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Expressions of macronutrient deficiency in seedlings of the shea butter tree (*Vitellaria paradoxa* C. F. Gaertn.)

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Macronutrient deficiencies on shea seedling growth, dry matter attributes and foliar properties were investigated at Makurdi, Nigeria, in 2007 – 2008. There were seven (7) treatments consisting of a complete nutrient solution and complete nutrient solutions less each of N, P, K, Ca, Mg and S. Results showed that deficiency of all the nutrients resulted in plants with smaller leaf areas. Seedlings starved of N, P and K produced fewer leaves. Dry matter content of normal seedlings was generally higher than that of nutrient deficient seedlings except for S. Deficiency of all the nutrients markedly reduced total dry matter produced. Seedlings grown in N and P deficient sand culture were stunted while deficiency of all nutrients except Ca produced some noticeable foliar colour change. Deficiency of each nutrient led to an imbalance in foliar nutrient concentration

Key words: Macronutrient, deficiency, shea seedlings, *Vitellaria paradoxa*, nutrient

Running Title: solutions, growth, morphology, dry matter.

Introduction

The shea butter tree, *Vitellaria paradoxa*, also widely known by its synonym *Butyrospermum parkii* is a popular species on the African continent. This popularity stems from the variety of uses to which the plant and its products can be put. For instance, the oil, known as shea butter, is used for cooking for which the plant is considered the second most important source of cooking fat after oil palm, in Africa (ICRAF, 2000). It is also used for pomade, candle and soap production (Awoleye, 1995). The nutritional value of the fruit pulp has been reported (Maranz *et al*., 2004; Ugese *et al*., 2008 a, b). The use of various parts of the plant in traditional human and animal medicine has been well documented (ICRAF, 2000; Popoola and Tee, 2001).

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In Europe and Japan, the butter, imported from Africa is used mainly in the food and cosmetic industries (Umali and Nikiema, 2002). The presence of vitamins E and other acids in shea butter makes it able to maintain a healthy skin, preventing premature wrinkles (FAO, 2006).

The invaluable contribution of the shea tree to meeting diverse human needs has made a case for its inclusion among species identified for domestication in the tropics (Leakey, 1999; Leakey *et al*. 2005). Under cultivation, *Vitellaria* would require more serious attention to cultural practices including fertilizer application. The reported slow growth rate of the species (Jackson, 1968) is an added impetus to fertilization. However, for the effective correction of nutrient imbalances, an understanding of nutrient deficiency symptoms is imperative (Chweya, 1982). For every species and nutrient, expression of deficiency is specific (Wallace, 1961). Since work of this nature has not been reported for *Vitellaria*, we decided to investigate the effect of macronutrient deficiencies on seedling growth and dry matter distribution, seedling morphology and foliar nutrient composition of shea seedlings.

Materials and methods

Seeds of the shea butter tree, *Vitellaria paradoxa* obtained from fruits collected from Jalingo, Nigeria, were planted in 7-litre plastic containers filled with acid - washed river sand in 2007. Since seedling emergence in *Vitellaria* is not always uniform, a larger number of seeds were sown from which more uniform seedlings were later selected for this study.

Treatments imposed on the seedlings 14 weeks after sowing included the following: complete nutrient solution, complete nutrient solution less each of the following macro nutrient elements – nitrogen, phosphorus, potassium, calcium, magnesium and sulphur. The experiment was a completely randomized design (CRD) replicated four times with each pot containing one seedling and representing a replicate.

The macro nutrient composition of the nutrients was based on Nwoboshi *et al.* (1982, 1987) and is shown in Table 1. In addition, a basal micro nutrient solution consisting of Fe (5 ppm) B (0.54 ppm), Mn (0.54 ppm), Cu (0.064 ppm), Zn (0.065 ppm), Mo (0.48 ppm) and Co (0.12 ppm) was added to each solution. Preparation of solutions and watering of seedlings were done with distilled water. The pH of each solution was adjusted to 6.5 (Nwoboshi *et al.,* 1982, 1987). Treatment solutions were applied to the seedlings every other day at the rate of 200mls per pot while watering with distilled water was done freely every other day. The leachates were not recycled.

