.2	23.2	0.54
M9	6.33	22.2	0.44
M10	18.48	32.0	0.65

*Growing medium: M1 = 25% sand + 75% forest soil; M2 = 50% sand + 50 forest soil; M3 = 75% sand + 25% forest soil; M4 = 50% forest soil + 50% saw dust; M5 = 75% forest soil + 25 saw dust; M6 = 33.33% sand + 33.33% forest soil + 33.33% saw dust; M7 = 25% sand + 25% forest soil + 50% saw dust; M8 = 25% sand + 50% forest soil + 25 % saw dust; M9 = 50% sand + 25% forest soil + 25% saw dust; M10 = 100% forest soil

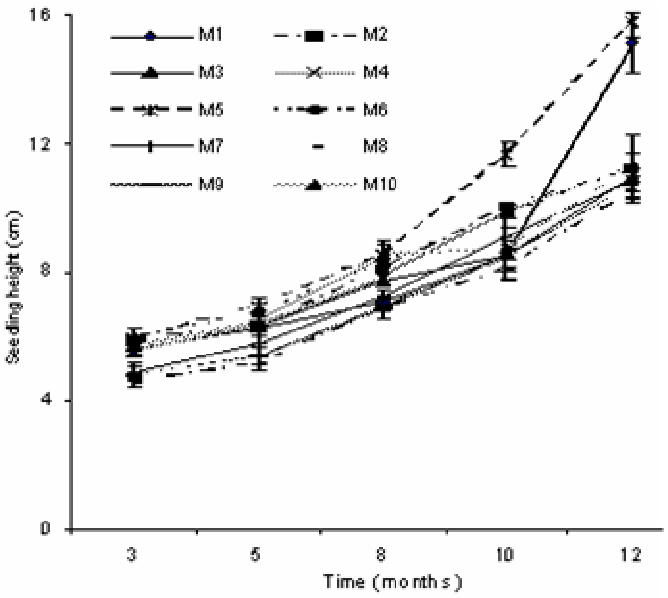

Figure 1. Effect of growing medium amended with fertilisers on *U. kirkiana* seedling growth height measured up to 12 months after planting. Vertical bars indicate standard error of means (M1 = 25% sand + 75% forest soil; M2 = 50% sand + 50 forest soil; M3 = 75% sand + 25% forest soil; M4 = 50% forest soil + 50% saw dust; M5 = 75% forest soil + 25 saw dust; M6 = 33.33% sand + 33.33% forest soil + 33.33% saw dust; M7 = 25% sand + 25% forest soil + 50% saw dust; M8 = 25% sand + 50% forest soil + 25 % saw dust; M9 = 50% sand + 25% forest soil + 25% saw dust; M10 = 100% forest soil).

comprising 75% forest soil and 25% sawdust, and followed by growing medium comprising 100% forest soil. The last treatment comprising 100% forest soil had the highest total N and P contents. The trend shows that the third growing medium comprising 75% sand and 25% forest soil had the lowest N, P and K contents.

Plant height

Treatments (growing media) significantly differed ($P < 0.05$) in seedling height (Figure 1), but no significant differences were obtained with respect to fertiliser and the interaction between the growing media and fertiliser ($P > 0.05$) 12 months after planting. Data in Figure 1 show that there was a rapid increase in seedling height for the growing medium comprising 75% forest soil and 25% sawdust from 8 to 12 months after planting (MAP). There was also a rapid increase in plant height for a growing medium comprising 25% sand and 75% forest (Figure 1). These two growing media were superior compared to the rest of the growing media used with respect to seedling height.

Root collar diameter

There were significant differences ($P < 0.05$) in root collar diameter among the growing medium treatments, fertiliser levels and their interactions (Figure 2) at 12 months after planting. Growing medium comprising 75% forest soil and 25% sawdust had significant increase in root collar diameter compared to the rest of the growing media at 12 months after planting. The rapid increase was obtained from 8 to 12 months after planting (Figure 2). The growing medium comprising 25% sand and 75% forest soil had the lowest root collar diameter (thinner seedlings).

