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ARTICLE

Growth Medium and Soil Amendment Influence on Seedling Growth Responses of African Star Apple (*Chrysophyllum albidum*)

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ABSTRACT

African Star Apple (*Chrysophyllum albidum*) classified as a forest food tree with economic potentials requires domestication attention for improved productivity. A study conducted in Abeokuta, Nigeria in 2017 using one year old *C. albidum* seedlings determined the plant's growth responses when cultivated using different growth medium and soil amendment methods. The 3 x 9 factorial experiment was arranged in a Completely Randomized Design (CRD) at three replications. Three textural soil types (sandy, loamy and clayey soils) were evaluated using nine soil amendment methods (5, 10, 15t/ha poultry manure (PM) and 150, 250 and 500kg/ha NPK, and integrated amendment methods using 5t/ha PM+150kg/ha NPK and 10t/ha PM+150kg/ha NPK), and the un-amended plot as control. The results showed that plants in loamy and clayey soils had more leaves compared to those in sandy soil only at 74WAS. *C. albidum* had most numerous leaves with 150 kg/ha, taller plant and wider canopy with 250 kg/ha, and thicker girth with all NPK rates compared to control, manure rates and integrated fertilizers. The plants with loamy soil had highest CPC, Ash C, FC, starch and sugar. Plants with inorganic fertilizers and integrated fertilizers had higher FW and DW compared to manure rates. The 5 t/ha manure rate and the 250 kg/ha NPK produced plants with high sugar content and were lowest in starch content compared to other applied rates. In conclusion, *C. albidum* from juvenile to vegetative stage with proper management can be grown on the different soil types while the 150 kg/ha NPK fertilizer rate appeared as optimum for the plant growth.

1. Introduction

African star apple (*Chrysophyllum albidum* (Linn)) belongs to the family Sapotaceae comprised of the eighty species [1]. As a forest food tree species the diverse natural occurrence is spread across ecozones in Uganda, Nigeria and Niger Republic [2]. In Nigeria, it grows under the lowland tropical rain forests where it flowers in April to June, fruiting period begins with the month of July and ripens between January and February [3,4]. The plant can grow up as far as 36.5m height and the stems are often branched and buttress at the base.

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Across Nigeria, *C. albidum* has diverse ethno-medicinal uses among the populace and contributes to economic well-being of the people [5]. The several local names include agbalumo (Yoruba language) and udara (Igbo language) in Nigeria. The unripe dark green fruit turns into yellowish orange at ripening but rusty orange when over ripe. Globally, wild foods (mostly from plants) support about one billion people [6], among which between 300 and 350 million people depend almost entirely on forests for their nutrition and livelihood support [7,8]. The *C. albidum* is a berry which comprises of a fleshy pulp eaten as snacks, an exocarp chewed to form stable chewing gum, and encloses in most cases five hard seeds.

It is an excellent source of vitamins, iron, flavourings to diets, contains 8.75% protein, 17.1% fatty acid content, 29.6% carbohydrate and 42.1 moisture content. The very high ascorbic acid (AA) content (1000 to 3,300 mg AA per 100 g of edible fruit) is about 100 times that of oranges and 10 times that of guava or cashew [5]. The industrial uses include the production of jams and jellies, extraction of anacardic acid for protecting wood, and the efficient nutrient recycling of its leaf litters has beneficial effects on soil fertility [9]. It also protects the soil against erosion by serving as wind breaks, intercepting rainfall and reducing rain splash [4]. Despite the numerous important uses attached to the plant [10,11,12,13], the low tree population, large tree sizes and the long gestation periods underscore the need for domestication.

The fragile tropical soils are low in organic matter and poor in nutrient availability which results in low productivity and fail to support continuous cultivation. The texture of a soil will influence the total porosity and structure, and therefore has impact on infiltration and moisture retention [14]. The deficiencies would require a correction through the utilization of the sole application of mineral fertilizers and/or organic manures and sometimes the integrated approaches of both [15]. Nonetheless, mineral fertilizers are scarce, costly and have negative impact on soils while although the environmental friendly organic manures are bulky, slow in mineralization and often low in nutrient quality. The resultant high content of incorporated organic matter from addition of animal manure including cow dung continuously revamp the land and increases soil fertility thereby promoting moisture infiltration. Moreover, application of biodegradable fertilizers have beneficial effects on the food value chain compared to chemical fertilizers [16]. The evaluation of organic manure from different sources showed that poultry and goat/sheep manures significantly improved plant growth compared to manure sourced from cattle droppings [17].