Table 1. Macronutrient composition of the nutrient solutions* applied to shea seedlings

Stock solutions (g/l)	Nutrient solution						
	Complete	**-Nitrogen**	**-Phosphorus**	**-Potassium**	**-Calcium**	**-Magnesium**	**-Sulphur**
KNO_3 (202)	+		+		+	+	+
$Ca(NO_3)_2$ (328)	+		+	+		+	+
$CaCl_2$ (222)		+					
K_2SO_4 (174)		+					
$MgSO_4.7H_2O$ (184)	+	+	+		+		
$Na_2SO_4.10H_2O$ (161)			+	+		+	
NaNo (340)					+		
$Mg(NO_2)_2.6H_2O$ (340)				+			+
$NaH_2PO_4.2H_2O$ (208)	+	+		+	+	+	+

* 1 ml of stock per 1 litre of treatment solution.

The experiment was located under a green polythene shade (Baiyeri, 2006) at the Teaching and Research Farm of the University of Agriculture Makurdi (7.41^{0}N, 8.37^{0}E and 97m above sea level). Seedlings were monitored weekly for changes in morphology and colour. The Royal Society of Horticulture Colour Charts was used to aid colour description. At the end of 12 weeks of imposing the nutrient solutions, the plants were harvested. Parameters determined were plant height, total shoot length, seedling girth, linear dimensions of leaf, and root length. Fresh and oven dry weights of component plant parts: root, shoot and leaf were taken. From this, dry matter content and distribution were estimated. Leaf area was calculated from linear dimensions of length and width using the model developed by Ugese *et al*. (2008c) as follows:

$LA = 4.41 + 1.14\ LW$

Where

LA = leaf area (cm^2)

LW= product of length and width of leaves.

Oven dry samples of leaves were ground for laboratory determination of elements. Ground samples were digested in an acid mixture of 1$HCLO_4$: IHNO_3. Aliquots of digested samples were used for the actual determinations. Thus N was determined using the macro- Kjedahl method (Black, 1965). Phosphorus was estimated by the ascorbic acid method while Ca and Mg were determined by the EDTA method. Flame photometry was employed for estimation of K, while S was analyzed for using turbidimetric method (Hart, 1961).

Data collected were subjected to analysis of variance (ANOVA) using GENSTAT Discovery edition 3, Release 7.2DE (GENSTAT, 2007) while means were separated by means of F-LSD.

Results

Seedling growth response to macro nutrient deficiencies: The growth response of seedlings to macronutrient deficiencies is summarized in Table 2. The deficiency of nitrogen, phosphorus and potassium produced plants that had lower number of leaves. On the other hand, the absence of all nutrients considered produced plants with smaller leaf areas, N and P deficiencies giving least values. Seedlings that received complete nutrient solution were statistically taller than others ($P<0.05$) except those that were deficient in Ca. Similarly, seedlings that lacked P and Mg had shoots that were shorter. Stem girth of seedlings that were given complete nutrient solution failed to differ significantly with those whose solutions were deficient in N and Mg. On the other hand, absence of all nutrients resulted into shorter seedling roots except that of P that still produced seedlings of comparable root length with the control.

Table 2. Effect of macronutrient deficiencies on growth of *Vitellaria* seedlings

Nutrient solution	Number of leaves	Leaf area (cm^2)	Plant height (cm)	Total shoot length (cm)	Stem girth (cm)	Total root length (cm)
Complete	5.7	29.2	6.3	13.0	0.32	71.3
– Nitrogen	4.3	13.5	5.2	11.8	0.25	54.8
– Phosphorus	3.7	12.9	4.0	10.5	0.29	73.7
– Potassium	4.5	20.0	5.4	11.4	0.31	48.3
– Calcium	4.7	24.2	5.9	12.2	0.32	59.3
– Magnesium	4.8	15.0	3.4	10.1	0.26	48.5
– Sulphur	5.5	19.5	5.2	11.1	0.29	31.5
$LSD_{(0.05)}$	1.3	3.5	1.0	2.2	0.05	7.2

Dry matter yield and distribution of the seedlings as influenced by the treatments is presented in Table 3. Total dry weights of seedlings were negatively affected by deficiencies of N, P, K and Mg. It was remarkable that absence of all nutrients investigated markedly reduced total dry matter content of seedlings, that of N being the most severe. The only exception was the absence of S, which did not impact negatively on total dry matter content. Dry matter content of shoot was significantly reduced by absence of each of the elements.

