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Effects of nutrient deficiencies on the growth potential and vigour of *khaya senegalensis* (desr.) A. Juss. seedlings in South West Nigeria Nursery

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Abstract

Successful afforestation and reforestation projects are dependent on various factors, but the quality of seedlings placed in the field is extremely important as fertile growth medium contributes to seedling vigour in the nursery. The study investigated the nutrient requirements for optimum growth of *K. senegalensis* and their deficiency symptoms in a bid to enhance vigorous seedlings. One-month-old seedlings of *K. senegalensis* were transplanted to polythene pots filled with washed and sterilized 4kg river sand for application of different nutrient solutions (NS). Treatments include Deionized water [No nutrient (control)] (T1), Standard NS of known nutrient concentration (complete nutrients) (T2), NS lacking K (T3), NS lacking Ca (T4), NS lacking Mg (T5), NS lacking N (T6), NS lacking P (T7), NS lacking S (T8) and NS lacking Fe (T9) in ten replicates laid in a complete randomized design. Visual deficiency symptoms were observed and recorded based on unusual growth patterns and coloration. Data on seedling height, stem diameter and number of leaves were collected and subjected to analysis of variance (ANOVA). The symptoms on T6 were first observed three weeks after transplanting when the older leaves changed colour to pale green. T7 older leaves and Stems turned to dark green and had stunted growth. Curling of leaf tips, brown scorching and chlorosis were observed in T3. There were significant differences among the treatments in growth variables at ($P< 0.05$). It is found that different components of nutrient solution play significant roles in the growth and development of *K. senegalensis* seedlings. For optimum growth and development, planting of *k. senegalensis* seedlings in nutrient-rich soil are recommended.

Keywords: Growth variables, Nutrient concentration, Deficiency, Growth medium, Afforestation

1. Introduction

Establishing forest plantations to compensate the dwindling timber source from natural forests has been identified as a way to mitigate against the negative impact of climate change [1]. Shortage of timber supply and the long gestation period had initiated the search for potential fast-growing species [2]. Several exotic species among which are *Acacia mangium*, *Paraserianthes falcataria*, *Tectona grandis*, *Gmelina arborea and Morinda citrifolia* to mention a few were introduced for the establishment of short-rotation forest plantation towards prompt returns from the investment [3]. The genus *Khaya* belongs to the family Meliaceae, originating from Senegal in Africa, the family comprises 51 genera covering 1.400 species, 60% of which are part of the forest economy of various countries. The genus *Khaya* spp. is known by many authors as African mahogany [2]. The Meliaceae family is highly sought after by the furniture industries. The wood is of fine-quality, with great economic potential on the domestic and international markets, and can be used in the furniture and naval industries, in civil construction, and for producing panels, laminates, cabinets, superior joinery and other decorative works among other uses [4]. Wood of the genus *Khaya* is highly valued on the international market; one cubic metre of native logs can fetch approximately USD 1000, according to import and export records for different wood products of the genus [1]. In some part of Africa continent, it is used in treatment of malaria and some other ailments [5]. More so, mahogany is still one of the most exploited species in the country, and as such, is threatened with extinction, as renewal of the native tree is not in proportion to its exploitation [6]. The need to invest in developing research into the production of mahogany seedlings for the purposes of reforestation is therefore essential [4]. The success of afforestation and reforestation projects depends on various factors, but the quality of seedlings placed in the field is extremely important [6]. In order to achieve this, optimum knowledge about silvicultural management of the species is required. Most single or intercropped species fail due to problems related to the growing conditions, including seedling quality [7]. The nutrition level of soils greatly influences the development of seedlings and the need for and type of fertilizer application depends on the nutrient content of the soil [8]. Tree crops require adequate supply of all essential minerals so as to grow properly otherwise the growth will be distorted. By and large, one of the ways through which growth distortion can be averted is by fertilizer application to the seedlings which is a useful tool in the improvement of growth rate and development of the plant species. However, because of the variation in nutritional requirements of different plant species, in-depth study must be carried out on *Khaya senegalensis* to ascertain the type of fertilizer, rate of application and quantity required. Fertilising plants with nutrient solution have increasingly been used in the nutritional management of forest species, aiming to optimise the use of inputs and plant growth under different cropping systems with minimal waste to the environment [9]. Nutrient solutions also have a wide application in studies of plant physiology, with a view to studying and correlating the presence and concentration of mineral nutrients with the processes that coordinate plant growth [10]. According to [11], adding the complete nutrient solution formulated is a promising technique for the initial formation of forest plants in the greenhouse. Another strategy for identifying nutritional requirements is to determine the ideal concentration for promoting the best uptake, distribution and use of nutrients, and their effects on growth variables and of dry matter partitioning on the mineral composition of plant roots, stem and leaves [10]. Among the most-used organs to estimate the nutritional status of plants is the leaf. It is the most important as the seat of metabolism, responsible for the production of photo assimilates, reflecting nutritional changes in its composition, and expressing the symptomatic effects of nutrient status in its colouration [11; 12; 13]. The importance of establishing healthy stands of forest tree species nurtured from the seedling stage cannot be overemphasized and, in most cases, healthiness of the seedlings is been determined by presence of required mineral nutrients. However, there are dearth of information on macro and micro nutrients requirement at the nursery stage of *Khaya senegalensis*. This study therefore investigated nutrient requirement for optimum growth of *K. senegalensis* and their deficiency symptoms in a bid to enhancing vigorous seedlings towards actualization of healthy *K. senegalensis* plantation

