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Research Article

Effect of growing media on seedling growth of African baobab (*Adansonia digitata* L.)

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Abstract

Adansonia digitata L. is a major multipurpose tree species which has an important economic value not only for food but also medicine and fibre. A pot experiment was conducted in the net-shade at Botswana College of Agriculture from January to May 2014 to evaluate the growth response of *A. digitata* potted seedlings to different growth media. The experimental design was a completely randomized design (CRD) with four treatments each replicated four times. The four treatments were as follows; top garden soil (TGS), top forest soil (TFS), commercial compost (CC) and a mixture of the three (TGS+TFS+CC) being treatments 1-4, respectively. The results revealed a non-significant treatment effect ($p>0.05$) on plant height across treatments in weeks 2 and 4. The mixture (TGS+TFS+CC) significantly ($p<0.05$) increased seedling plant height from week 6 to 8 and a highly significant effect was observed from week 10 to 12 compared to other treatments. A non-significant ($p>0.05$) treatment effect was observed in *A. digitata* seedling leaf number across treatments in weeks 2 and 4. The number of leaves were significantly ($p<0.05$) higher in the TGS+TFS+CC treatment in weeks 8 and 10and highly significant in week 12. The collar girth of *A. digitata* seedlings was significantly ($p<0.01$) lower in the commercial compost than other treatments in the first two weeks following transplanting. A non-significant treatment effect was observed in weeks 4 and 6, but the collar girth was significantly increased in the TGS+TFS+CC treatment from week 10 until the end of the study. The TGS+TFS+CC treatment significantly ($p<0.01$) increased both total (roots + shoots) fresh and dry weights. TGS revealed significantly ($p<0.05$) lower plant biomass than the TFS and the TGS+TFS+CC treatments. Based on these results the soil mixture (TGS+TFS+CC) is recommended as the most suitable medium that can be used by tree growers to propagate *A.digitata* seedlings.

Keywords: *Adansonia digitata*, growth media, completely randomized design, tree nursery

Introduction

The successful production of quality seedlings in a nursery is largely dependent on the composition of the growing media (Wilson *et al*., 2001; Osaigbovo and Orhue, 2012). A suitable potting medium should be well drained with the ability to retain sufficient water to reduce the frequency of watering (Unal, 2013). The selection of the proper media components is critical to the successful production of seedlings (James and Michael, 2009) because media play an important role in seed germination and directly affect the development and later maintenance of the extensive functional rooting system (Bhardwaj, 2014). Suitable growing medium provides sufficient anchorage or supports the plant, serves as a reservoir for nutrients and water; allows oxygen diffusion to the roots and gaseous exchange between the roots and atmosphere outside the root substrate (Abad *et al*., 2002).

The quality of nursery seedlings is influenced by potting media (Agbo and Omaliko, 2006) because it does not only act as a growing media but as a source of nutrients (Bhardwaj, 2014). Quality of growth media used to raise containerized seedlings is a key determinant factor to successful tree planting programmes (Manenoi *et al*., 2009). The performance of seedlings when planted out in the field is determined by their performance in the nursery (Agbo and Omaliko, 2006). It is critical to use growth media with a balanced supply of nutrients to support the production of healthy and vigorous seedling while ensuring adequate root development and plant hardiness (Mason and Aldhous, 1994). Adding organic matter to potting media is important because it supplies essential nutrients required by seedlings (Khan *et al*., 2006).Soil organic matter determines the biological, physical and chemical properties of soils (Merino *et al.,* 2004; Grace *et al.,* 2006) and is important in sustaining the productivity of many ecosystems (Hirschel *et al.,* 1997; Kirchmann *et al.,* 2004).