Table 3. Dry matter yield and distribution pattern of *Vitellaria* seedlings as influenced by nutrient solution

Nutrient solution	Total dry weight(g)	Total dry matter content (%)	Dry matter content of leaves (%)	Dry matter content of stem (%)	Dry matter content of root (%)	Dry matter distribution to the leaves (%)	Dry matter distribution to stem (%)	Dry matter distribution to the roots (%)
Complete	5.7	45.8	61.7	47.5	44.0	13.0	10.2	77.4
– Nitrogen	3.0	28.7	52.2	37.7	25.7	12.5	11.6	75.8
– Phosphorus	3.3	34.7	48.2	34.9	33.5	11.4	9.3	79.4
– Potassium	4.4	34.6	43.1	36.4	33.4	12.6	9.8	77.6
– Calcium	5.6	39.7	46.0	39.9	38.8	12.5	8.9	78.7
– Magnesium	3.5	37.9	50.0	40.8	34.5	13.5	10.8	72.5
– Sulphur	5.6	41.6	42.1	39.4	41.1	13.1	9.9	77.0
$LSD_{(0.05)}$	0.6	5.0	7.4	6.5	6.1	NS	1.7	NS

Dry matter partitioning to the different plant parts was significantly influenced only in terms of allocation to the shoot. In this case absence of Ca tended to have influenced less dry matter to the shoot, comparatively. In general, dry matter partitioning to the leaves and roots ranged from 11.4 – 13.5%, and 72.5 –79.4% respectively.

Morphological deficiency symptoms

Deficiency of various nutrients elicited various morphological responses in the seedlings. Stunting of N deficient seedlings was noticed about 3 weeks after application of nutrient solutions to the seedlings. Formation of new leaves was not observed during the treatment period. Younger leaves that occurred prior to nutrient application remained so, failing to expand further. As deficiency advanced, they tended to register some pale green colouration at the edges of the lamina. Generally, at the on-set of treatment, older leaves began to appear pale green, some brownish spots being noticed in the later weeks after imposition of treatment.

Similarly, with P deficiency, stunting of seedlings was noticed even at the early stage and persisted to the end of the experiment. Yellowing of older leaves was noticed at the edges of the lamina and spread inwards with advance of the deficiency. However, the mid rib and portions of the leaf close to the petiole remained green.

Seedlings deficient in K started showing what looked like interveinal chlorosis, beginning with first formed leaves. Later, entire leaves appeared chlorotic or yellowish. Tip burn was also observed on some older leaves.

Deficiency of Ca however, was not detected on the appearance of the seedlings especially as regards colour change.

Absence of Mg in solution did not produce striking symptoms at first. However, with the passage of time, older leaves began to appear light green. Towards the end of the experiment, they were yellow to light green in colour.

Marginal scorching, beginning from leaf tips and spreading to the lower margins became evident.

Deficiency of sulphur also did not manifest so early. First signs of deficiency were patches of the leaf lamina becoming yellow or chlorotic. Later, chlorotic mottling appeared to be more visible. However, younger leaves remained more or less greenish.

Generally, dark spots were observed on leaves of seedlings across treatments especially in March and early April when temperatures are normally very high in Makurdi.

