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Full Length Research Paper

Nursery Media and Water Stress Effects on African Breadfruit (Treculia africana) Seedling Growth and Development

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The production of high quality seedlings for orchard and plantation establishment involves several cultural inputs. The quality of potting media perhaps stands out as the most important. Therefore, the effects of three soilless media and a soil-based medium on seedling emergence, seedling growth and susceptibility to water stress were studied using African breadfruit as a test crop. Most of the seedling parameters evaluated was significantly influenced by the potting media used. Percent seedling emergence and whole-plant dry matter content were higher in media 1:2:3 ricehull-based (ricehull : poultry manure : river sand, RHB) and 2:3:1 RHB. After induction of water stress, seedling grown in these media remained turgid for a longer period than those grown in media 1:2:3 soil-based (top soil : poultry manure : river sand, SB) and 1:4:3 RHB. Seedlings raised in the soil-based medium were generally poorer in most of the parameters measured. General growth responses and reaction to water stress suggested that media 1:2:3 RHB and 2:3:1 RHB were the best. Seedling grown in these media had delayed water stress symptom expression suggesting a better water economy.

Key words: Potting media, physicochemical properties, seedling growth, water stress.

INTRODUCTION

Nursery operations in Nigeria are in most cases, subsistence. However, there are a few fairly organized standard nursery setups in colleges and agricultural establishments. A few existing peri-urban commercial nurseries are mostly manned by non-professional technicians or are operated with cultural practices that degrade the environment.

Nursery potting media influence quality of seedlings produced thereof (Baiyeri, 2005; Sahin et al., 2005; Agbo and Omaliko, 2006). The quality of seedling obtained from a nursery influences re-establishment in the field (Baiyeri, 2006) and the eventual productivity of an orch-ard (Baiyeri and Ndubizu, 1994). The traditional nursery potting medium in Nigeria is topsoil dug up from farmland and amended with poultry manure (PM).

Digging up agricultural soils will not only render the land unproductive for cropping, but will also make the land susceptible to erosion and other forms of degradation. Besides, field soils are generally unsatisfactory for the production of plants in containers (Sahin et al., 2005). Thus, the conventional nursery practice in Nigeria is environmentally unsustainable.

The use of soilless potting media is a common practice in the developed countries. Commercial potting media are commonly based on sphagnum peat and coir-dust based substrates (Evans and Iles, 1997). Quality of seedlings obtained is influenced by the composition of the media used (Corti et al., 1998; Wilson, et al., 2001; Sahin et al., 2005, Baiyeri, 2003).

Ekwu and Mbah (2001) reported on the relative importance of soilless media for growing potted ornamental plants in Nigeria. More recently, Baiyeri (2005) evaluated three soilless media for weaning banana and plantain plantlets. The study showed that most of the genotypes evaluated grew into high quality seedlings when grown in ricehull (RH) composted with

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Table 1. Physicochemical properties of nursery potting media evaluated for African breadfruit seedlings.

	Potting media*			
Properties	1:2:3 SB	1:2:3 RHB	1:4:3 RHB	2:3:1 RHB
Physical				
Total sand (%)	86.0	90.0	88.0	92.0
Silt (%)	4.0	2.0	4.0	2.0
Clay (%)	10.0	8.0	8.0	6.0
Water holding capacity (%)	36.0	28.0	48.0	74.0
Chemical				
Organic carbon (%)	1.12	1.16	1.60	3.99
Organic matter (%)	1.98	2.00	2.76	6.88
Total nitrogen (%)	0.30	0.28	0.48	0.16
Potassium (%)	0.18	0.16	0.16	0.24
Phosphorus (%)	0.22	0.24	0.20	0.26
Calcium (%)	0.26	0.12	0.28	0.30
Magnesium (%)	0.13	0.06	0.10	0.21
Sodium (%)	0.19	0.20	0.20	0.32
pH (H_2O)	5.8	6.9	6.3	5.4
Correlation matrix showing the relationship between the physicochemical properties				
	1:2:3 SB	1:2:3 RHB	1:4:3 RHB	2:3:1 RHB
1:2:3 SB	1.00	0.994**	0.993**	0.949**
1:2:3 RHB		1.00	0.977**	0.915**
1:4:3 RHB			1.00	0.979**
2:3:1 RHB				1.00

Potting media*: SB: Soil-based; RHB: Ricehull-based. Media were formulated as v/v/v ratios. First ratio in the formulation is topsoil (SB medium), and ricehull (for RHB media). The second and third ratios are poultry manure and river sand, respectively.