Baobab (*A. digitata)* belongs to the family Bombacaceae (Roodt, 1998; Palgreave, 2002; Sidibé and Williams, 2002; Assogbadjo *et al*., 2006) and is indigenous to Africa where it is found in many countries (Venter and Venter 1996; Gebauer *et al*., 2002; Bosch *et al*., 2004; Kamatou *et al.* 2011) from 0−1000 m above sea level (Bosch *et al.*, 2004) as a component of secondary forest (Woolfe *et al*., 1977). It is a large iconic deciduous tree attaining a height of 12−20 m or more (Mulofwa *et al*., 1994; Storrs, 1995; Venter and Venter, 1996; Palgreave, 2002; Bosch *et al*., 2004) and may live for thousands of years (Wickens, 1982; Storrs, 1995; Gebuaer *et al*., 2002; Palgreave, 2002). *A. digitata* has a thick, angular, wide spreading branches and short trunk which grows 4.5−14 m or more in diameter (Storrs, 1995; Venter and Venter, 1996; Gebauer *et al*., 2002; Palgreave, 2002).

A. digitata has a conical shape when young (Storrs, 1995; Gebauer *et al*., 2002) which becomes massively fluted as the tree grows and occasionally swollen at the base (Storrs, 1995). The bark is smooth, reddish brown or grey and later rough and winkled (Mulofwa *et al*., 1994; Storrs, 1995; Gebauer *et al*., 2002). Leaves are alternate and hand shaped, with 39 sessile tapering leaflets (simple on young trees) at the end of branches (Venter and Venter, 1996). The wood is whitish, soft, spongy and light (Storrs, 1995; Venter and Venter, 1996) and has little use except for making fishing boats (Storrs, 1995). Flowers are large and white opening at night and their unpleasant-smelling nectar attracts pollinators such as bats (Harris and Baker 1959; Start, 1972; Mulofwa *et al*., 1994; Baum, 1995; Storrs, 1995). The flowers do not live more than 24 hours (Gebauer *et al*., 2002). The fruit has various shapes but is mostly ovoid 100−50 mm long (Venter and Venter, 1996) with a hard woody shell covered with velvety hairs (Venter and Venter, 1996; Palgreave, 2002). The ovoid shell contains numerous edible hard brown seeds, round or ovoid up to 15mm long embedded in a floury acidic pulp (Gebauer *et al*., 2002; Palgreave, 2002).

A. digitatais a multipurpose tree species that is valued for food, fibre and medicine in Africa *(*Kamatou *et al*., 2011; Venter and Witkowski, 2011). Baobab products are sold in informal markets and form an important source of income for thousands of rural people (Sidibé and Williams, 2002). Leaves are sources of protein (*Gebauer et al.,* 2002*)* and minerals (Prentice *et al*., 1993; Yazzie *et al.*, 1994; Nordeide *et al.*, 1996; Smith *et al.*, 1996; Glew *et al*.,1997; Lockett *et al*., 2000; Boukari *et al*., 2001). The fruit pulp contains vitamin C almost ten times that of orange (Gebauer *et al*., 2002). The plant parts are used to treat various ailments such as diarrhoea, malaria and microbial infections (Kamatou *et al*., 2011). It is an excellent anti-oxidant due to the high vitamin C content (Gebauer *et al*., 2002; Kamatou *et al*., 2011).

Little is known about growth media suitable for propagating seedlings of indigenous trees in arid and semi-arid areas. There has been an increasing demand for multi-purpose trees in recent years, and farmers' attempts to propagate them have not succeeded due to lack of information on their agronomic requirements. Most indigenous species grow naturally in the wild and are popular for their multiple uses. Very few species have been raised in tree nurseries because their nursery requirements are not understood. Therefore the objective of this study was to evaluate the effect of growing media on the growth of *A. digitata* in a tree nursery

Materials and Methods

Experimental site

The study was conducted at the tree nursery of Botswana College of Agriculture (BCA). The College is situated in Sebele content farm, Gaborone. Sebele is located between latitude 24°33’S and longitude 25°54’E at an elevation of 994 m above sea level, 10 km from Gaborone city, along Gaborone-Francistown highway. Seeds used in this study were obtained from Botswana National Tree Seed Centre, Department of Forestry and Range Resources, Ministry of Environment, Wildlife and Tourism, Gaborone. Analysis of growth media physical and chemical properties was conducted at the Department of Crop Science and Production, Soil Science Laboratory, Botswana College of Agriculture.