Most previous works conducted on *C. Albidum* focused on the ecology [2], chemical composition and physical properties of fruits [3,11] and on anti-oxidant activities of the leaves, germination and seedling establishment [4], storage conditions and the storage effect on its food value chain [5], while production systems involving studies on agronomical requirements are scanty. In this experiment, the performance of *C. albidum* cultivated under different soil types in response to different soil amendment methods using organic and inorganic fertilizer types and the integrated approaches was investigated. The general objective was to determine the crop growth responses under different soil types as affected by the applied fertilizer type/rate. The specific objective include determination of the best soil medium when managed using organic and inorganic fertilizer, determination of crop growth responses to each fertilizer type and rate as well as the residual effects of such fertilizer on post cropping soil status.

2. Materials and Methods

The experiment was conducted in 2017 at the Parks and Garden Unit, Federal University of Agriculture (FUNAAB), Abeokuta, Nigeria (latitude 7°15′N, Longitude 32°5′E and altitude 100m above sea level). The weather data showed a mean temperature 24.2°C to 32.9°C, average rainfall 924.2 - 1,465.5 mm and relative humidity 80.3 - 81.5% (National Bureau of Statistics, 2011). The pre-cropping soil fertility analysis (Table 1), revealed a moderate % N in sandy and clayey soils but high in loamy, high Av. P (mg/kg) with a trend of loamy>sandy>clayey, high K (cmol/kg) with a trend of clayey>loamy>sandy, a generally low % org. carbon and % org. matter with a trend of loamy> clayey >sandy [18]. For the manure, the nutrient elements N, P and K and both % org. carbon, % org. matter were high. (Table 1).

The experiment conducted in containerized medium utilized one year old plants from the nursery to determine the crop responses to soil and fertilizer treatment till grown to vegetative stage. The 3 x 9 factorial experiment was arranged in a completely randomized design at three replications. The different growth medium evaluated comprised of sandy, loamy and clayey textural classes amended with three fertilizer types which included organic manure at 5, 10, 15 t/ha poultry manure (PM), inorganic fertilizer at 150, 250 and 500 kg/ha NPK 15:15:15, and the integrated fertilizer at 5 t/ha PM + 150 kg/ha NPK and 10 t/ha PM + 150 kg/ha NPK (PM 1+NPK 1 and PM 2+NPK 1) while the un-amended (0 t/ha) plot served as control.

The 20 kg each of air dried and sieved sandy, loamy and clayey soil used was weighed into 27 experimental pots. The soil amendment method comprised of premixing the soil with organic manure at the point of bagging at two weeks before transplanting while the inorganic fertilizer treatment was imposed at one week after seedlings transplant with an assumption of one week allowance for plant recovery from transplanting shock. Seedlings were sorted and graded into different sizes before being transplanted to minimise experimental error. Watering to field capacity was done at every 2days. Regular weeding by manual rouging was done. Routine analysis of pre- and post-planting soil was carried out using methods described by AOAC [19], respectively to determine the basal nutrient available for plant use and the residual nutrient status, and analysis of the poultry manure was done. Samples of seedlings were taken per treatment for tissue analysis which was conducted in the laboratory at the University.

Data collection commenced at two weeks after transplanting of seedlings. Data collection was done fortnightly on morphological growth parameters of plant height, stem girth, number of leaves and foliar tissue analysis of N, P, K, Ca, Mg, Mn, and Fe alongside the proximate content of fresh weight (FW), dry weight (DW), crude protein, ash, fat, starch and sugar content. Analysis of variance (ANOVA) was carried out using the SAS [20] software package and treatment means separated using the least significant differences (LSD) [21].

3. Results

3.1 Crop Growth Responses to Soil Type and Fertilizer Type/rate

With respect to morphological growth responses of plant height, stem girth and canopy spread from 62 - 74 weeks after sowing (WAS), there was no significant difference observed in crop growth responses among the soil type (Table 2 & 3). Nonetheless, significantly more number of leaf production at 74WAS was observed in the plant growth, where plants in loamy soil followed by those in clayey soil although not different from one another but both had significantly more leaves compared to plants grown in sandy soil.