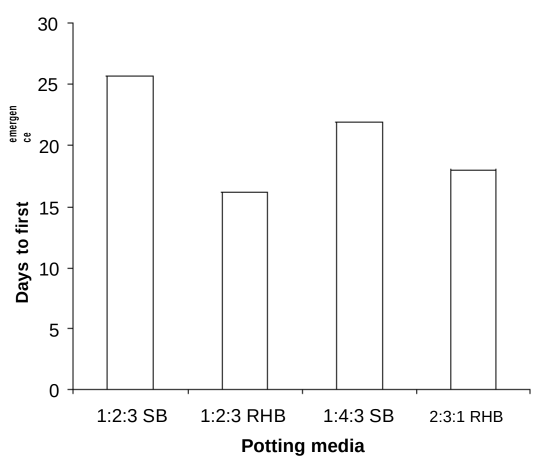

Figure 1. Variations in number of days to onset of African breadfruit seedling emergence as influenced by potting media.

poultry manure compared with those grown in SD composted with PM or RH+SD+PM. In an earlier study, Baiyeri (2003) using soil-based media reported on variable crop species responses to ratios of topsoil (TP), poultry manure and river sand (RS). The study showed that the best seedling qualities of African breadfruit (*Treculia africana* Decne) were obtained when raised in medium formulated with TP:PM:RS in 1:2:3 (v/v/v) ratios.

Besides the obvious scarcity of fertile topsoil for use in the nursery industry, digging up large volume of soil is laborious and has negative consequence on the soil environment. Thus, development of soilless potting media will be an important cultural intervention strategy for sustainable commercial nursery practice in Nigeria and elsewhere in the developing tropical countries.

In this study therefore, three soilless media differing in composition were evaluated together with the conventional soil-based medium. Seedling emergence, growth and susceptibility to water stress of the test-crop were determined and compared in the four potting media.

MATERIALS AND METHODS

Two experiments were conducted in the research land of the Department of Crop Science, University of Nigeria, Nsukka, Nigeria, between November 2002 and August 2003. The seedling emergence and growth experiment was set up under blue polyethylene- shade, while the water stress experiment was conducted at the corridor of the departmental building to avoid rain water reaching the plants. Treatments were four nursery potting media. The media were formulated on volume ratios of ricehull, poultry manure and river sand; the control treatment was a soil-based medium. The ricehull-based media differed in their relative

Table 2. Effect of potting media and weeks after planting on African breadfruit seedling emergence.

	Weeks after planting						
Media*	2	3	4	5	6	7	8
1:2:3 SB	0.0	8.0$^{\psi}$	13.0	14.0	17.0	18.0	18.0
1:2:3 RHB	3.0	37.0	45.0	53.0	56.0	57.0	57.0
1:4:3 RHB	0.0	11.0	30.0	34.0	38.0	39.0	41.0
2:3:1 RHB	1.0	26.0	39.0	42.0	46.0	51.0	52.0
LSD(0.05)	ns	15.5	13.6	13.0	13.8	13.3	13.4

Media*: see Table 1 for interpretation of formulation.

$^{\psi}$Seedling emergence (%).

composition (by volume) of the base materials. The media included:

1:2:3 Soil-based (SB) - top soil : poultry manure : river sand;
1:2:3 Ricehull-based (RHB) – ricehull : poultry manure : river sand;
1:4:3 Ricehull-based (RHB) – ricehull : poultry manure : river sand; and
2:3:1 Ricehull-based (RHB) – ricehull : poultry manure : river sand.
Prior to use the media were composted for six weeks, and were analyzed for physicochemical properties. Three-liter plastic buckets were utilized as the growing container. Freshly extracted and water-washed seeds were used. Viability test by floatation method was performed, and non-viable seeds were discarded.

