Effect of Seed Source and Watering Intervals on Growth and Dry Matter Yield of Shea Butter Tree (*Vitellaria paradoxa* Gaertn F.) Seedlings

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Abstract

Shea butter tree seeds obtained from five locations in Guinea and Sudan savanna zones of Nigeria were evaluated for seedling growth under three watering intervals. The accessions were named after the site of collection, which included Makurdi, Minna, Jalingo, Yola and Kano while the watering intervals included 3, 6, and 9 day-intervals. Factorial combinations of the accessions and the watering intervals were laid out in a completely randomized design (CRD) replicated three times. Data on growth pattern, dry matter yield and distribution were collected between July 2006 and April 2007. Result indicated that accession had significant ($P < 0.05$) effect on all traits except number of leaves, total shoot length, shoot dry matter content and dry matter distribution to the roots and leaves. Watering intervals exerted significant effect only on fresh weight of roots, total fresh weight of seedling, root dry weight, leaf dry weight, total plant dry weight, and per cent total dry matter. Generally, the Jalingo accession was superior in most seedling attributes while Makurdi was the most inferior, a pattern probably associated with heavier seed weight of Jalingo and light seeds from Makurdi used for planting. The interaction between accession and watering intervals was significant ($P < 0.05$) on most characters except seedling girth, total shoot length, fresh weight of shoot, dry matter distribution to the root and per cent total dry matter. Dry matter content of the leaves and roots varied significantly ($P < 0.05$) with seedlings from the Makurdi seed source giving the lowest values. Amount of dry matter allocated to the roots was more than 70% in all the accessions. Generally, the longest watering interval produced seedlings with the longest roots. The Kano accession appeared more tolerant to water stress judging mainly from its dry weight/matter traits. On the other hand, the Minna provenance performed better under the 3 and 6 days watering intervals. Other accessions performed more or less uniformly under all watering intervals.

Keywords: Shea butter tree seeds, Accession, Watering intervals, Seedling growth, Dry matter

Introduction

The shea butter tree, *Vitellaria paradoxa*, is a key component of West African savanna parklands (Boffa *et al*., 1996). It occupies a 500 – 700 km wide and 5000 km long belt of African savanna, occurring within a distance of 50 km from the coast only in Nigeria and Ghana. Subspecies paradoxa which occurs in Nigeria grows in areas with annual precipitation in the range of 600 – 1400 mm with a dry period of 5 - 8 months (Umali and Nikiema, 2002). The species can grow in sahelian areas but only on sites that can supply adequate moisture such as seasonal water courses (ICRAF 2000).

In Nigeria, the species occurs mainly in the guinea and sudan savanna zones (Keay, 1989) with limited occurrence in some parts of Western Nigeria (Keay *et al*., 1964) as well as within the Boki area of Cross River State in south-eastern Nigeria. Although *Vitellaria* thrives in dry savannas (Dalziel, 1931), the seedlings have been known to succumb to drought (Boffa *et al*., 1996; ICRAF, 2000). Water logging equally constitutes an unfavourable environment to its growth (ICRAF, 2000). Therefore, an understanding of the response pattern of seedlings of differing accessions to moisture regimes may provide an important clue about adaptation and possible areas of domestication.

The shea butter tree species has no doubt been an important forest resource among African peoples for a very long time. This is due principally to the fat extracted from its kernels for cooking and in soap, candle and pomade production (Awoleye, 1995). In addition, various parts of the plant have been credited with medicinal properties (Popoola and Tee, 2001) while the nuts have being an export item to the European market (Umali and Nikiema, 2002).

Boffa *et al*., (1996) predicted increased demand for shea butter tree nuts due in part to the new realization of its surpassing pharmacological and cosmetic properties. A recent report (Umobong, 2006) indicated that there is indeed a higher demand for shea butter tree nuts in the international market. This, coupled with the need to conserve the species in the face of aggressive deforestation (Okafor, 1985), has necessitated the need to bring shea butter tree to regular cultivation culture as a plantation crop (Popoola and Tee, 2001; Ugese *et al*., 2005). For effective management of seedlings for such enterprise, influence of differing watering intervals on seedling performance needs to be assessed across different accessions. This study was therefore undertaken to test the response of different accessions of shea butter tree seedlings to watering intervals.

Materials and Methods

Naturally abscised shea butter tree fruits were collected from nine locations as part of a wider study in July, 2006. The locations covered the southern guinea savanna, northern guinea savanna and the Sudan savanna, identified as the major shea butter tree belt in Nigeria (Keay, 1989). The fruits were depulped and the nuts (seeds) washed in water before planting (Awoleye, 1995). For this study however, only seeds from five locations namely, Makurdi, Minna, Jalingo, Yola and Kano were used. Mean nut weights were 10.1g (Makurdi), 13.8g (Minna), 19.5g (Jalingo), 11.8g (Yola) and 12.0g (Kano).