Significantly taller plant was observed in plot supplied with moderate inorganic fertilizer (250 kg/ha) at 62-66WAS, although not different from plant supplied with lower inorganic fertilizer (150 kg/ha), while plants with 250 kg/ha exhibited significantly taller responses compared to plants treated with control, or supplied with manure and the lower and higher integrated fertilizer. There was no significant difference among plants with lower inorganic fertilizer (150 kg/ha), control, manure rates and integrated fertilizer.

Significantly thicker girth was observed in plant supplied with higher inorganic fertilizer (500 kg/ha) although not without an initial depression at 62WAS compared to those with control, manure and integrated fertilizer rates. Nonetheless, after the non-significant response observed at 66WAS, crop growth responses exhibited a switch from 70-74WAS where plants with inorganic fertilizer rate (150, 250 and 500 kg/ha NPK) exhibited significantly thicker girth at 70 and 74WAS compared to plants treated with control, manure rates and lower or higher integrated fertilizer rates.

Significant influence of inorganic fertilizer (150, 250 and 500 kg/ha) and the lower integrated fertilizer rates with more leaves was observed at 66 - 74WAS compared to fewer leaves of plants treated with manure and higher integrated fertilizer rates (Table 3). Although at the 66 and 70WAS, no significant difference was observed among plants treated with 500 kg/ha and manure rates and also among the manure and integrated fertilizer treated plants, nonetheless at the 74WAS significantly more leaves was observed with plants supplied with 250 kg/ha, 500 kg/ha and lower integrated fertilizer rates which were not different from the plant treated with manure rates and the higher integrated fertilizer rates. Only plants with 150 kg/ha had consistently more leaves compared to those with control.

There was a consistently wider canopy spread response exhibited in plants supplied with 250 kg/ha compared to control while no significant difference was observed among other inorganic, organic and integrated fertilizer rates. Except for the 5t/ha, consistently narrower canopy spread response was observed with 10 t/ha and 15t/ha compared to 150 kg/ha, 250 kg/ha and the lower integrated fertilizer rates. The trend of response observed for canopy spread was similar to that exhibited in the stem girth responses.

3.2 Interaction Effect between Soil Type and Fertilizer Application Rate

The interaction effect between soil type and fertilizer application rate was significant only at 74WAS (Figure 1). Significantly more leaves was exhibited by plants in loamy soil at the unfertilized plot and with 15 t/ha PM followed by sand and clay in that order. Nonetheless when the growth media were supplied with 5 and 10 t/ha, significantly more leaves was observed for both clayey and sandy soils, respectively. Significantly more leaves was exhibited by plants treated with NPK compared to those that received poultry manure methods. Significantly more leaves was exhibited by plants cultivated in clayey soil and supplied with 150 kg/ha NPK followed by plants in

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loamy soil while those in sandy soil had less than half and a third of leaves in loamy and clayey soils, respectively. Significantly more leaves with similar responses was exhibited by plants treated with 250 kg/ha NPK in both clayey and loamy soils while a lower response was observed for plants in sandy soil although with highly improved performance compared to observed in plants treated with 150 kg/ha NPK. Significantly lesser leaves with similar responses was exhibited by plants treated with 250 kg/ha NPK in either loamy or sandy soil, although with no difference in performance observed in plants with 150 kg/ha NPK compared with significantly more leaves exhibited by plants cultivated in clayey soil. Significantly more leaves was exhibited by plants in loamy soil when treated with lower integrated fertilizer (5 t/ha PM + 150 kg/ha NPK) compared to lesser leaves exhibited by plants in clayey and sandy soils in that order. Although lesser leaves exhibited by plants that received integrated fertilizer addition compared to those with inorganic fertilizer, improved leaf production was exhibited by plants in all the integrated fertilizer either at lower or higher rate compared to that exhibited by plants supplied with purely organic manure addition.