The media were, each, replicated ten times, and in each replicate ten viable seeds were planted at about 2 cm depth; planting was done on January 24, 2003. Watering was done at two days interval and weeds were hand picked. Ambient temperature during the first two months of planting, which was the period when seedling emergence was monitored, varied between 29 and 33^{o}C. Temperature of the media was similar, and in most cases, about 2^{o}C higher than the ambient during the first week of planting, and thereafter media temperature more or less equated the ambient. As from the sixth week after planting, there was no more appreciable increase in percent seedling emergence; however, monitoring of seedling emergence continued till the eight week of planting. Seedlings were thinned to three per container. The water stress experiment commenced when the seedlings were about twenty weeks old. Four replicates per medium were utilized for the water stress experiment. The pots were copiously watered and allowed to drained overnight; leaves per seedling was pruned to the five youngest. Thereafter, seedlings were withdrawn from every water source. The stress experiment was to further elucidate the variable effects of potting media on nursery management. Medium that supports good seedling growth and as well delayed susceptibility to water stress will enhance returns on investment.

Seedling growth parameters and dry matter yield and distribution were measured at the 24th and 26th weeks after planting, respectively. Leaf samples were analyzed for mineral elements. Data were analyzed with GENSTAT Discovery Edition 1 Release 4.23 (GENSTAT, 2003), following completely randomized design procedure. Means separation to detect the effects of potting media was by Least Significant Difference (LSD) at 5% probability level.

RESULTS

The potting media

There were some slight variations in both physical and chemical composition of the potting media (Table 1). Water holding capacity ranged between 28% (for medium 1:2:3 RHB) to 74% (for medium 2:3:1 RHB). The percent organic matter was lowest (1.8%) for the soil based medium and highest (6.88%) for medium 2:3:1 RHB. Elemental composition was relatively similar. In some cases, higher values were obtained in medium 2:3:1 RHB, although, this potting medium had the lowest pH and percent nitrogen. Despite the differences in the ratios of the ricehull, poultry manure and river sand of the potting media, multiple correlation analysis revealed that the physicochemical properties of the four media were significantly interrelated. Media 1:2:3 SB and 1:2:3 RHB had the same ratios in composition but differed in base materials (i.e. topsoil and ricehull). However, the relationship between their physicochemical properties had a high coefficient of determination (98.8%). Media 1:2:3 RHB and 2:3:1 RHB, though had the same base material (ricehull) differed in ratios of the base materials, and had lower interrelationship (r^2 = 83.7%).

Seedling emergence

The percent emergence was generally low and spanned through eight weeks (Table 2). However, percent seedling emergence was consistently highest in medium 1:2:3 RHB and lowest in medium 1:2:3 SB. There was no more appreciable increase in percent emergence after the sixth week of planting. Figure 1 shows apparent variability in days to onset of seedling emergence as influenced by potting media. The soil-based medium which had the poorest total emergence (Table 2) similarly had the longest days to first seedling emergence (Figure 1). The earliest days to seedling emergence was obtained in medium 1:2:3 RHB.

Seedling growth, dry matter yield, and leaf mineral composition

Seedlings raised in medium 1:4:3 RHB had more leaves, longer stem and thicker stem girth at 24 week after planting (WAP). However, seedlings that grew in the soil-based medium had longer roots (Table 3). Total dry matter was higher in soil-based medium followed by those grown in 1:4:3 RHB (Table 4) . Dry matter distribu-tion pattern was influenced by the potting media. Soil-based medium had similar proportion of the total dry matter to the leaves and roots whereas the ricehull-based

Table 3. Variations in African breadfruit seedling growth parameters at 24 weeks after planting as influenced by potting media.

Media*	Number of leaves	Stem length (cm)	Stem girth (cm)	Root length (cm)
1:2:3 SB	13.0	20.4	0.84	25.8
1:2:3 RHB	10.9	21.4	0.98	17.6
1:4:3 RHB	12.8	26.9	1.24	20.8
2:3:1 RHB	12.5	24.8	1.12	18.8
LSD(0.05)	ns	ns	0.23	ns

Media*: see Table 1 for interpretation of formulation.

Table 4. The effect of potting media on African breadfruit seedling total dry matter yield, dry matter distribution, and dry matter content at 26 weeks after planting.

