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Nursery Media Influences Growth of Seedlings of the Shea Nut Tree (*Vitellaria paradoxa* C. F. Gaertn.)

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ABSTRACT

Four nursery media comprising a soil-based (SB) medium and three rice hull-based (RHB) media, formulated on a volume basis were used to grow seeds of shea butter tree (*Vitellaria paradoxa*) obtained from three sources: Makurdi, Jalingo and Kano, in Nigeria. The specific media were topsoil: poultry manure: river sand (1: 2: 3); rice hull: poultry manure: river sand (1: 2: 3); rice hull: poultry manure: river sand (1: 3: 2) and rice hull: poultry manure: river sand (2: 3: 1). Factorial combinations of the four media and three accessions were laid out in a completely randomised design (CRD) replicated three times. Analysis of variance results indicated significant effect of accession on leaf area and all dry matter traits except shoot dry matter content. Growth media also exerted significant influence on all seedling growth and dry matter attributes except plant height and number of leaves. Interaction between accession and growth media significantly influenced all the traits measured. It was evident that across all accessions, the growth medium 1: 2: 3 (RHB), gave better values of seedling growth, dry matter yield and distribution of *Vitellaria* seedlings while results from the control medium were, in most cases, inferior. Generally, dry matter partitioned to the roots varied between 58.3 and 80.0%.

Keywords: accession, growth media, growth performance, dry matter, shea seedlings

INTRODUCTION

Perhaps, one of the most useful woody perennials on the African savanna landscape is the shea butter tree, *Vitellaria paradoxa*, also widely known by its synonym *Butyrospermum parkii*. The seed of its fruit, known as shea nut, is an important item in international trade. In recent times, major importing countries have been named as Belgium, Denmark, Japan, the Netherlands, Sweden and the United Kingdom (Umali and Nikiema 2002). In the importing countries, the fat extract of the nut, called shea butter, is used for chocolate and cosmetic production (Boffa *et al*. 1996).

In the 19 African shea nut producer countries led by Nigeria (355,000 t/year), Mali (85,000 t/year) and Burkina Faso (70,000 t/year) in that order (Umali and Nikiema 2002), the fat is used as cooking oil, lamp illuminant and in the production of soap, candle and pomade (Vickery and Vickery 1969; Awoleye 1995). It is also useful in the treatment of cough and inflammations (Badifu 1989). Tella (1979) established that the fat could be more effective against nasal congestion than conventional nasal drops. The leaves, barks and roots are used in the treatment of various human and livestock ailments (ICRAF 2000). The widely consumed fruit pulp, has excellent nutritional properties with carbohydrate, protein and fat having values of 29.3-45.3, 2.6-7.0 and 0.7-1.7% respectively, of dry pulp weight (Ugese *et al*. 2008a).

Based on its usefulness, the tree has already been identified by farmers for domestication (Leakey 1999). In Nigeria, as elsewhere, *V. paradoxa* is threatened by deforestation (Okafor 1985) and the yearly savanna bush fires (Boffa *et al*. 1996). In addition to these, charcoal burning, overgrazing and unfavourable land tenure are potent threats to the continued dominance of the shea tree on the African savanna landscape (Carette *et al.* 2009; Buyinza *et al*. 2011). This gives additional impetus to efforts towards its full domestication.

However, emergence of seedlings is slow (Joker 2000), taking up to 45-99 days (Ugese *et al*. 2005), as well as their growth (Jackson 1968). According to Baiyeri (2003) seedling emergence speed and growth can be enhanced by use of a suitable growth medium. Generally, of all nursery factors determining seedling quality, growth medium have been identified as the most critical (Baiyeri and Mbah 2006). In *Vitellaria paradoxa*, there is no report of the use of more standard growth media for seedling production apart from the conventional topsoil whose use as a growth medium has been severely criticised (Sahin *et al*. 2005; Baiyeri and Mbah 2006). This work was therefore undertaken to assess the suitability of various media composted from readily available substrates for production of high quality seedlings of *V. paradoxa*.

MATERIALS AND METHODS

Four nursery growth media were composted from topsoil, rice hull, poultry manure and river sand. The base materials were composted on volume basis in various ratios:
Medium 1. topsoil: poultry manure: river sand = 1: 2: 3;
Medium 2. rice hull: poultry manure: river sand = 1: 2: 3;
Medium 3. rice hull: poultry manure: river sand = 1: 3: 2;
Medium 4. rice hull: poultry manure: river sand = 2: 3: 1.