Foliar nutrient composition: Foliar nutrient properties of shea seedlings grown in complete and deficient nutrient solutions are presented in Table 4. Deficiency of each nutrient caused significant reduction in amount of that nutrient in the foliage of seedlings. In addition, deficiency of each nutrient resulted in either abnormal or subnormal level of one or more other nutrients.
For instance, deficiency of N led to subnormal levels of K but accumulation of S. Similarly, P deficiency resulted in subnormal amount of N, K and Mg but abnormally higher amount of Ca and S. When K was lacking, seedlings had lower levels of N and P but higher amounts of S than healthy seedlings. Calcium deficiency resulted into seedlings with lower levels of N and Mg but accumulated amount of P. Deficiency of Mg caused subnormal levels of N. It was however remarkable, that N levels in Mg deficient seedlings were significantly higher than all the other nutrient deficient seedlings and second only to that in the healthy seedlings. With S deficiency, subnormal levels of N and Ca were observed, though accumulation of any macro element was not detected.

Table 4. Foliar nutrient composition of *V. paradoxa* seedlings fed various nutrient deficient solutions

Nutrient Solution	**Nitrogen**	**Phosphorus**	**Potassium**	**Calcium**	**Magnesium**	**Sulphur**
			% of plant dry weight			
Complete	2.38	0.14	0.23	0.80	0.31	0.10
– Nitrogen	1.82	0.15	0.16	0.84	0.31	0.22
– Phosphorus	1.68	0.08	0.18	0.92	0.26	0.14
– Potassium	1.82	0.11	0.20	0.08	0.29	0.14
– Calcium	2.10	0.20	0.25	0.56	0.26	0.12
– Magnesium	2.24	0.16	0.22	0.84	0.25	0.12
– Sulphur	2.10	0.16	0.20	0.48	0.29	0.09
$LSD_{(0.05)}$	0.09	0.02	0.04	0.05	0.03	0.02

Discussions

Deficiency of macro nutrients led to some more or less distinct foliar appearance and growth response. The suppression of growth by the absence of most of the nutrients is in general conformity with results obtained with some forest tree species (Nwoboshi *et al.* 1982, 1987). The reduced plant growth could be ascribed to low chlorophyll content as a result of low nitrogen levels. It was interesting that deficiencies of all the nutrients led to varying degrees of subnormal concentration of nitrogen in the leaves. Low chlorophyll content is normally associated with low N content (Keller and Koch, 1964) which implies reduced photosynthetic rates and ultimately growth.

The absence of any foliar colour change occasioned by lack of Ca in solution contrasts with reports by Nwoboshi *et al.* (1982) in gedunohor, *Enthandrophragma angolense* and Chweya (1982) in Kale, *Brassica olercea*. However, such observations of lack of colour change may be indicative of differential response of species to particular nutrients. For instance, Nwoboshi *et al.* (1982) in the work cited did not obtain any visible morphological change with absence or deficiency of P. They however observed changes with P deficiency in seedlings of *Terminalia superba* (Nwoboshi *et al.* 1987). Similarly, Chweya (1982) did not detect any visual, external or internal symptoms from Mg and Fe deficiencies.

The first appearance of deficiency symptoms of N, P, K and Mg on older leaves is attributed to the relative mobility of the elements within the plant. Thus, elements that are highly mobile normally manifest their symptoms in the older leaves from where they are exported to the younger ones. The opposite trend seems to be the case with less mobile nutrients such as Ca and S. However, in this study, deficiency of Ca was also seen on older leaves. Chweya (1982) also observed yellowing of older leaves of *Brassica olerace* when Ca was deficient.

Deficiency symptoms of nutrients on *Vitelleria* seedlings were not exactly the same with those reported for other species. For instance, P deficiency here caused yellowing of the edges of the leaf lamina while the mid rib remained green. Deficiency of same nutrient in *Terminalia superba* caused older leaves to turn purplish with apical and marginal scorches (Nwoboshi *et al.*, 1987). In *Brassica oleracea*, P deficiency did not produce any foliar colour change (Chweya, 1982). Similar observations could be made with foliar chemical composition characteristics. This serves to reinforce the observation that visual and chemical characteristics of nutrient deficient plants vary with species and mineral nutrient (Wallace, 1961). The appearance of dark spots on the leaves of seedlings during the hot period could be a physiological response to heat stress.

Foliar nutrient imbalances as a result of specific deficiencies underscore the need for balanced nutrition for shea tree seedlings. This could enhance physiological efficiency and higher growth performance.

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