		Dry matter distribution (%)		
Media*	**Total dry matter (g)**	**Leaves**	**Stem**	**Root**
1:2:3 SB	16.0	35.2	28.8	36.0
1:2:3 RHB	8.1	30.8	34.2	35.0
1:4:3 RHB	11.6	26.2	35.4	38.4
2:3:1 RHB	9.9	27.0	34.6	38.3
LSD(0.05)	ns	3.0	3.1	Ns
		Dry matter content (%)		
Media*	**Whole plant**	**Leaves**	**Stem**	**Root**
1:2:3 SB	31.3	30.8	33.8	30.2
1:2:3 RHB	41.0	38.1	49.2	40.9
1:4:3 RHB	34.1	33.9	37.2	31.9
2:3:1 RHB	36.3	34.8	37.7	36.3
LSD(0.05)	3.9	2.4	Ns	2.9

Media*: see Table 1 for interpretation of formulation.

media partitioned more of the photo-assimilates to the stem and roots. Seedlings raised in medium 1:4:3 RHB had the highest proportion of its dry matter partitioned to the roots. The percent dry matter content (DMC) of whole-plant and components also varied with potting media used (Table 4). Seedlings grown in 1:2:3 RHB had higher dry matter, but those that grew in 1:2:3 SB had the lowest DMC. Mineral compositions of the leaves were, in most cases, statistically similar (Table 5) . However, seedlings that grew in medium 1:4:3 RHB had higher values for leaf mineral elements except percent nitrogen.

Response to water stress

Seedlings used for the water stress were statistically similar in height and they produced similar number of leaves during the stress period (Table 6). The oldest leaf drooped (loss of turgidity) after 21 days of moisture withdrawal in the soil-based media as against more than 30 days in the ricehull based media. The first leaf to lose turgidity in potting medium 2:3:1 RHB was after 42 days. Loss of turgidity by all leaves was markedly different when comparing the soil-based medium with the ricehull based media. It was evident that the ricehull media significantly prolonged the duration for all the leaves on seedling to lose turgidity. The duration between the onset of loss of turgidity and when all leaves have drooped as influenced by potting media is shown on Figure 2. All leaves on seedlings raised in the soil-based medium lost turgidity within four days. Whereas, it took about 15 days between onset and complete loss of turgidity by all leaves for seedlings raised in media 1:2:3 RHB and 2:3:1 RHB. Leaf yellowing followed a similar trend of loss of turgidity.

Linear correlation analysis revealed that the water holding capacity of the potting media explained 55.4% of the variation in number of days to first leaf drooping. The relationship between onset of loss of turgidity and total dropping of all leaves was positive and significant (r = 0.82**); suggesting that the media that delayed onset of leave drooping similarly prolonged the duration for all leaves to droop. Also, it was observed that, delay in loss of turgidity by all leaves similarly delayed duration to leave yellowing (r = 0.83**). Height of seedlings at the time of moisture withdrawal had a significant negative relationship (r = -0.56*) with duration to loss of turgidity by all leaves.

DISCUSSION

Studies elsewhere had shown that the base materials for formulating potting media are a significant determinant of its physicochemical properties (Wilson et al. 2001; Sahin et al., 2005). Thus, variability in the ratios of the base

Table 5. Macronutrient contents of African breadfruit leaves at 26 weeks after planting.

	Nutrients (%)				
Media*	N	P	K	Ca	Mg
1:2:3 SB	1.20	0.28	0.27	1.20	0.63
1:2:3 RHB	1.16	0.29	0.27	1.40	0.72
1:4:3 RHB	1.23	0.31	0.25	1.40	0.84
2:3:1 RHB	1.31	0.29	0.24	1.20	0.72
LSD(0.05)	ns	0.01	ns	ns	ns

Media*: see Table 1 for interpretation of formulation.

Table 6. Variability in African breadfruit seedling responses to water stress as influenced by potting media.

Media*	PHTonset	DLT1	DLT5	DLYL1	NL3WAS
1:2:3 SB	30.6	21.4	25.4	25.1	1.8
1:2:3 RHB	26.8	32.4	47.1	36.1	1.8
1:4:3 RHB	29.8	35.5	42.1	36.9	1.9
2:3:1 RHB	27.1	42.2	57.5	45.4	1.6
LSD(0.05)	ns	5.6	11.7	11.5	ns

Media*: see Table 1 for interpretation of formulation.