3.3 Tissue Analysis Responses to Soil Type and Fertilizer Type/rate

The plants cultivated in loamy soil had significantly higher nutrient uptake of P, K, Ca, Mg and Cu compared to lower responses from those in clayey soil, while plants with clayey soil had significantly higher N and those with sandy soil had significantly higher Mn and Fe (Figure 2). Plant in sandy soil was least in N, P, K, Ca, Mg and Cu while the clay was least in Mn and Fe. There was significantly higher nutrient uptake for the N, P and K for plants supplied with 500kg/ha NPK fertilizer, significantly higher Ca, Mg and Mn uptake in plants with higher integrated fertilizer although closely followed by 5 and 10 t/ha, and the 150 kg/ha in Mn uptake. The highest Fe uptake was observed in 150 kg/ha, followed by 10 and 15 t/ha, 250 kg/ha and lower integrated fertilizer rate which were not different from one another in value. The least nutrient uptake was observed in 5 t/ha for N, P, K and Fe alongside 10 t/ha in the P uptake and alongside the lower and higher integrated fertilizer rates in the K uptake. The least nutrient uptake in Ca and Mg was observed for plants in 15 t/ha PM plots, while the least Cu uptake was observed in higher followed by lower integrated fertilizer rate. The higher nutrient uptake of Ca and Mg was observed in plants treated with higher integrated fertilizer rate and the least in plants with 15 t/ha which was corrected in the higher integrated fertilizer rate.

3.4 Proximate Analysis Responses to Soil Type and Fertilizer Type/rate

The plants cultivated in loamy soil had a higher fresh weight (FW) and dry weight (DW) followed by those in clayey soil while sandy soil was least (Figure 3). The plants in loamy soil had the highest proximate content in the crude protein content (CPC), Ash C, fat content (FC), starch and sugar contents, followed by plants in clayey soil in the FW, DW, FC, starch and sugar, and plants in sandy soil in the CPC and Ash content. Higher FW and DW was observed for all plants treated with the inorganic and integrated fertilizer compared to those with manure rates, while those with 250 kg/ha and lower integrated fertilizer had highest CPC, highest manure rate and the low and high integrated fertilizer rates had highest Ash content. Plants with 250 kg/ha and lower integrated fertilizer had highest CPC, 15 t/ha manure rate and the low and high integrated fertilizer rates had highest Ash content. For plants in fertilizer types, except for the 5 t/ha manure rate and the 250 kg/ha NPK all the manure and inorganic fertilizer types had a high sugar content, moreover plants in both 5 t/ha manure rate and 250 kg/ha NPK were lowest in starch content compared to other fertilizer rates.

3.5 Post Cropping Responses to Soil Type and Fertilizer Type/rate

The post cropping soil fertility status showed a more acidic nature with clayey soil (5.7) and sandy soil (6.7) compared to compared to pre-cropping soil pH (clayey 7.4 and sandy 7.2) unlike the more stable responses of loamy soil (6.9 and 6.8 respectively) (Table 1 & Figure 4). Loamy soil at post cropping obtained moderate % N (1.3) and both clayey and sandy soils were low (0.1 and 0.1) compared to high pre-cropping for loamy (0.206) and moderate for sandy and clayey (0.105 and 0.129). Post cropping was higher in Available P value of 41.8, 31.1 and 28.5 respectively for loamy, clayey and sandy soils compared to pre-cropping 41.2, 26.7 and 32.7 respectively. Pre-cropping K was 0.9 and 0.46 respectively for clayey and sandy soils but lower in post cropping with 0.6 and 0.4 respectively but pre-cropping was 0.4 for loamy which had higher value of 0.6 at post cropping. Pre-cropping for organic carbon (org C) was 0.61, 0.38 and 0.31 which at post cropping was 0.9, 0.3 and 0.3 while for organic matter (org M) pre-cropping was 1,056, 0.65 and 0.53 which at post cropping was 1.5, 0.6 and 0.5 respectively for the loamy, clayey and sandy soils respectively. The loamy soil was highest in Na, Ca and Mg compared to lower value in clay for Ca and Mg and lower value in sand for Na.

In the fertilizer types, the soil pH was lowest with 5 t/

ha but highest in plots with 250 kg/ha > 10 t/ha and 500 kg/ha. There was excessive build- up of % N in 15 t/ha and a corresponding drop in org C and org M compared to a generally moderate %N observed in plots for control, manure, inorganic fertilizer and integrated fertilizer types. In consonance with a generally higher P observed in the pre-cropping soil followed by relatively high P in corresponding NPK which now peaked at 250 kg/ha > higher integrated fertilizer showed the contributive effect of the fertilizer on available P at residual level, also a function of poor nutrient uptake in the plant. Except for the lower K value for control and plants treated with 150 and 250 kg/ha, there was no difference in K value across all treatments. Except for the low organic carbon for the plot with 15 t/ha and lower value for the organic matter in the plots with 10 and 15 t/ha and higher integrated fertilizer rate, there was no significant difference in organic carbon and organic matter of the plots. The fertilizer type/rates had similar response across board for Na and Mg.