2. Materials and Methods

The study was carried out in the screen house of Forestry Research Institute Nigeria, Ibadan Oyo State. It is located on longitude 07°23′18″ to 07°23′43″N and Latitude 03°51′20″ to 03°23′43″E. The temperature of the screen house ranged from 27 to 34 °C, light intensity at 22% penetration and relative humidity at between 65 and 77%. River sand was collected, washed and sieved to remove debris and large clay particles with a 2mm sieve. It was thereafter sterilized to remove organic matter and nutrient residues. The sterilized sand was then tested for residual acid and chloride. The pH and nutrient concentrations of the river sand were examined prior to applications (Table 1.1). The sterilized washed river sand was then filled into 8 × 15 cm polythene pot for application of different nutrient solutions. One-month-old uniform seedlings of *Khaya senegalensis* were transplanted to polythene pots filled with 4kg sand soil. Seedlings were supplied with standard nutrient solution of known nutrient concentration for 10 days before treatment application

Table 1.1: pH and nutrient concentrations of river sand prior to the treatment applications

Treatment	pH	Organic C (%)	N (%)	Avail P (mg kg-1)	K	Ca	Mg
Unwashed river sand	5.5	0.21	0.02	0.95	0.002	0.21	0.011
Sterilized/washed sand	5.1	ND	ND	0.23	ND	ND	ND

Key: ND = Not detectable

Plate 2.1: Application of Nutrient solution at different to the seedlings of *K. senegalensis*

The treatments applied to the seedlings in the polythene pots are as follows (Table 2.1): (1) Deionized water [No nutrient (control)] (T1); (2) Standard nutrient solution of known nutrient concentration (complete nutrients) (T2); (3) Nutrient solution lacking K (T3) ;(4) Nutrient solution lacking Ca (T4); (5) Nutrient solution lacking Mg (T5) ;(6) Nutrient solution lacking N (T6) ;(7) Nutrient solution lacking P (T7) ;(8) Nutrient solution lacking S (T8); (9) Nutrient solution lacking Fe (T9).

Each treatment is replicated ten times and laid out in a complete randomized design. The visual deficiency symptoms as observed at interval were recorded based on unusual growth patterns and coloration.

Measurements of seedling height, stem diameter and number of leaves were made fortnightly for 6 months after which the dry mater of each treatment was determined. In order to the dry mater, Leaves stem and root of the selected seedlings of the species were excised with a sharp razor blade. The leaves of the species were separately gathered so also the stems and roots. Their fresh weights were determined using a Sensitive Weighing Balance for Biomass estimation of *A. africana* and then oven dried to constant weight for twenty-four hours at 70ºc. The combined weight of the leaves, stems and roots of each specie accounted for the total weight. Data collected on growth variables were subjected to analysis of variance (ANOVA) and Duncan Multiple Range Test was used to separate means where there was significant difference among the treatments.

Table 2.1: Chemical composition of 100 × strength macronutrient stock solutions

Solution	Source	gl^{-1}
Control	Deionized water	None
Complete Macronutrient solution	KNO_3; KH_2PO_4; Ca $(NO_3)_2$; $MgSO_4$ and Fe_2SO_4	1
Minus K	Ca $(NO_3)_2$; $MgSO_4$; NaH_2PO_4; $NaNO_3$; and Fe_2SO_4	1
Minus Ca	KNO_3; KH_2PO_4; (Na_2) SO_4; Mg $(NO_3)_2$ and Fe_2SO_4	1
Minus Mg	KNO_3; KH_2PO_4; Ca $(NO_3)_2$; $(Na_2)SO_4$ and Fe_2SO_4	1
Minus N	KH_2PO_4; $MgSO_4$; KCl; $CaCl_2$ and Fe_2SO_4	1
Minus P	KNO_3; Ca $(NO_3)_2$; $MgSO_4$; KCl and Fe_2SO_4	1
Minus S	KNO_3; KH_2PO_4; $Ca(NO_3)_2$; $MgCl_2$ and Fe_2SO_4	1
Minus Fe	KNO_3; KH_2PO_4; $Ca(NO_3)_2$ and $MgSO_4$	1

3. Results and Discussion

3.1 Visual deficiency symptoms

All the seedlings (T1-T9) were healthy and produced dark green normal shaped foliage at the onset of the experiment probably because of the little nutrient trapped by the seedlings from germination trays prior to its movement to the polythene pot. This is in line with assertion of [11] that seedlings of *Prunus persica* grew healthy for few hours under normal environmental conditions before the plant utilized the applied nutrients.