PHTonset: Plant height at the onset of water stress; DLT1: Number of days to loss of turgidity (drooping) of leaf 1 (oldest leaf); DLT5: Number of days to loss of turgidity of all leaves; DLYL1: Number of days to first leaf yellowing; NL3WAS: Number of new leaves produced three weeks after water stress imposition.

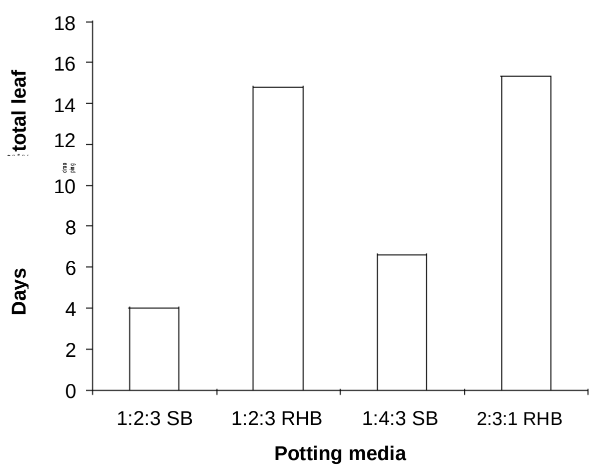

Figure 2. The effect of potting media on number of days between commencement of loss of turgidity by the oldest leaf and loss of turgidity by all leaves on each African breadfruit seedling.

materials utilized for composting the four potting media in this study probably explained the marked differences in their water holding capacity. Medium 2:3:1 RHB which had the highest proportion of ricehull similarly retained the highest volume of water. Wilson et al. (2001) similarly reported variations in water holding capacity of coir and peat based substrate amended with different quantity of compost. The slight trend in interrelationships among the four media was likely due to the ratio of poultry manure; for example media 1:2:3 SB and 1:2:3 RHB had the same proportion of PM and thus, more correlated. Similarly, 50% (in composition) of media 1:4:3 RHB and 2:3:1 RHB was PM, and their correlation coefficient was very high. It was important to note that only medium 1:2:3 RHB had pH that approximates neutrality while all others were slightly acidic. Acidity was highest in medium 2:3:1 RHB. Potting media pH influences nutrient availability and consequently plant growth (Bugbee, 1996; Fitzpatrick et al., 1998)

The significant media effects on onset of seedling emergence, and duration of emergence was probably due to differences in their physical characteristics. Media 1:2:3 RHB and 2:3:1 RHB which had relatively higher proportion of sand (and consequently lower percent of silt and clay) similarly enhanced earlier seedling emergence and higher percent emergence. Delayed emergence and lower percent emergence in the soil-based medium and medium 1:4:3 RHB was probably due to lower porosity due to higher proportion of silt and clay. Lower porosity meant poorer aeration and seed respiration, and consequently lower metabolic energy required for seed germination. It was probable therefore, that most of the seeds might have decayed. It thus, suggests that nursery medium for African breadfruit must be sufficiently aerated and has high water holding capacity. The relative balance of air and water within a soil's pore space is critical to plant growth (Bruckner, 1997; Caron and Nkongolo, 1999).

Although the general physicochemical properties of the four media were highly correlated, plant responses significantly varied suggesting that some specific attributes of each medium might have far reaching effect on seedling performance as observed in this study. Higher growth qualities of seedlings raised in media 1:4:3

RHB and 1:2:3 RHB was probably associated with higher pH, low pH (high acidity) makes nutrient unreadily available for plant use.

Water deficit imposes huge reductions in crop yield via diminished leaf carbon fixation and general growth inhibition (Chaves and Oliveira, 2004). Seedling plants are tender and are therefore more responsive to water availability. Thus, potting medium that possesses high water holding capacity alongside optimum nutrient and aeration for plant growth will be an advantage in nursery industry. The variability in the water holding capacity of the media probably explained distinct responses to water stress by seedlings grown in them. The water holding capacity of the media was probably determined by the relative proportion of ricehull and or poultry manure.

Evidences from the seedling emergence, seedling growth, and seedling dry matter content and distribution, and seedling responses to water stress suggested that media 1:2:3 RHB and 2:3:1 RHB were adjudged the best soilless media. Seedling grown in these media had delayed water stress symptom expression suggest a better water economy.

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