4. Discussion

4.1 Crop Growth Responses to Soil Type and Fertilizer Type/rate

The no significant difference observed in the different soil' type at the early growth stages on plant height, number of leaves, stem girth and canopy spread response of *C. albidum* indicated that if properly managed the plant can be grown on any type of soil. Nonetheless, although the soil types at initial stages equally supported the leaf production until the plant attained the advanced growth stage when it required greater nutrient support that exceeded what sandy soils could supply, hence poor growth was observed in sandy soils compared to loamy and clayey soils. Leaf area which has contributive effect from number of leaves production has been reported as a plant stress indicator [22,23]. The observed response could be due to poor moisture and nutrient retention ability of sandy soil compared to the loamy and clayey soil.

The slow growth of *C. albidum* notwithstanding, the initial crop establishment had equal support from the soil amendment methods of unfertilized control, manure rate and integrated fertilizer, but eventually crop growth requirement was only supported by the 250 kg/ha application rate. Thus the poor crop growth response under 500 kg/ha and integrated fertilizer could be due to growth depression by nutrient antagonism and the poor mineralization of the manure component of the integrated fertilizer, respectively. An earlier report [24] on the positive influence of higher N and P application rate on the attainment of budding size in citrus indicated that N is required for rapid plant growth and P for stem girth development. Hence, the quick release of both the moderate 250 and higher 500 kg/ha NPK supported leaf production but compared to lower 150 kg/ha NPK, the complication from nutrient antagonism of 250 and 500 kg/ha and poor mineralization of integrated fertilizer rates could have hindered adequate nutrient release.

The optimum rate required for canopy spread was observed at 500 kg/ha. The higher responses from plants treated with 5 t/ha PM, 150 kg/ha NPK and integrated fertilizer rates could be due to the early nutrient release as well as the improvement on soil physical properties indicating a drip line influence of plant rooting activities on canopy spread. According to Lombin *et al.*, [25], the use of integrated organic manures and mineral fertilizers had proved to be a sound soil fertility management strategy in many countries of the world. Wu *et al.* [26] has earlier indicated that the above and below plant growth interactions are equally important. The more stable loamy soil was more supportive of crop growth at the control (indicating an inherent fertility of soil used) and at higher manure application rate of 15 t/ha probably because of the influence of improved soil physical structure in loamy soil on plants, thus having improved porosity compared to obtainable in clayey soil which although had improved moisture retention compared to sandy soil, while the improved leaf production at the 5 t/ha lower PM rate in clayey soil and at 10 t/ha for sandy soil indicated that PM at lower rate was sufficient for clayey soil while a higher rate was required for the sandy soil.

The *C. albidum* plants responded more to the fast nutrient release inorganic fertilizer NPK compared to slow release of nutrients in organic manure and was better with clayey soil compared to loamy and sandy soil probably due to more adsorption of nutrients to clay particles which was lesser prone to leaching compared to both loamy and sandy soils. The presence of manure in the integrated fertilizer with higher C: N had delayed influence on rate of mineralization. The influence of the growth medium resulted in the slower release of nutrients compared to responses observed in plants with purely inorganic fertilizer NPK. Hence clayey soil was less supportive of crop growth compared to loamy soil but better than sandy soil.

4.2 Plant Tissue Responses to Soil Type and Fertilizer Type/rate

The loamy soil ability to support more nutrient uptake could be due to the good soil texture accommodating maximum percolation and capillarity allowing easy flow of moisture, plant's need for aeration and ability to allow mass flow of nutrients for plants nutrient uptake. The

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clay supported N uptake by disallowing leaching and the higher moisture retention aid in this regard, while sand support for Mn and Fe could be due to relative immobility of the nutrients unlike other nutrients where percolation could have allowed leaching and the poor capillarity due to moisture stress could have discouraged nutrient uptake. Nutrients have three different ways by which they are taken up by the plants which include mass-flow, diffusion and root interception. Nonetheless overuse of N causes excess vegetative growth particularly in tropical areas [27]. The excessive N uptake in this study was favoured by the application of 500 kg/ha, and as earlier reported [27], the N uptake supported commensurate uptake of P and K as the maximum uptake of both P and K was observed alongside the N compared to other treatments having lower responses. Nonetheless the higher nutrient uptake could not transform into good plant growth and proximate content compared to other treatments. The lowest nutrient uptake value observed for plants with 5 t/ha in the N, P and K and Fe despite the good plant growth could be due to excessive nutrient pull for plants growth and organ development compared to other treatments. The similar Fe, Mn and Cu uptake in most treatment plots indicated the importance of Fe as a requirement for chlorophyll formation and Mn and Cu in most enzymatic reactions. Although the least value for Fe in 5 t/ha indicated the diversion into vegetative growth sink. The Ca and Mg uptake could be due to nutrient aided uptake from the rapid mineralization of the manure in integrated fertilizer rate compared to sole manure application.