Seedling pre-treatment and germination

Seeds were treated using a hot wire method to break the dormancy, and they were germinated in a seedbed measuring 2 m × 5 m filled with a layer of sand and compost (leaf mould). The seedbed was watered twice a day when required. Weeds were carefully hand removed whenever they appeared to avoid pulling out seedlings. After germination and development of true leaves, seedlings were transplanted into black polyethylene pots filled with different growth media (inside diameter 25 cm).

Determination of growth media physical and chemical properties

Growth media pH was measured from a soil-water suspension (1:1, v/v) by a pH meter (model: Hannah HI 110). Cation exchange capacity (CEC) was determined by the ammonium acetate saturation method (Schollenberger and Simon, 1945).Total nitrogen (N) content was determined by Kjeldahl method (Bremner, 1965) and measured on a distillation unit (model: BuchiK-350). Available phosphorus (P) was determined by the Bray II method (Bray and Kurt, 1945) and measured on an inductively coupled plasma - optical emission spectrophotometer (model: Perkinelmer DV 2100). Exchangeable potassium (K^+) was measured by flame photometer (model: Sherwood 410) after extraction with 1 N ammonium acetate pH 7.0.

Experimental design

The experiment was laid out in a completely randomized design (CRD) with four treatments (growth media) each replicated four times. The four treatments were as follows; top garden soil (TGS), commercial compost (CC), top forest soil (TFS) and mixture of TGS+CC+TFS (1:1:1, v/v), being treatments 1−4, respectively. There were 10 polythene pots, each with a seedling per replicate which were randomly located in the nursery (Fig. 1). This gave a total of one hundred and sixty (160) pots. The experiment was conducted under a 60% green net-shade to minimize loss of water. Seedlings were watered twice a day, in the morning and in the afternoon when necessary throughout the duration of the experiment. Weeds were removed manually by hands whenever they occurred. No fertilizer was supplied to the seedlings.

Growth parameters

The experiment was monitored for twelve (12) weeks after transplanting (WAT) and the growth parameters measured were: plant height, number of leaves, collar girth and total (roots + shoots) fresh and dry weight. Measurements were taken bi-weekly after transplanting except for fresh and dry weights which were taken at the end of the study. Plant height (cm) was measured using a meter ruler from the soil level to the terminal bud. The number of leaves was measured quantitatively by counting. The collar girth (mm) was measured at about 2.5 cm above the soil level using a calibrated digital caliper (0-150 mm). A destructive method was used to determine both fresh and dry weights (g) which were measured at week 12 and 5 seedlings were used per replicate. The average was then taken to represent the replicate. The seedlings were uprooted from the polyethylene pots and placed into weighing paper bags. The fresh samples were taken to the laboratory and measured using a bench top electric balance (PGW 4502e). The samples were then oven dried to constant weight at 80°C using a hot air oven (Scientific Series 2000) and dry weight was recorded.