Seeds were sown on July 28, 2006 at a depth of 5 cm in perforated 7-litre plastic containers filled with topsoil. The soil was a sandy loam with a pH of 5.2 ($CaCl_2$). Organic carbon, organic matter, total nitrogen and phosphorus content were 0.6%, 1.03%, 0.042% and 8.96 ppm, respectively. Exchangeable bases (in meq/100g of soil) were Ca (3.2), Mg (1.4), K (0.24) and Na (0.50). The CEC of the soil was 24 meq/100g of soil. The experiment was conducted under a nursery shelter at the Teaching and Research Farm of the University of Agriculture, Makurdi (7^o 41´ N, 8^o 37´ E, 97 m above mean sea level). Seedling emergence in *Vitellaria* is not uniform (Ugese *et al*., 2005) therefore, large population of seeds were sown from which uniform seedlings were selected and utilized for this study.

The study was a two-factor experiment comprising three watering intervals and five accessions (obtained from five locations earlier mentioned above), giving rise to 15 treatment combinations. The watering intervals were 3, 6, and 9-day. Three seedlings uniform in height were selected from each accession after 17 weeks from sowing and the watering schedule was imposed for 18 weeks. Before imposing the watering schedules, leaves of seedlings were pruned to only two per seedling to maintain uniformity. Watering was done generously to allow free drainage of water through the perforations at the base of the containers. Each of the 15 treatment combinations was replicated three times and the experiment was laid out as a factorial in completely randomized design (CRD).

After 18 weeks of imposing the watering schedule treatment, plant height (PLHT), seedling girth (SG) (determined at 1.5cm above soil level) and number of leaves (NLEV) were determined. After seedling harvest, leaf area (LA) by squared graph method, shoot length (SL) and root length (RL) (distance between the points of attachment of the shoot to the end of the root) were determined. Thereafter, seedlings were partitioned into leaves, shoots and roots. Fresh weights of leaves (FWL) shoot (FWS), roots (FWR) and total fresh weight of plant (TFW) were taken before oven drying at 70^oC to a constant weight. Dry weights of leaves (LDW), shoot (SDW), roots (RDW) and total plant dry weight (TDW) were determined. Dry matter content was estimated for each seedling and its components as a ratio of the dry weight to the fresh weight multiplied by 100%. Dry matter distribution was calculated as the per cent proportion of the dry weight of leaves, shoot and roots to the total plant dry weight. The dry matter distribution was denoted as LDM %, SDM % and RDM % for the leaves, shoot and roots, respectively. Data collected were subjected to analysis of variance (ANOVA) by means of GENSTAT Discovery edition 2 Release 4.24DE (GENSTAT, 2005).

Results

Main effect of accession and watering intervals: Most of the seedling growth and fresh weight parameters varied significantly ($P < 0.05$) with accession, but not with watering intervals (Table 1). Yola seedlings were the shortest (3.0 cm) while those of Kano were the tallest (5.4 cm). Number of leaves and shoot length were statistically similar across the accessions. A comparison of the other traits revealed that Makurdi provenance recorded least values while the Jalingo accession gave the highest values. Watering intervals significantly ($P < 0.05$) affected only fresh weight of roots (FWR) and total fresh weight (TFW). Watering every 3 days gave significantly higher FWR and TFW while the effects of 6- and 9-day watering intervals were statistically similar.

Accession had significant effect on all dry matter traits except shoot dry matter content (SDMC) and per cent dry matter distribution to the leaves (LDM%) and roots (RDM %) (Table 2). Total dry weight and its components were lowest in Makurdi accession while Jalingo accession recorded the highest values. Photosynthate partitioning to the shoot (SDM %) was highest for seedlings of Makurdi and Jalingo accession compared to the rest. However, TDMC of the Kano seedlings was comparable to that of others except Makurdi which was lower. Watering intervals significantly impacted only on RDW, TDW, LDM% and TDM%. Watering every 3 days produced seedlings with higher RDW and TDW. Values for LDW were higher for the 6- and 9-day watering intervals. On the other hand, watering at the 3- and 6-day intervals favoured per cent total dry matter distribution against watering every 9 days. It is remarkable that more than 70% of the total dry matter of all accessions and watering intervals was partitioned to the roots.