4.3 Plant Proximate Responses to Soil Type and Fertilizer Ttype/rate

The plant tissue analysis in the soil types showed that loamy soil supported plant growth more than other types of soils, and exhibited succulence in the CPC and ash content and stress condition in the high sugar content, while plants in clay although not showing succulence had a higher stress condition in the high sugar content compared to plants in sandy soil. The FW and DW values showed a rapid release and uptake of N for growth due to the quick release mechanism of the inorganic fertilizer compared to manure fertilizers. The proximate content of plants treated with 250 kg/ha and lower integrated fertilizer types indicated a build-up of minerals and succulence respectively, nonetheless the higher growth and development resulted in a stress condition from metabolic transformation in the plants. Stress can occur either when excessive nitrogen has been applied or when a moderate amount of ammonia is being produced but photosynthetic production of carbohydrate is significantly reduced because of very heavy cloud cover. These metabolic transformation becomes critical to a plant when the amount of ammonia in the tissues become high relative to the amount of sugar acids available to serve as carbohydrate acceptors [28].

Sugar signalling is part of cellular adjustment to shifting environmental condition which is crucial in responses to various stimuli, most importantly to the carbohydrate status of the plant [29]. Soluble sugars are highly sensitive to environmental stress, which is reflected in the supply of carbohydrates from source organs to sink ones [28]. Stress conditions of drought, salinity, low temperature and flooding generally lead to increased soluble sugar concentrations, compared to situations of decreased sugar concentrations under high light irradiance (PAR, UVBR), heavy metals, nutrient shortage and ozone [30,31,32,33]. Descriptive ecological and agronomic studies have uncovered a strong correlation between soluble sugar concentrations and stress tolerance [34]. The stress situation for the plants treated with inorganic and organic fertilizer types notwithstanding was different for 5 t/ha and 250 kg/ha that had significantly higher growth performances compared to other fertilizer rates which indicated the influence of balance nutrient in 5 t/ha PM and higher available growth stimulating nutrients in the 250 kg/ha.

The rate of crop residue or organic waste mineralization is strongly influenced by prevailing environmental conditions of temperature and water availability [35,36], hence N mineralization is greatest during warmer periods when soils are moist [37]. This indicates that the much bulky manure rates would require higher moisture and heat for mineralization compared to less bulky rates. The manure applied to *C. albidum* seedlings had delayed mineralization which affected the plant's nutrient uptake, despite the advantage of increase in soil organic matter. The depletion and or shortage of N indicate that either the crop will not be able to maintain its leaf area expansion rate or cannot maintain its leaf and plant N concentration [38].

The biological functions of starch is described as either the transitory starch which is synthesized in the leaves directly from photosynthates during the day and degraded in the night to sustain metabolism, or the storage starch which exists in non-photosynthetic tissues, such as seeds, stems, roots or tubers, and is generally stored for longer periods [39]. The low starch content in plants that received either 5 t/ha manure rate or 250 kg/ha NPK compared to other fertilizer rates indicated poor transitory starch indicating active metabolism in place of storage.

4.4 Residual Studies Responses to Soil Type and Fertilizer Type/rate

Contrary to the expected high pH in manure and corre-

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sponding low value in inorganic, the reverse showed a high rooting activity in plants with 5 t/ha and lower activity in 250 kg/ha followed by moderate manure (10 t/ha) and higher inorganic (500 kg/ha NPK). The % N, organic carbon and organic matter values indicated a swing in C:N ratio which could be due to many factors such as improved bulk density and moisture content retention hence nutrient availability to *C. albidum* but not reflected in the growth due to the slow nature of the plant. The higher % N under the bulky 15 t/ha at a corresponding poor uptake by *C. albidum* and a higher retentive nature of the clayey was shown in the high leaf N content. The slow build-up in the organic carbon in the plots that received 15 t/ha was due to the slow mineralization. Avnimelech [40] had earlier stated that high rate of nutrient release from fast decomposition occurs only when the organic substrate is rich in nutrients (low C:N and C:P ratios), and the net nutrient release therefore from organic matter is a function of decomposition ratios of organic matter fractions and uptake of nutrients by the growing biomass.