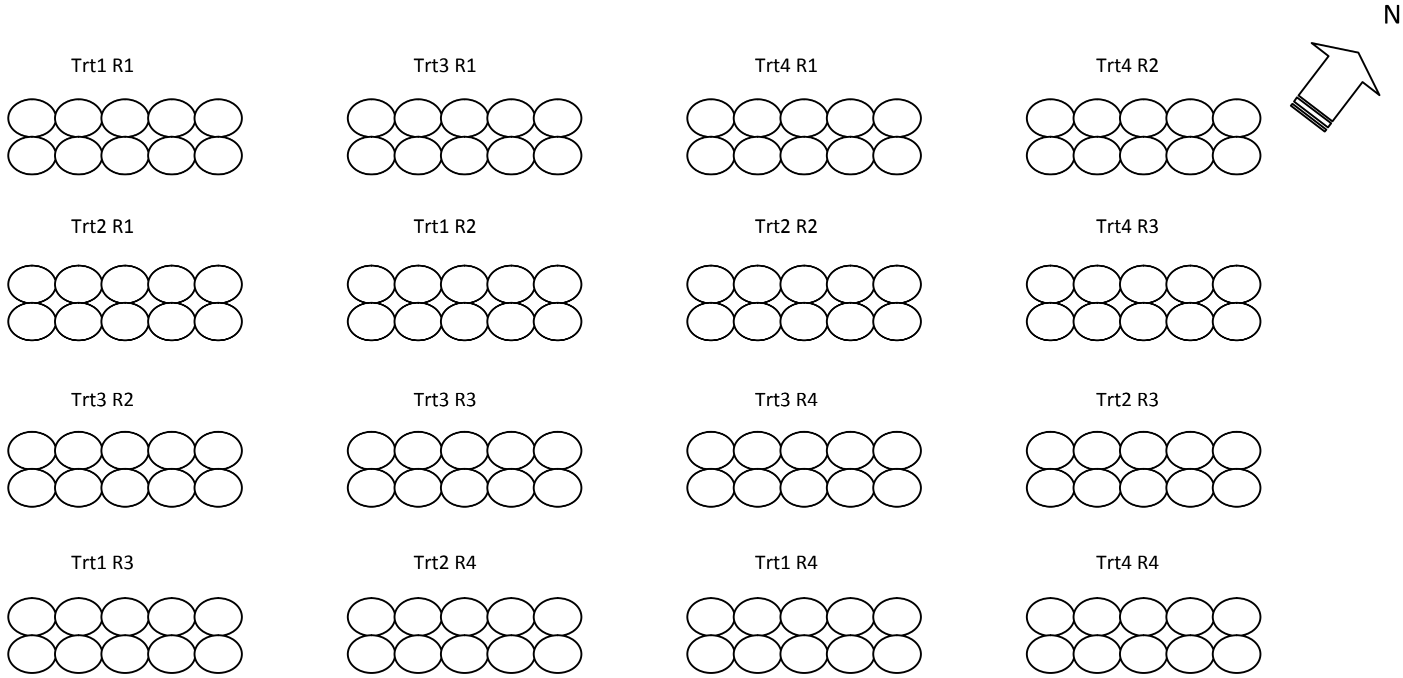
Data analysis

The data collected was subjected to analysis of variance (ANOVA) using the STATISTIX-8 program. Where a significant F-test was observed and means comparison test were carried out using Least Significant Difference (LSD) at $p \leq 0.05$ to separate treatment means.

Results and Discussion

The physical and chemical properties of growth media data presented in Table 1 shows that the pH ranged from 5.0 to 7.1, slightly acidic to neutral. Soil pH is an

Fig (1). Sketch map showing the experimental design.



important chemical property of any soil or growing media that influences essential mineral nutrients availability (Roberts, 2006). Growth media with a higher pH can be deficient in iron and phosphorus, whereas acidic media lack calcium and magnesium (Kramer and Kozlowski, 1979). The CEC ranged from 0.80 to 1.63 cmol kg^{-1} and was high in the TGS and the TGS+TFS+CC. Total N ranged from 0.52−1.01% and was high in the TGS+TFS+CC followed by TGS and CC, respectively. Values for available P ranged from 7.0 to 98.0 ppm and the highest was recorded in the CC and lowest in the TGS. Exchangeable K^+ ranged from 1.61 to 2.98% and the highest was recorded in the CC and the lowest in the TGS treatment. Results presented in Table 1 shows that, overall, the growth media are sandy loam, slightly acidic to neutral, with good aeration, high permeability, and low water holding capacity, low in nitrogen content, phosphorus and potassium.