The symptoms of N deficiency (T6) were first observed at three weeks after transplanting when the older leaves begin to change colour to pale green and became conspicuous two months after transplanting. Towards the end of the experiment, tissue death was observed on leaf edges that move inward. This established the potentials of nitrogen which is absorbed in form of nitrate as major component of proteins, hormones, chlorophyll, vitamins and enzymes essential for plant life [10]. [9] reported that Nitrogen metabolism is a major factor in stem and leaf growth (vegetative growth) and deficiencies can reduce yields, cause yellowing of the leaves and stunt growth.

At the initial stage, the green colouration of the T7 (Phosphorous deficient) plants leaves and Stems (Older leaves) were observed to be turning to dark green and the growth stunted in terms of height compared to other treatments. Later as the experiment progressed, leaves tips turn brown and appear weak, the stem becomes thin and the growth is delayed compared to other treatment which is an indication of P deficient. However, 60% of seedlings in the treatment died off at the end of the six months. Phosphorous is considered second to nitrogen as the most essential nutrient to ensure health and function. Phosphorus is used by plants in numerous processes such as photophosphorylation, genetic transfer, the transportation of nutrients, and phospholipid cell membranes [14]. [9] confirmed in a study on selected vegetables that green leaves turned darker and purplish or red pigment with phosphorus deficiency.

Curling of leaf tips and brown scorching as well as chlorosis between leaf veins were observed in T3 (Potassium (K) deficient) plants after two months of transplanting. Some of the plants upon close observation displayed purple spots on the leaf undersides at the later stage. Plant growth was also observed stunted compared with the treatment treated with complete nutrients. [15] reported that Potassium is often referred to as a quality element for plant production and has proven to have a crucial role in many product quality parameters. Product quality parameters such as fruit size, appearance, color, soluble solids, acidity, vitamin content, taste, and shelf life are affected positively by supplying K in sufficient quantity. These properties are influenced by photosynthesis, translocation of photosynthesis, protein.

Plants which were deprived of Ca (T4) showed symptoms that appeared initially as localised tissue necrosis at the young leaves and the rapidly growing plant tissue part leading to stunted plant growth and eventual death of terminal bud. The presence of brown lesions was evident at later stages in some older leaves. In spite the fact that calcium is a passive element in plant, it functions in the production of plant tissues which enhance better growth. Calcium is responsible for holding together the cell walls of plants. It is also crucial in activating certain enzymes and to send signals that coordinate certain cellular activities [16; 17].

Magnesium deficiency (T5) showed symptoms with interveinal chlorosis, a sign of degraded chlorophyll in the older leaves which stayed green that gave the leaves a marbled appearance was noticed from the second month onwards. This is in conformity with assertion and findings of [9] that Mg is a critical structural component of the chlorophyll molecule and is necessary for functioning of plant enzymes to produce carbohydrates, sugars and fats. [15] reported deficient plants appear chlorotic, show yellowing between veins of older leaves; leaves may droop.

The symptoms observed from the plants that are deficient in Sulphur (S) and Iron (Fe) T8 and T9 are similar to most of the observation above ranging from yellowing and pale green colour of the plants, chlorosis in younger leaves with the tips becoming necrotic which are absent in the older leaves as regards to sulphur and interveinal chlorosis (yellow leaves with green veins) on the young leaves that turns white and scorched outer edges as the experiment advanced in term of Iron. This is in line with the report of [18] that iron deficiency firstly appears with a reduced growth and leaf chlorosis in young leaves and then on older ones associated with alteration of the main metabolic pathways. Its deficiency provokes serious imbalances in the ultra-structure and functionality of chloroplasts, with 90% of Fe present in a leaf localized in the chloroplasts [19; 20]. Sulphur deficiency symptoms in many ways resemble those of nitrogen and iron that is, the leaves become pale-yellow or light-green [18]. Unlike nitrogen, sulphur -deficiency symptoms appear first on the younger leaves, and persist even after nitrogen application. In cotton, tobacco and citrus, some of the older leaves are affected first [18].