Plant survival

Significant differences were obtained with respect to plant survival ($P < 0.05$), but not the interaction between fertiliser level and growing media (Figure 3). The growing medium comprising 25% sand and 75% forest soil had

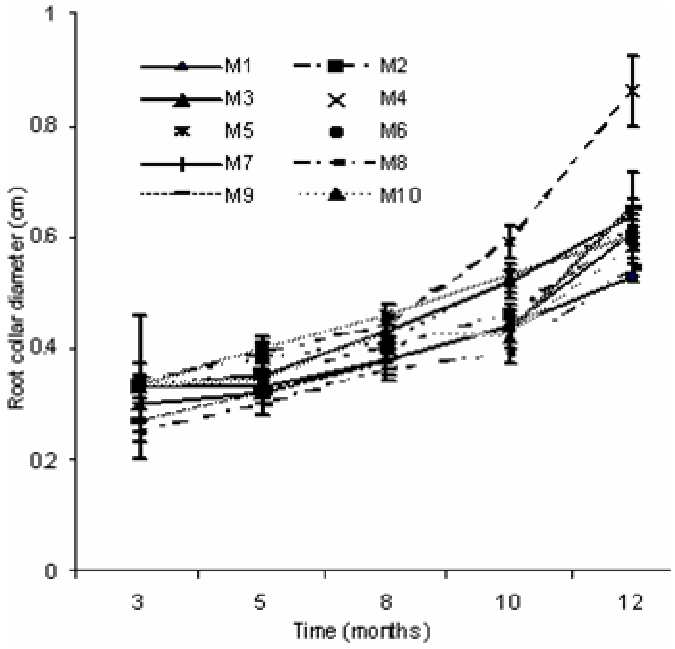

Figure 2. Effect of growing medium amended with fertilisers on *U. kirkiana* root collar diameter measured up to 12 months after planting. Vertical bars indicate standard error of means (M1 = 25% sand + 75% forest soil; M2 = 50% sand + 50 forest soil; M3 = 75% sand + 25% forest soil; M4 = 50% forest soil + 50% saw dust; M5 = 75% forest soil + 25 saw dust; M6 = 33.33% sand + 33.33% forest soil + 33.33% saw dust; M7 = 25% sand + 25% forest soil + 50% saw dust; M8 = 25% sand + 50% forest soil + 25 % saw dust; M9 = 50% sand + 25% forest soil + 25% saw dust; M10 = 100% forest soil).

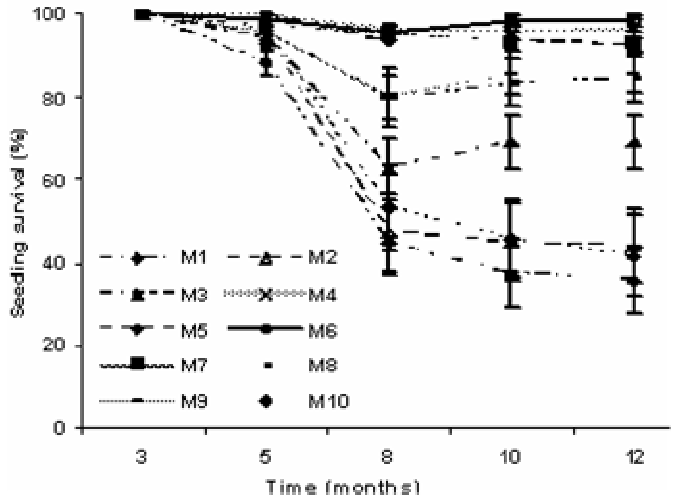

Figure 3. Percentage survival of *U. kirkiana* seedlings in response to different growing medium amended with fertilizers. Vertical bars indicate standard error of means (M1 = 25% sand + 75% forest soil; M2 = 50% sand + 50 forest soil; M3 = 75% sand + 25% forest soil; M4 = 50% forest soil + 50% saw dust; M5 = 75% forest soil + 25 saw dust; M6 = 33.33% sand + 33.33% forest soil + 33.33% saw dust; M7 = 25% sand + 25% forest soil + 50% saw dust; M8 = 25% sand + 50% forest soil + 25 % saw dust; M9 = 50% sand + 25% forest soil + 25% saw dust; M10 = 100% forest soil).