Plant height

Results presented in Table 2 shows that plant height across treatments was not significantly ($p>0.05$) affected by growth media between weeks 2 and 4. Plant height was significantly ($p<0.05$) affected by growth media from week 6 to 8 with the tallest seedlings recorded in the TGS+TFS+CC treatment. A highly significant increase in plant height was also observed in the TGS+TFS+CC treatment from week 10 to 12. The significant increase in plant height observed in the TGS+TFS+CC treatment could suggest the mixture is the best medium for raising *A. digitata* seedlings in a tree nursery. A balanced growth medium that contains an adequate supply of nutrients is critical if seedlings raised in a tree nursery are to develop and attain maximum growth (Mehmood *et al*., 2013). The use of media with sufficient essential nutrients is important for seedlings to attain maximum height (Ikram *et al*., 2013). The TGS+TFS+CC medium increased plant height (Table 2) because the addition of compost, which is organic matter, affects soil physics, chemistry and biology as it binds soil aggregates together and is source of soil nutrients. Clay and organic matter colloids adsorb a lot of cations and the media such a TGS+TFS+CC with sufficient organic matter and clay content has a much higher CEC (Table 1) which enhanced seedling height. The compost in the mixture could also have improved aeration and the water holding capacity (Osaigbovo and Orhue, 2012) which enhanced plant height.

Most tree nurseries use natural soils to produce containerized seedlings (Tariq *et al*., 2012). These soils lack essential nutrients required for plant growth and hence the compost in the TGS+TFS+CC medium could have ameliorated the physical and chemical properties, and ultimately improved the water holding capacity and nutrient availability (Khan *et al*., 2006; Kung'u *et al*., 2008). Our results are consistent with other studies conducted elsewhere using different plants which recorded tall plants in mixtures of soils combined with organic manures such as yard manure (Shamet *et al*.,1994; Sudhakara *et al*.,1995; Nayital *et al*.,1995; Thakur *et al*., 2000; Baiyeri, 2003; Nandeshwar and Patra, 2004; Radhakrishnan and Mahendran, 2010). For example, Thakur *et al*. (2000) recorded tall *Albizia lebbeck* Benth seedlings in a mixture composed of sand+soil+farm yard manure. Nandeshwar and Patra (2004) reported that a mixture of soil+sand+compost in the ratio of 1:1:2 was the best media for growing and improving the survival of *Acacia catechu* seedlings.

Leaf number

Results presented in Table 3 shows that the number of leaves was not significantly ($p>0.05$) affected by growth media across treatments in weeks 2 and 4. The number of leaves increased with time and seedlings in the TGS+TFS+CC treatment recorded significantly more leaves in week 8 to 10 ($p<0.05$) and 12 ($p<0.01$) than in other treatments. Plants manufacture most of their food in leaves whose development is influenced by several factors, soil being one of the most critical. The number of leaves recorded in our treatments at week 12 is as follows: TGS+TFS+CC (31.72), TFS (22.20), TGS (19.98) and CC (19.08). The high number of leaves in the TGS+TFS+CC treatment could be due to higher production of photosynthesizing functional leaves (Borah *et al*., 1994) enhanced by a well-balanced media with sufficient organic matter and clay (Table 1). This result is consistent with results from other experiments, which collectively found that using soil mixtures with organic substrates such as leaf manure (Riaz *et al*., 2008) and farmyard manure (Sudhakara *et al*., 1995; Malewar *et al*.,1998; Parasana *et al*., 2013) enhanced the number of leaves. Organic matter in potting mixtures regulates water and nutrient availability (Peter-Onoh *et al*., 2014) and enhances seedling production (Baiyeri, 2003) and the compost in our mixture may have released nutrients for seedling growth in addition to improving the water holding capacity.