Accession x watering intervals interaction: Variability in growth traits and fresh weight of seedlings of various accessions as influenced by watering intervals is presented in Table 3. The most frequent watering produced taller seedlings among Yola and Kano provenances as opposed to Makurdi. When watered every 3 days, seedlings of Makurdi and Jalingo seed origins produced more leaves which also translated to higher leaf area (LA) values. For most accessions, the least frequently watered seedlings produced the longest roots. A notable exception is the Kano accession which however, seemed to have compensated for the deficiency by giving higher FWR. On a general note, FWR seemed to have been favoured by watering every 3 days. TFW among accessions was high irrespective of watering intervals although Makurdi values were generally lower. Table 4 presents results of interaction between seed source and watering intervals effect on dry matter production and partitioning. LDWs of Minna, Jalingo, Yola and Makurdi provenances did not differ significantly across watering intervals although

Table 1: The main effects of accessions and watering intervals on growth and fresh weight of *Vitellaria* seedlings

Accession	PLHT (cm)	NLEV	LA (cm)	SG (cm)	SL (cm)	RL (cm)	FWL (g)	FWS (g)	FWR (g)	TFW (g)
Makurdi	4.6	5.1	14.1	0.23	10.9	78.5	1.3	0.72	6.1	8.1
Minna	3.9	4.7	22.4	0.30	11.1	85.6	2.3	1.07	11.3	14.7
Jalingo	4.9	4.0	34.6	0.32	12.7	111.9	3.4	1.67	12.6	18.3
Yola	3.0	4.6	19.9	0.29	9.7	80.6	2.1	0.92	8.4	11.5
Kano	5.4	5.4	14.8	0.28	10.5	99.8	2.1	1.03	11.2	13.8
LSD(0.05)	1.0	NS	4.0	0.03	NS	20.4	0.6	0.37	2.2	2.5
Watering intervals (days)										
3	4.8	5.0	22.2	0.28	10.7	85.5	2.1	1.05	11.6	14.5
6	4.1	4.3	20.6	0.30	11.2	92.0	2.3	1.03	8.5	11.8
9	4.3	4.9	20.8	0.27	11.1	96.4	2.4	1.17	9.6	13.4
LSD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	1.7	1.9

PLHT=Plant height; NLEV=Number of leaves; LA=Leaf area; SG=Stem girth; SL=Shoot length; RL=Root length; FWL=Fresh weight of leaves; FWS=Fresh weight of shoot; FWR=Fresh weight of roots; TFW=Total fresh weight; NS – Non-significant.

Table 2: The main effects of accession and watering intervals on dry matter yield and distribution of *Vitellaria* seedlings

Accession	LDW (g)	SDW (g)	RDW (g)	TDW (g)	LDMC %	SDMC %	RDMC %	TDMC %	LDM (%)	SDM (%)	RDM (%)
Makurdi	0.5	0.24	2.6	3.3	38.3	36.3	42.7	40.9	15.6	7.5	78.3
Minna	1.0	0.42	5.4	6.8	45.8	41.2	47.7	46.8	15.5	6.1	78.3
Jalingo	1.8	0.70	6.7	9.2	52.5	40.6	53.7	50.3	20.2	7.6	71.8
Yola	0.9	0.37	4.4	5.7	45.1	42.5	52.0	49.0	16.3	6.4	77.7
Kano	1.1	0.47	5.6	7.1	46.4	48.5	50.2	51.6	15.8	6.8	79.4
LSD(0.05)	0.4	0.13	1.1	1.5	7.0	NS	5.9	6.2	NS	1.0	NS
Watering intervals (days)											
3	1.0	0.47	5.9	7.4	44.3	45.3	50.6	50.5	13.8	6.7	78.9
6	1.1	0.41	4.4	5.9	47.7	42.7	50.7	49.1	18.5	7.2	75.2
9	1.1	0.43	4.5	6.0	44.9	37.3	46.4	43.6	17.8	6.8	77.1
LSD(0.05)	NS	NS	0.8	I.I	NS	NS	NS	4.8	3.4	NS	NS

LDW=Leaf dry weight; SDW= Shoot dry weight; Root dry weight; TDW= Total dry weight; LDMC=Leaf dry matter content; SDMC=Shoot dry matter content; RDMC=Root dry matter content; TDMC=Total dry matter content; LDM%= Leaf dry matter distribution; SDM%=Shoot dry matter distribution; RDM%=Root dry matter distribution; NS – Non-significant

Table 3: Interaction effect of accession and watering intervals on growth characteristics and fresh weight of *Vitellaria* seedlings