The first medium was soil-based (SB) and was considered as the control while the rest were rice hull-based (RHB).

The composted media were left for three weeks before seeds were planted. Similarly, samples of the media were taken for analysis of physico-chemical properties at the Soil Science Laboratory of the University of Nigeria, Nsukka, prior to planting.

The media were filled into 7-L plastic containers perforated at their bases. Seeds of shea butter tree obtained from fresh fallen fruits collected from three locations: Makurdi, Jalingo and Kano, were planted on the 30^{th} July 2007. Makurdi is in the Southern Guinea Savanna, Jalingo is in the Northern Guinea Savanna while Kano falls within the Sudan Savanna of Nigeria. More detailed

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Table 1 Pysico-chemical properties of growth media used for shea seedling evaluation at Makurdi, Nigeria, in 2007.

Properties	1: 2: 3 SB	1: 2: 3 RHB	1: 3: 2 RHB	2: 3: 1 RHB
Physical				
Total sand (%)	97	90	91	91
Silt (%)	7	5	3	3
Clay (%)	6	6	6	6
WHC (%)	20.0	20.8	11.3	58.5
Bulk density (g/cm^3)	1.18	0.84	0.80	0.43
Porosity (%)	55.0	68.0	69.2	83.6
Chemical				
Organic carbon (%)	1.36	3.41	5.55	11.68
Organic matter (%)	2.35	5.87	9.57	20.14
Total nitrogen (%)	0.17	0.24	0.20	0.36
Phosphorus	70.7	68.7	71.6	95.5
Sodium (meq/100 g)	0.39	0.39	0.48	0.87
Potassium (meq/100 g)	0.62	0.86	0.91	1.91
Calcium (meq/100 g)	4.0	4.0	3.6	3.4
Magnesium (meq/100 g)	0.6	2.6	3.09	8.6
CEC (%)	8.0	8.8	9.6	20.0
pH: H_2O	7.2	6.9	6.8	6.7
$CaCl_2$	6.8	6.3	6.4	6.2

geographic information about these sites has been given in another report (Ugese *et al.* 2010). Each seed source had 18 seeds sown per medium with each container having two seeds. Mean seed weights were 11.3 g (Makurdi), 18.7 g (Jalingo) and 12.9 g (Kano). Factorial combinations of seed source and growth media were arranged in completely randomized design (CRD) and replicated three times.

Seedlings were watered from time to time to provide adequate moisture for satisfactory growth. Seedling growth attributes, namely plant height, leaf number, stem girth and leaf area were measured nine months after planting when the seedlings were adjudged to have attained a reasonable level of growth. Afterwards, seedlings were carefully removed from the growth media and shoot length and root length measured with a ruler. Shoot length was measured as the distance between the tip of the stem and the point where the true root attaches to the false radicle which occurs below ground level. The seedlings were subsequently divided into leaves, shoot and root and their fresh weight measured. Samples were oven dried at 70°C to a constant weight. Dry matter content of leaves (DMCL), shoot (DMCS) and root (DMCR) were estimated as the ratio of oven dry weight to that of fresh weight multiplied by 100. Dry matter partitioned to the leaves (DMDR), shoot (DMDS), and root (DMDR) were calculated as the ratio of the dry weight of the particular plant part to that of the whole plant, expressed as a percentage. Leaf area was calculated based on the model developed by Ugese *et al.* (2008b):

$$LA = 4.41 + 1.14 \times LW$$

where LA = leaf area and LW = the product of linear dimensions of the length and width at the broadest part of the leaf.

Data collected were subjected to analysis of variance by means of GENSTAT Discovery edition 3, Release 7.2DE (GENSTAT 2007). Where significant *F*-test was found, mean separation was effected using Fisher's least significant difference (F-LSD) procedure at the 5% level of probability.

RESULTS

The proportion of the base materials no doubt had some noticeable effect on the physico-chemical properties of the growth media (**Table 1**). Thus, the soil based medium (1: 2: 3) had the highest percentage of sand and silt. Its bulk density was also expectedly higher. Conversely, medium 2: 3: 1 (RHB) had lowest values for bulk density but recorded comparatively higher porosity and water holding capacity. The latter medium also had higher values for most of the chemical attributes namely, organic carbon, organic matter, phosphorus, magnesium and cation exchange capacity (CEC). Values of pH were higher for the medium 1: 2: 3 (SB) and lowest for medium 2: 3: 1 (RHB).