3.2 Seedling growth

The summary of treatment effects on the growth of *K. senegalensis* seedlings are shown in Table 3.1. At the end of the study, analysis of variance in terms of height revealed that there were significant differences among the treatments with T2 having separated means of 34.90 cm followed by T4 (29.70 cm) and the least with T1 18.10 cm. In terms of stem diameter, the T2 had the highest means of 3.90 mm, T6 had 3.0mm and T1 had the least (1.80 mm). The treatment 2 also have the highest mean leave production of 14.0, followed by T3 and T4 with 13.0 each while T1 had the least leave production of 2.00. The total dry matter yield was highest in T2 with 3.40g; the T4 had 2.00g while the T1 had the least dry matter yield of 0.5g. The treatment with complete standard nutrient solution of known nutrient concentration (T2) having the best growth development is an indication that each nutrient has specific role being contributed to the normal growth of green plant. This is in accordance to the findings of [13] that complete nutrient solution to growing medium is essential for the optimum growth and development of forest plants in the greenhouse. [21] stated that the use of suitable growing media with presence of essential nutrients affects the development and later maintenance of the extensive functional rooting system. Nursery soil mixtures have been found to influence the quality of seedlings produced [22; 23]. This implies that incorporation of necessary nutrients into the plant growing medium is vital to the healthy growth of such plant.

The percentage increase of growth parameters dry matter between the first two weeks of harvest and at the end of the 6th month of study is presented in 3.2. The treatment with standard nutrient solution (T2) had the highest percentage increase of 67.20%, 83.50%, and 88.44% for height, numbers of leaves produced and the stem diameter respectively. While the T1 had the least of 49.88%, 66.31%, and 65.86% for height, numbers of leaves produced and the stem diameter respectively

Accumulation and improvement of dry matter in plant is the function of several factors that include environmental, biotic and edaphic factors [24]. Dry matter production is a complex process which involves plant dry weight measurement at particular period of time. It increases with plant growth under normal environmental condition [21]. This is enhanced by presence of essential mineral elements/nutrients that encouraged accumulation of carbon as the major component of plant dry matters [25, 26].

Table 3.1: Post hoc analysis on effects of nutrient deficiencies on *khaya senegalensis* seedling growth

Growth	**T1 (Deionized Water)**	**T2 (Std Nutrien)**	**T3 (Minus K)**	**T4 (Minus Ca)**	**T5 (Minus Mg)**	**T6 (Minus N)**	**T7 (Minus P)**	**T8 (Minus S)**	**T9 (Minus Fe)**
Height (cm)	18.10c	34.90a	27.40bc	29.70b	29.0b	24.30bc	29.90b	28.80bc	26.00bc
Stem Diameter (mm)	1.80c	3.90a	3.10a	3.20a	2.90ab	3.30a	2.80ab	2.90ab	2.70ab
No. of Leaves	2.00d	14.00a	13.00a	13.00a	12.00b	9.00bc	9.00bc	10.00bc	11.0b
Total Dry matter Yield (g) ns	0.50d	3.40a	1.80ab	2.00b	1.80ab	1.2c	1.50b	1.50b	1.30b

Means with the same letters in a row are not significantly different ($p > 0.05$)

Table 3.2: Percentage increase of growth parameters' dry matter between the first two weeks of harvest and at the end of the 6th month of study on *Khaya senegalensis* seedling growth

Variables/Treatments	1	2	3	4	5	6	7	8	9
Height									
Initial	10.06	11.56	11.31	12.56	12.5	13.44	12.44	13.13	12.5
Final	20.07	33.3	33.74	38.29	33.85	27.43	23.93	35.14	30.96
% Increase	49.88	67.20	66.47	65.29	63.07	51.00	48.02	62.64	59.63
No. of Leaves									
Initial	3.13	4.00	3.37	3.63	3.90	3.63	3.75	3.88	3.30
Final	9.29	16.43	17.71	20.00	20.00	10.14	9.00	14.58	13.86
% Increase	66.31	83.50	80.89	75.65	80.5	64.20	58.33	73.39	76.19
Stem Diameter									
Initial	1.27	1.21	1.21	1.26	1.26	1.56	1.41	1.29	1.12
Final	3.72	3.74	4.50	4.98	4.03	4.57	3.90	4.02	4.25
% Increase	65.86	88.44	73.11	74.70	68.73	65.86	63.85	67.91	73.65

4. Conclusion

Different component of nutrient solution plays significant roles in the growth and development of *Khaya senegalensis* seedlings. The morphological characteristics of the species were influenced by each elemental nutrient. Each nutrient specifically affects at least growth variables of the species within the period of study. It is inferred that the species will thrive well in nutrients rich soil.

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