Collar girth

Planting media has large effect on the plant growth characteristics (Shah *et al*., 2006; Riaz *et al*., 2008). *A. digitata* seedling collar girth was significantly affected by growth media (Table 4). The collar girth in the TGS, TFS and TGS+TFS+CC treatments was significantly ($p<0.01$) increased compared to CC in week 2. Compost constitutes a slow release source of nutrients that supply plants with essential nutrients when they needed them (Chaoui *et al*., 2003; Nevens and Reheul, 2003) and this could have affected the development of seedlings in the CC treatment in the first two weeks of this work. At weeks 4 and 6, collar girth across treatments was not affected by growth media ($p>0.05$). The recorded collar girth values ranged from 2.91 to 3.16 mm in week 4 and 3.14 to 3.56 mm in week 6, respectively. At week 8, the collar girth in the TFS and TGS+TFS+CC treatment was significantly ($p<0.01$) higher than in the other two treatments. Collar girth increased with time and from week 10 to 12 seedlings in the TGS+TFS+CC treatment had a significantly higher collar girth than their counterparts in other treatments. Compost added to the growing media has shown to improve the performance of a wide range of plants (Grigatti *et al*., 2007; Peter-Onoh *et al*., 2014) because of enhanced nutrients upply (Grigatti *et al.*, 2007) which was probably the case with the TGS+TFS+CC treatment (Table 1). The presence of compost in potting media has also been shown to supress soil-borne plant pathogens (Hoitink and Boehm, 1999; Szczech, 1999; Scheuerell *et al*., 2005; Noble and Coventry, 2005; Termorshuizen *et al*., 2006), enhance microbial activity (Domínguez, 2004) and mycorrhiza colony formation (Cavender *et al*., 2003) and hence improve the plant growth.

Fresh, dry weights and biomass

Plant dry weight is an important parameter which reflects the interaction between genetic, environment and physiology process in plants (Prameswari and Tata, 2004). Results in Table 5 shows that fresh weight of plants grown in the TGS+TFS+CC treatment was significantly ($p<0.01$) higher than in the TFS and CC. There were no significant ($p>0.05$) differences in fresh weight between the TGS and

Table (1): Physical and chemical properties of growth media

Growth media	pH (H_2O)	CEC ($cmolkg^{-1}$)	Total N (%)	Available P (ppm)	Exchangeable K^+ (%)	Textural class		
						Sand (%)	Clay (%)	Silt (%)
Top garden soil (TGS)	6.3^c	1.61^a	0.87^{ab}	7.00^c	1.78^c	87	7	6
Top forest soil (TFS)	7.1^a	0.80^b	0.52^c	11.00^c	1.61^c	75	9	16
Commercial compost (CC)	5.0^d	-	0.74^b	98.00^a	2.98^a	-	-	-
Mixture (TGS+TFS+CC)	6.7^b	1.63^a	1.01^a	41.00^b	2.37^b	87	7	6
Significance	**	**	**	**	**	-	-	-
LSD 0.05	0.40	0.33	0.18	8.83	0.36	-	-	-
CV (%)	3.38	12.31	11.98	11.95	8.64	-	-	-

** Highly significant at $p<0.01$. Means separated by Least Significance Difference (LSD) Test at $p\leq0.05$, means within columns followed by the same letters are not significantly different, ppm denotes parts per million.

Table (2): *A. digitata* seedlings height (cm) under various growth media.

Growth media	Week 2	Week 4	Week 6	Week 8	Week 10	Week 12
Top garden soil (TGS)	11.40	12.28	14.65^{ab}	17.32^b	18.80^b	19.98^b
Top forest soil (TFS)	10.42	11.13	13.50^b	17.10^b	19.53^b	22.20^b
Commercial compost (CC)	8.90	9.58	11.65^b	15.83^b	17.03^b	19.08^b
Mixture (TGS+TFS+CC)	10.55	10.99	17.95^a	24.79^a	27.92^a	31.72^a
Significance	ns	ns	*	*	**	**
LSD 0.05	ns	ns	3.58	5.90	5.57	5.10
CV (%)	15.20	13.96	16.09	20.40	17.36	14.24

** Highly significant at $p<0.01$, * significantly at $p<0.05$, ^{ns} non-significant at $p>0.05$. Means separated by Least Significance Difference (LSD) Test at $p\leq0.05$, means within columns followed by the same letters are not significantly different.

Table (3): Leaf number of *A. digitata* seedlings under various growth media.