Table 2 The main effects of accession and growth media on growth of *Vitellaria* seedlings grown at Makurdi, Nigeria.

Accession	Shoot length (cm)	Plant height (cm)	No. of leaves	Leaf area (cm^2)	Stem girth (cm)	Root length (cm)
Makurdi	13.1	7.8	4.7	22.9	0.30	66.8
Jalingo	13.1	8.3	3.9	33.3	0.31	93.1
Kano	14.2	8.4	3.7	27.4	0.33	88.0
LSD $_{(0.05)}$	NS	NS	NS	4.3	NS	6.6
Growth media						
I:2:3 SB	12.2	7.1	3.7	20.8	0.26	72.6
1:2:3 RHB	13.1	7.7	3.8	35.8	0.35	93.1
1:3:2 RHB	15.0	9.4	3.9	29.5	0.34	71.7
2:3:1 RHB	13.6	8.5	5.1	25.3	0.31	93.4
LSD $_{(0.05)}$	1.7	1.1	NS	4.9	0.03	7.6

NS – No significant difference

Main effect of accession and growth media on seedling growth and dry matter attributes

Accession exerted significant influence on seedling growth of shea butter tree seedlings (**Table 2**). Seedlings of the Jalingo accession had larger leaf areas and longer roots ($P < 0.05$) although the latter was not significantly different from that of Kano seedlings.

With respect to growth media, the seedling characters of leaf area, stem girth and root length were favoured by medium 1: 2: 3 RHB while medium 1: 3: 2 RHB appeared to favour shoot length and plant height (as well as girth). Medium 2: 3: 1 RHB exerted more favourable impact on plant height and root length.

Main effect of the factors on dry matter yield and distribution pattern is shown in **Table 3**. Seedlings of Makurdi origin had comparatively higher total dry matter content as well as dry matter content of leaves and roots. Its dry matter distribution to the leaves was also higher. The Jalingo provenance had higher total plant dry weight and higher dry matter distribution to the roots. Its total dry matter content was comparable to that of Makurdi. Kano seedlings had comparatively higher amount of their photosynthates partitioned to the leaves and shoots.

Interaction effect of accession and growth media on growth and dry matter attributes

Interaction between accession and growth media exerted significant effect on seedling growth and dry matter attributes (**Tables 4, 5**). Seedling growth of the Makurdi accession was more vigorous under medium 1: 2: 3 RHB. Similarly, with the Kano seed source, medium 1: 2: 3 RHB supported better seedling growth.

It was clearly evident that dry matter production and distribution pattern was remarkably affected by the interaction between treatment factors (**Table 5**). Total plant dry weight of seedlings of Makurdi and Jalingo origins was better under medium 1: 2: 3 RHB, while those of Kano were so under medium 1: 3: 2 RHB. The shoot dry matter content of the Makurdi seedlings was significantly lower with medium 2: 3: 1 RHB, compared to the rest. Similar profile was recorded with dry matter content of root in which case the soil based medium was also a culprit. With medium 1: 2: 3 RHB, more dry matter was partitioned to the leaves than the stem for all accessions except the Kano accession where dry matter allocation to both parts of the plants was equal.

It was remarkable that medium 1: 2: 3 RHB influenced more dry matter partitioning of Makurdi seedlings to the leaves and less to the roots. Media 1: 2: 3 SB and 1: 2: 3 RHB, influenced comparatively higher dry matter distribution to the leaves than the remaining two media. The later media also had higher photosynthates partitioned to the

Table 3 The main effect of accession and growth media on dry matter yield and distribution of *Vitellaria* seedlings grown at Makurdi, Nigeria.