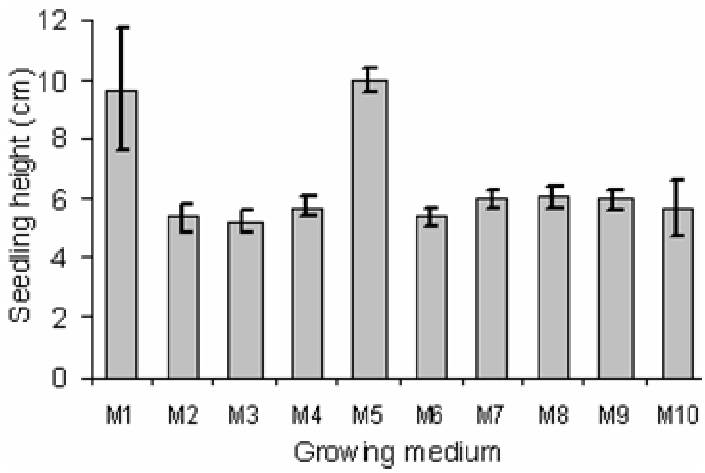

Figure 4. *U. kirkiana* seedling height increment in response to different growing media at 12 months after planting. Vertical bars indicate standard error of means (M1 = 25% sand + 75% forest soil; M2 = 50% sand + 50 forest soil; M3 = 75% sand + 25% forest soil; M4 = 50% forest soil + 50% saw dust; M5 = 75% forest soil + 25 saw dust; M6 = 33.33% sand + 33.33% forest soil + 33.33% saw dust; M7 = 25% sand + 25% forest soil + 50% saw dust; M8 = 25% sand + 50% forest soil + 25 % saw dust; M9 = 50% sand + 25% forest soil + 25% saw dust; M10 = 100% forest soil).

the lowest seedling survival. At the end of the experiment (12 months), the highest seedling survival were obtained from the growing medium comprising 33.33% sand, 33.33% forest soil and 33.33% sawdust; 50% forest soil and 50% sawdust; 25% sand, 25% forest soil and 50% sawdust, and also growing medium comprising 75% forest soil and 25% sawdust.

Growing media amendment with fertilizer

There were no significant differences ($P < 0.05$) in seedling height and survival with respect to different levels of fertilizer applied. Significant increase in mean root collar diameter were obtained at 12 months after planting for the growing medium amended with 2.5 g N, 5.0 g P_2O_5 and 1.5 g K_2O fertilizer (data not shown). The growing medium comprising 75% forest soil and 25% sawdust was superior in mean root diameter after fertilizer amendment as indicated in Figure 2.

Incremental seedling growth

Data in Figure 4 shows that the growing medium comprising 25% sand and 75% forest soil and the growing medium with 75% forest soil and 25% sawdust (Figure 4) had taller seedlings. The growing medium comprising 25% sand and 75% forest soil had lower seedling root collar diameter increment compared to the growing medium with 75% forest soil and 25% sawdust (Figure 5).

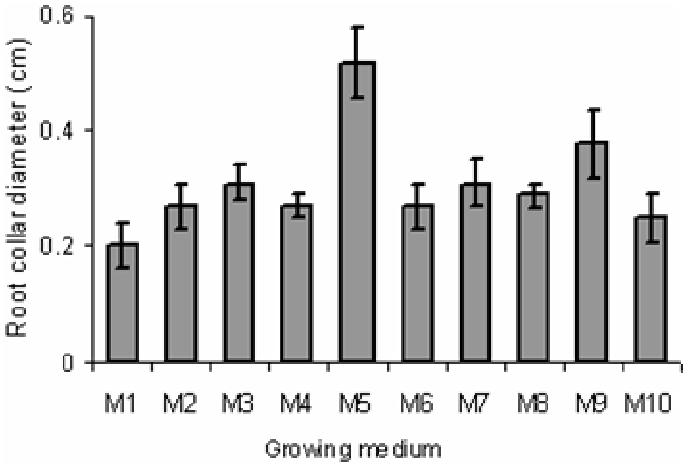

Figure 5. Root collar diameter (cm) increment of *Uapaca kirkiana* in response to different growing media 12 months after planting. Vertical bars indicate standard error of means (M1 = 25% sand + 75% forest soil; M2 = 50% sand + 50 forest soil; M3 = 75% sand + 25% forest soil; M4 = 50% forest soil + 50% saw dust; M5 = 75% forest soil + 25 saw dust; M6 = 33.33% sand + 33.33% forest soil + 33.33% saw dust; M7 = 25% sand + 25% forest soil + 50% saw dust; M8 = 25% sand + 50% forest soil + 25 % saw dust; M9 = 50% sand + 25% forest soil + 25% saw dust; M10 = 100% forest soil).

The seedlings grown to the growing medium with 25% sand and 75% forest soil were thin (whip) as evidenced by Figure 5.