Accession	Watering intervals (days)	PLHT (cm)	NLEV	LA (cm)	SG (cm)	TSL (cm)	TRL (cm)	FWL (g)	FWS (g)	FWR (g)	TFW (g)
Makurdi	3	3.5	6.0	21.4	0.25	9.9	74.0	1.6	0.8	6.2	8.6
	6	5.5	4.3	8.4	0.23	11.0	67.6	1.1	0.7	5.3	7.0
	9	4.7	5.0	12.4	0.20	11.8	94.0	1.3	0.7	6.8	8.8
Minna	3	3.9	4.0	22.4	0.30	12.5	81.5	2.0	1.3	14.4	17.6
	6	3.3	5.3	25.9	0.30	12.3	75.5	3.1	1.1	8.5	12.7
	9	4.7	4.7	19.0	0.30	8.5	99.8	1.9	0.8	10.9	13.7
Jalingo	3	4.4	5.0	38.1	0.32	10.3	107.5	3.6	1.4	14.4	19.7
	6	4.0	3.0	29.9	0.31	12.1	118.5	3.2	1.4	12.4	16.9
	9	6.3	4.0	35.8	0.33	15.7	109.8	3.5	2.2	10.9	18.4
Yola	3	4.8	5.0	21.6	0.30	11.4	64.8	2.4	1.0	9.4	13.1
	6	2.5	3.0	18.2	0.30	9.5	65.5	1.3	0.9	7.3	9.5
	9	1.8	5.7	19.8	0.26	8.2	111.7	2.7	0.9	8.5	12.0
Kano	3	7.2	5.0	7.3	0.25	9.3	99.7	0.9	0.8	13.8	13.8
	6	5.0	6.0	20.5	0.33	11.0	133.0	2.9	1.1	9.1	13.1
	9	4.8	5.3	16.8	0.26	11.4	66.8	2.6	1.2	10.7	14.4
LSD(0.05)		1.8	1.8	6.9	NS	NS	35.3	1.0	NS	3.7	4.3

PLHT=Plant height; NLEV=Number of leaves; LA=Leaf area; SG=Stem girth; TSL=Total shoot length; TRL=Total root length; FWL=Fresh weight of leaves; FWS=Fresh weight of shoot; FWR=Fresh weight of roots; TFW=Total fresh weight; NS – Non-significant

Makurdi values were comparatively lower. Similar pattern of lower values for the Makurdi accession were observed for SDW. For most accessions, watering at 3-day intervals resulted into seedlings with the highest TDW values. Most dry matter traits of the Kano accession were favoured by the 6- and 9-day watering intervals. The Minna accession however, showed a strong tendency to do better under the 3- and 6-day watering intervals. Dry matter distribution to the leaves (LDM %) varied with accession across watering intervals. Seedlings of Kano and Minna seed origin had the lowest

Table 4: Interaction effect of accession and watering intervals on dry matter yield and distribution of *Vitellaria* seedlings

Accession	Watering intervals (days)	LDW (g)	SDW (g)	RDW (g)	TDW (g)	LDMC %	SDMC %	RDMC %	TDMC %	LDM (%)	SDM (%)	RDM (%)
Makurdi	3	0.6	0.3	2.8	3.7	36.9	38.9	44.9	43.1	17.3	8.0	74.6
	6	0.5	0.2	2.2	2.9	44.8	41.0	43.1	41.2	16.7	8.3	80.2
	9	0.4	0.2	2.7	3.4	33.3	29.0	40.2	38.5	12.9	6.0	80.2
Minna	3	0.9	0.6	7.3	8.9	49.1	44.3	51.4	50.7	10.4	6.5	83.0
	6	1.4	0.4	4.3	6.1	42.8	47.6	50.4	49.6	22.0	7.1	69.8
	9	0.8	0.3	4.5	5.5	45.6	31.7	41.1	40.1	14.0	4.7	81.9
Jalingo	3	1.9	0.6	7.2	9.7	51.9	37.2	51.3	50.3	19.5	6.1	70.6
	6	1.7	0.6	6.8	9.1	52.0	43.9	54.9	53.4	18.7	6.5	74.8
	9	1.9	0.9	6.0	8.8	53.7	40.7	54.8	47.3	22.5	10.3	70.1
Yola	3	1.0	0.5	5.1	6.6	41.6	55.8	53.9	50.4	15.2	7.6	77.2
	6	0.6	0.3	3.9	4.8	46.7	33.6	53.6	50.5	12.6	6.3	81.6
	9	1.2	0.3	4.2	5.6	47.1	38.0	48.5	46.2	21.2	5.3	74.5
Kano	3	0.5	0.4	7.1	8.0	42.2	50.5	51.5	58.1	6.4	5.0	89.3
	6	1.5	0.5	4.6	6.6	52.2	47.7	51.6	50.8	22.5	7.6	69.8
	9	1.2	0.5	5.1	6.6	44.9	47.2	47.6	45.8	18.6	7.7	79.1
LSD(0.05)		0.6	0.2	1.9	2.5	12.1	NS	NS	NS	7.7	1.8	NS