Accession	TDW[b] (g)	TDMC (%)	DMCL (%)	DMCS (%)	DMCR (%)	DMDL (%)	DMDS (%)	DMDR (%)
Makurdi	3.6	42.3	48.2	42.2	42.3	15.6	13.5	70.5
Jalingo	5.2	40.6	42.0	42.1	40.0	11.4	9.3	77.9
Kano	4.2	37.5	41.6	40.2	36.3	15.8	15.6	67.9
LSD $_{(0.05)}$	0.4	1.9	3.8	NS	1.8	1.0	0.9	1.5
Growth media								
I:2:3 SB	3.7	39.2	50.8	41.4	36.3	12.0	12.9	72.7
1:2:3 RHB	4.9	43.6	45.8	45.8	44.0	18.0	11.9	69.6
1:3:2 RHB	5,1	42.1	43.9	39.9	42.7	13.4	12.5	73.5
2:3:1 RHB	3.6	35.5	35.2	38.9	35.1	13.7	14.0	72.6
LSD $_{(0.05)}$	0.4	2.2	4.4	1.8	2.1	1.1	1.0	1.7

[b]TDW = total plant dry weight; TDMC = total dry matter content; DMCL = dry matter content of leaves; DMCS = dry matter content of stem; DMCR = dry matter content of root; DMDL = dry matter distribution to leaves; DMDS = dry matter distribution to stem; DMDR = dry matter distribution to the roots.

Table 4 Interaction effect of accession and media on growth of *Vitellaria* seedlings grown at Makurdi, Nigeria.

Accession	Growth medium	Shoot length (cm)	Plant height (cm)	No. of leaves	Leaf area (cm^2)	Stem girth (cm)	Root length (cm)
Makurdi	1: 2: 3 SB	11.6	6.5	5.0	17.1	0.26	64.5
	1: 2: 3 RHB	14.0	7.9	5.8	31.3	0.36	61.5
	1: 3: 2 RHB	14.1	8.8	3.8	21.7	0.29	62.3
	2: 3: 1 RHB	12.8	8.1	4.2	21.3	0.31	79.1
Jalingo	1: 2: 3 SB	12.0	6.2	2.8	25.4	0.25	75.2
	1: 2: 3 RHB	14.2	8.0	3.7	40.7	0.33	96.7
	1: 3: 2 RHB	13.0	9.5	5.3	35.3	0.34	93.7
	2: 3: 1 RHB	13.2	9.3	4.0	31.7	0.32	107.0
Kano	1: 2: 3 SB	12.9	8.6	3.3	19.8	0.28	78.1
	1: 2: 3 RHB	14.0	7.0	5.8	35.4	0.35	121.0
	1: 3: 2 RHB	14.1	10.0	3.8	31.5	0.40	59.0
	2: 3: 1 RHB	12.8	8.0	4.2	22.8	0.30	94.0
LSD $_{(0.05)}$		3.1	2.0	3.0	8.5	0.06	13.1

Table 5 Interaction effect of accession and growth media on dry matter yield and distribution pattern of *Vitellaria* seedlings grown at Makurdi, Nigeria.

Accession	Growth medium	TDW[c] (g)	TDMC (%)	DMCL (%)	DMCS (%)	DMCR (%)	DMDL (%)	DMDS (%)	DMDR (%)
Makurdi	1: 2: 3 SB	3.1	39.8	52.4	44.3	37.8	11.9	14.0	74.0
	1: 2: 3 RHB	5.0	46.0	48.3	42.1	48.9	26.9	13.4	58.3
	1: 3: 2 RHB	3.9	45.0	50.0	45.7	44.9	11.8	11.8	76.3
	2: 3: 1 RHB	2.5	37.8	42.1	36.7	37.4	11.9	14.9	73.2
Jalingo	1: 2: 3 SB	4.4	41.1	51.9	39.7	37.8	15.7	9.1	75.5
	1: 2: 3 RHB	6.8	43.5	44.6	51.0	42.6	14.3	9.4	76.4
	1: 3: 2 RHB	4.7	41.7	43.4	40.6	41.8	9.6	9.6	80.0
	2: 3: 1 RHB	5.0	36.0	28.3	37.3	37.7	11.5	9.4	78.8
Kano	1: 2: 3 SB	3.6	36.6	48.4	40.1	33.2	15.5	15.6	68.6
	1: 2: 3 RHB	3.1	41.3	44.4	44.4	40.4	12.9	12.9	74.1
	1: 3: 2 RHB	6.7	39.2	38.2	33.5	41.3	19.0	16.4	64.2
	2: 3: 1 RHB	3.4	32.7	35.3	42.8	30.1	17.6	17.6	64.7
LSD $_{(0.05)}$		0.8	3.8	7.6	6.8	3.6	1.9	1.8	3.0

[c]TDW = total plant dry weight; TDMC = total dry matter content; DMCL = dry matter content of leaves; DMCS = dry matter content of stem; DMCR = dry matter content of root; DMDL = dry matter distribution to leaves; DMDS = dry matter distribution to stem; DMDR = dry matter distribution to the roots.

roots.