DISCUSSION

In this study, the native nitrogen or phosphate in the growing media did not have a clear effect on seedling height or diameter. For instance, growing medium comprising 100% forest soil had high N and P content, but this resulted in neither thicker nor taller seedlings. This could be attributed to other physical properties of the growing media rather than mineral nutrient compositions. Such physical factors could include the soil aeration, moisture retention and bulk density. The growing medium comprising 100% forest soils could be prone to water logging condition and this could affect root respiration. Therefore, this could have an adverse effect on growth and survival of *U. kirkiana* seedlings despite having a higher plant nutrient content. Also, water logging condition could have favour multiplication and growth of some diseases such as damping off. These could have adversely affected seedling growth and survival. The growing medium with 75% sand and 25% forest soil had the lowest N, P and K contents and this is attributed to high sand content (75%) in the growing medium since sand is deficient in many mineral nutrients. The forest soils were the main source of N, P and K.

Achieving an appropriate seedling diameter (pencil thick size) for grafting has been a problem in *U. kirkiana*. Consequently, proper matching of the scion and root-stock has been a major problem. Observations at Makoka Research Station indicated that *U. kirkiana* seedlings could remain in the nursery for one or two years before attaining a suitable diameter for grafting. The present trial has shown that the pencil-size (10 mm) of *U. kirkiana* seedlings could be obtained after ten months when grown on medium comprising 75% forest soil and 25% sawdust. This means it is possible to graft *U. kirkiana* seedlings ten months after planting.

The growing medium comprising 75% forest soil and 25% sawdust was superior for *U. kirkiana* seedling growth and possibly this could be attributed to better soil aeration and moisture retention. The poor seedling survival on growing medium comprising 100% forest soil could also be attributed to poor aeration, water-logging conditions and other diseases which could attack roots. Accumulation of water in the pots above the growing medium indicated poor drainage and this corroborates the limitation in growing medium aeration. According to Ferreira et al. (2007), water-logging conditions adversely affect root respiration and this is critical for the upland plants. Furthermore, observation made at Makoka nursery has shown that *U. kirkiana* seedlings are often prone to high mortality as a result of 'wet feet'. Therefore, a growing medium with 100% forest soil is likely to retain more water for a longer period. Consequently, the seedling mortality was high.

Generally, growing medium comprising 100% forest soil would be heavier than the rest of the media used. This is because incorporation of either sand or sawdust in the growing medium would make the combination light since sawdust and sand are both light. However, the growing media with higher sand content (> 25%) could be poor in moisture retention. Consequently, this could cause water stress, and hence adverse effect on seedling growth and establishment.

Poor response of *U. kirkiana* seedlings with respect to plant height and survival after the growing media were amended could be attributed to the fact that physical properties of the growing media were the overriding factors over the effects of mineral elements (fertilizer). Akinnifesi et al. (2008) reported that application of fertilizer and irrigation did not improve the survival and growth of *U. kirkiana* trees in the field. Their results agree with the present findings. Seedling survival could also depend on root development.

Comparatively, growing medium comprising 75% forest soil and 25% sand had the lowest seedling survival and with thinner root collar diameter. This has been a standard growing medium used to raise *U. kirkiana* seedlings at Makoka nursery. Probably, this explains why there was poor growth and high mortality of *Uapaca* seedlings at Makoka nursery at the time when this medium was being used.

In this study, the growing medium comprising 75% forest soil and 25% sawdust was superior. However, *U. kirkiana* scions collected from mother trees could still be

thicker than seedling rootstocks (>10 mm), and hence the need to improve the growing medium comprising 75% forest soil and 25% sawdust. Further research work is needed to improve the current superior growing medium to achieve thicker rootstocks raised from seeds within a year. This could improve graft success and survival of *U. kirkiana* trees in the field. This study indicates that the physical properties of the growing medium are important factors for growth, establishment and survival of *U. kirkiana* seedlings.

Conclusion

The growing medium comprising 75% forest soil and 25% sawdust was superior for the growth of *U. kirkiana* seedlings as it promoted seedling survival and thicker root collar diameter. Seedling growth was further improved when superior growing medium was amended with NPK fertilizer. However, research studies are warranted to further improve the root collar diameter of *U. kirkiana* seedlings.

ACKNOWLEDGEMENTS

We would like to acknowledge the financial support from the German Federal Ministry of Economic Co-operation (BMZ/GTZ) and Canadian International Development Agency (CIDA) for funding the work on Miombo Indigenous Fruit Trees.

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