LDW=Leaf dry weight; SDW= Shoot dry weight; Root dry weight; TDW= Total dry weight; LDMC=Leaf dry matter content; SDMC=Shoot dry matter content; RDMC=Root dry matter content; TDMC=Total dry matter content; LDM%= Leaf dry matter distribution; SDM%=Shoot dry matter distribution; RDM%=Root dry matter distribution; NS: Non-significant

proportion of their photosynthates allocated to the leaves. Watering intervals however, could not influence RDM% and TDM% across accessions.

Discussion

Variability of the accessions in seedling growth, fresh weight and dry matter yield and distribution could be due to differences in seed weight. In an earlier study, Ugese *et al*., (2007) found better seedling growth among seeds of higher weight classes which was attributed to a higher amount of food reserves. In the present study, Makurdi seeds were the smallest (10.1g) while those of Jalingo were the largest (19.5g), hence the superior growth performance of seedlings of Jalingo source.

Plant height varied with accession but total shoot length did not. This could be explained by the length of shoot that is buried underground relative to the length above ground. In *Vitellaria*, not all the shoot is seen above ground due to the peculiar nature of its germination, described as cryptogeal (Jackson, 1968). Interestingly, the portion of shoot that is buried underground could still vary even if seeds were sown at the same depth (Ugese *et al*., 2005). In this study, plant height referred to the portion of shoot above ground level while TSL comprised both the above and below ground portions.

Watering every 6 and 9 days appeared to have imposed some stress on the seedlings with the latter treatment giving more stress. Between January and February, seedlings receiving water every 9 days experienced total leaf drop except the Yola accession that still had 33% of its seedlings retaining their original leaves. Seedlings watered every 6 days were observed to exhibit loss of turgor for the same period although about 30% of seedlings of Yola accession experienced leaf drop. It is possible that the stress was aggravated by the harmattan winds that were very severe that season. Seedlings that experienced total leaf fall were however able to develop new leaves that expanded rapidly. *Vitellaria* seedlings have been reported to possess the ability to recover quickly from fire hazards (Jackson, 1968) and may have shown similar response in this case. It is apparent that the sudden absence of leaves may have constituted a threat to the survival of the seedling which needed photo-assimilate from the leaves, the main organs of photosynthesis. As such, growth resources from the well established roots were mobilized and exported to the shoot to ensure the formation of new leaves and their expansion at rates that surpassed those of the original leaves. This may explain why the 9-day watering intervals, while maintaining LDW values at comparable levels (in most cases) had lower values of RDW (Table 4).

Seedlings watered every 6 days behaved similarly even though they did not largely experience leaf fall. However, their loss of turgor may have been an indication of less than sufficient water levels for the photosynthetic process to proceed at optimal levels (Roberts, 1976). The more favourable levels of per cent total dry matter distribution under the 3- and 6-day watering intervals could still be explained on the basis of relative water availability. That Kano seedlings appeared more tolerant to water stress could suggest an ability to thrive better in drier environments. The slightly different pattern adopted by seedlings of Minna provenance could point to better performance under moist climates. The rest of the accessions may be less discriminative of habitats based on their moisture status.

The skewed dry matter distribution in favour of the roots (>70%) is viewed as an adaptation to survival in the extended dry period characteristic of savanna climates. Generally, *Vitellaria* root is known to grow to a reasonable extent before the shoot develops and emerges above ground (Jackson, 1968). Dry matter distribution as obtained in the shea butter tree contrasts sharply with results obtained by Baiyeri (2003) in cashew (*Anarcadium occidentale* L.) and African breadfruit (*Treculia africana* Decne) where dry matter allotted to the root was in the range of 13 - 22% and 14.5 - 18.7%, respectively. In both species greater proportion of the dry matter was partitioned to the leaves. That the least frequently watered seedlings had the longest roots may well be an adaptation to the savanna (dry) environment.

In conclusion, this study has shown that in most seedling traits considered, the Jalingo accession performed significantly better than the others, probably due to the heaviness of its seeds. The Makurdi accession with the least seed weight, gave the least performance; the other accessions maintained a more or less intermediate performances. Watering intervals had no severe effect on seedling growth although watering every 3 days appeared more promising. The differing performance of the accessions under the different watering intervals may be indicative of possible areas of adaptation of the accessions. It is however possible that the intensity of the harmattan winds influenced the result reported herein.

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