With the Kano accession, dry matter content of leaves was significantly less with media 1: 2: 3 RHB and 1: 3: 2 RHB, that of shoot was inferior with medium 1: 3: 2 RHB which together with 1: 2: 3 RHB recorded higher dry matter content of the root. Medium 1: 3: 2 RHB also influenced more dry matter distribution to the leaves compared to the rest of the media. Under this accession comparatively more dry matter went to the root (74.1%).

It was generally observed that across all accessions and growth media, dry matter partitioning to the roots was higher, ranging between 58.3 and 80%. Proportion of dry matter allocated to the leaves and shoots varied slightly depending on the particular accession and growth medium. Also, for most seedling and dry matter traits, the control medium gave inferior results.

DISCUSSION

Differences in physico-chemical properties of growth media could be ascribed to the media components (Wilson *et al* 2001; Baiyeri and Mbah 2006; Campos Mota *et al*. 2009). Thus the soil based medium had the highest bulk density and lowest total porosity. Among the chemical attributes, its values for organic carbon, organic matter and total nitrogen were also lower. Conversely, due to the higher proportion of rice hull and the lower ratio of river sand, medium 2: 3: 1 RHB had the least bulk density and highest water holding capacity and total porosity. The relative composition of the medium also resulted to its more impressive chemical properties. On a general note, the properties of the media seem to be in general agreement with those of Baiyeri and Mbah (2006).

The observed greater performance of medium 1: 2: 3 RHB in terms of seedling growth and dry matter attribute corroborates the findings of Baiyeri and Mbah (2006) in the case of African breadfruit, *Treculia africana*. They attributed it to the more favourable pH of the medium (6.9) which was also obtained in this study. It is worthy of note that in *Vitellaria*, shoot length is longer than plant height (Ugese *et al*. 2008c). This is due to the species' cryptogeal germination pattern which buries part of the shoot under-ground (Jackson 1968).

In contrast to what obtains in other tree species (Baiyeri 2003), *Vitellaria* normally partitions a greater amount of its photosynthates to the roots, an attitude that could be linked with its concern for survival in the harsh savanna environment. However, the effort by medium 1:2:3 RHB to partition more photosynthates to the leaves than the stem holds brilliant promise for seedling growth. This is because, this has the tendency of accelerating leaf area expansion and thereby seedling growth due to better light interception and ultimately higher levels of photosynthesis (Brown 1984).

It was curious that the medium (2: 3: 1 RHB) with lower bulk density, higher water holding capacity and total porosity and which was more nutritionally endowed did not enhance the best seedling growth and dry matter yield. Some of the above mentioned physical properties were credited with enhancing performance of African bread fruit (Baiyeri and Mbah 2006) and nutmeg (Abirami *et al*. 2010) seedlings, though in the latter enhanced nutrient levels of medium were also implicated. In *Coffea canephora*, topsoil + sawdust growth medium that was amended with NPK compound fertilizer could not register better seedling growth than one in which the two components were combined in an equal ratio (Adeyemi and Daniel 2006)

It is a fact that good growth media are characterized by some common physical attributes which influence water and air availability to the growing plant (Eberhard *et al*. 2008) and thereby facilitate better seedling emergence and growth (Abirami *et al*. 2010). However, it can be deduced from the foregoing that certain peculiar characteristics of some plant species could modify plant response to media generally adjudged to be good. Thus it could be that adaptation of *Vitellaria* to the savanna ecology makes the species less responsive to a growth medium with high water holding capacity which ordinarily is a quality criterion of a good medium. Such a medium may approximate to the natural condition of water logging which is known to hamper shea seedling growth (ICRAF 2000). Thus even though the medium had more nutrients content, it could not perform better than the others. This underscores the importance of physical attributes of a growth medium in determining its ultimate suitability. According to Jenkins and Jarrel (1989), such physical attributes includes bulk density, total and air filled porosities, water retention and hydraulic conductivity. They also mention pH and CEC as critical chemical properties.

In conclusion, this study has established the superior performance of medium 1:2:3 RHB in seedling growth and dry matter attributes. It was however evident that seedling response to growth media could be dependent on the adaptive behaviour of the species in question.

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