Growth media	Week 2	Week 4	Week 6	Week 8	Week 10	Week 12
Top garden soil (TGS)	5.15	6.35	9.30^b	10.35^b	11.50^b	12.20^b
Top forest soil (TFS)	5.65	7.15	9.25^b	9.95^b	10.70^b	12.05^b
Commercial compost (CC)	5.00	6.50	9.25^b	10.40^b	11.80^b	13.60^b
Mixture (TGS+TFS+CC)	5.25	7.00	10.88^a	13.05^a	14.95^a	16.75^a
Significance	ns	ns	*	*	*	**
LSD 0.05	ns	ns	1.25	2.00	2.54	2.40
CV (%)	10.31	7.43	8.34	11.85	13.48	11.87

** Highly significant at $p<0.01$, * significantly at $p<0.05$, ^{ns} non-significant at $p>0.05$. Means separated by Least Significance Difference (LSD) Test at $p\leq0.05$, means within columns followed by the same letters are not significantly different.

Table (4): Collar girth (mm) of *A. Digitata* under various growth media.

Growth media	Week 2	Week 4	Week 6	Week 8	Week 10	Week 12
Top garden soil (TGS)	2.50[a]	2.91[a]	3.56	4.83[b]	6.29[b]	7.09[b]
Top forest soil (TFS)	2.34[a]	3.00[a]	3.41	4.98[ab]	7.09[b]	8.21[b]
Commercial compost (CC)	1.98[b]	2.87[a]	3.14	4.89[b]	6.71[b]	7.54[b]
Mixture (TGS+TFS+CC)	2.33[a]	3.16[a]	3.56	5.92[a]	8.92[a]	9.98[a]
Significance	**	ns	ns	*	**	*
LSD 0.05	0.26	ns	ns	0.95	1.33	1.64
CV (%)	7.43	6.13	7.99	11.92	11.92	12.96

** Highly significant at $p<0.01$, * significantly at $p<0.05$, [ns] non-significant at $p>0.05$. Means separated by Least Significance Difference (LSD) Test at $p\leq0.05$, means within columns followed by the same letters are not significantly different.

Table (5): Total fresh and dry weights (roots + shoots)and biomass of *A. digitata*under various soil media.

Growth media	Fresh weight (g)	Dry weight (g)	Biomass (%)
Top garden soil (TGS)	289.08[ab]	72.88[b]	25.31[b]
Top forest soil (TFS)	223.65[bc]	68.74[b]	30.65[a]
Commercial compost (CC)	209.25[c]	60.21[b]	28.67[ab]
Mixture (TGS+TFS+CC)	340.25[a]	105.61[a]	31.06[a]
Significance	**	**	*
LSD 0.05	71.08	23.17	3.97
CV (%)	17.37	19.57	8.92

** Highly significant at $p<0.01$, * significantly at $p<0.05$. Means separated by Least Significance Difference (LSD) Test at $p\leq0.05$, means within columns followed by the same letters are not significantly different.

TFS and between the TGS+TFS+CC and TGS. Overall, maximum fresh and dry weight was observed in the TGS+TFS+CC treatment. This is not surprising because the treatment produced vigorous seedlings in terms of height and stem girth which may have contributed to the observed large weight. This could be attributed to the general improvement in the soil physical and chemical properties of the TGS+TFS+CC growth media (Table 1) which also improved the fresh and dry weight. Our results are consistent with Khayyat *et al*. (2007) and Mehmood *et al*. (2013) who observed high dry weight in seedlings of other plant species grown in silt + top soil mixed with either leaf mould or and peat moss. Parasana *et al*. (2013) also reported maximum fresh and dry weight in *Mangifera indica* L. seedlings grown in a mixture of soil+sand+farm yard manure. Maximum biomass percentage was recorded in the TGS+TFS+CC probably because the combination of the three improved the physical conditions and nutrient availability.

Conclusion and recommendations

Our results demonstrated that the TGS+TFS+CC delivered the best results with respect to all measured *A. digitata* growth parameters. Based on these results the mixture is recommended as the most suitable medium that can be used to propagate *A. digitata* seedlings. However, top garden soil could also be used by *A. digitata* growers. It is recommended that the experiment can be repeated and run for two growing seasons using bigger pots.

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