The residual effect with high difference between soil pre- and post- cropping analysis for % N indicated that *C. albidum* was a heavy feeder. The relative differences observed in available P among soil types indicated a stable loam, drop in clay and a gain in sand, hence fertilizer sourced P was sufficient for P in loam and sand but probably with fixation in clay residual P was dropped. The residual K values indicated significant drop in clay, slight increase in loam and slight drop in sand. Both organic C. and organic M had an increase.in loamy soil indicating a gain in loam but marginal differences in clay and sand. The micro nutrient values with a trend of loam>clay>sand indicated a loose hold in loam for all nutrients compared to high fixation in clay and loss through leaching in the sand.

5. Conclusion

Seedlings from juvenile stage to vegetative stage with proper management can be cultivated on any type of soil. Plants cultivated in soil type exhibited significantly late response only in number of leaves production which showed the influence of pronounced stress effect setting in, since sandy and coarse soils do not hold N while N-use efficiency is higher in those crops grown under clay and loamy soils. Nonetheless, the plants in 250kg/ha NPK application rate although not significantly different from those in lower application rate of 150 kg/ha, but most of the time exhibited a consistent positive influence from applied fertilizer. Therefore, provided an appropriate management practice is put in place the *C. albidum* can be grown on any type of soil, and the nutrition requirement would need an optimum application rate of 150kg/ha NPK and or 5 t/ha poultry manure. For soil requiring organic amendment the 5 t/ha and integrated fertilizer rate of 5 t/ha + 150 kg/ha could therefore be recommended.

Appendixes

Table 1. The pre-cropping physical and chemical properties analysis of soil and poultry manure

Parameter	Soil type			Manure
	Sandy	Loamy	Clayey	Poultry manure
pH	7.2	6.8	7.4	7.8
N (%)	0.105	0.206	0.129	4.489
Av. P (mg/kg)	32.673	41.361	26.716	26.615
Org. Carbon (%)	0.308	0.611	0.378	15.467
Org. Matter (%)	0.533	1.056	0.654	26.742
Ex. A (m Eq/100g)	0.1	0.2	0.4	0.3
Na (cmol/kg)	0.435	0.478	0.500	13.045
K (cmol/kg)	0.462	0.538	0.90	20.113
Ca (cmol/kg)	0.182	0.243	0.201	19.675
Mg (cmol/kg)	0.192	0.254	0.216	15.375
Sand (%)	91.42	52.46	31.87	ND
Clay (%)	0.00	5.87	62.78	ND
Silt (%)	8.58	41.67	5.35	ND

Note: ND = not determined

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Table 2. Plant height and stem girth responses of African Star Apple (*Chrysophyllum albidum*) to different soil type and fertilizer rate

Treatments	Plant height (cm)				**Stem girth (cm)**			
	62†	66†	70†	74†	62†	66†	70†	74†
Soil type (A)								
Sandy	18.11	18.67	19.11	19.62	0.06	0.07	0.08	0.10
Loamy	16.76	17.70	18.83	20.59	0.06	0.07	0.09	0.10
Clay	15.82	16.78	18.02	19.28	0.06	0.05	0.08	0.10
LSD	ns	ns	ns	ns	ns	ns	ns	ns
Fertilizer Type (B)								
Control -0 t/ha	17.76	18.51	19.66	20.38	0.06	0.07	0.08	0.10
5t/ha PM	15.48	16.02	16.60	17.93	0.06	0.05	0.07	0.09
10t/ha PM	16.14	16.97	17.37	18.62	0.05	0.06	0.06	0.07
15t/ha PM	13.27	13.76	14.36	15.01	0.05	0.04	0.05	0.07
150kg/ha NPK	18.47	19.23	20.23	21.70	0.07	0.08	0.10	0.12
250kg/ha NPK	20.22	21.44	22.91	25.02	0.07	0.09	0.13	0.16
500kg/ha NPK	16.51	17.52	19.14	20.54	0.04	0.06	0.10	0.12
PM 1 + NPK 1	14.08	14.64	15.52	16.51	0.05	0.06	0.07	0.10
PM 2 + NPK 1	20.18	21.36	22.10	22.73	0.08	0.08	0.09	0.08
LSD	3.43***	3.58***	3.78***	4.41***	0.0237*	ns	0.037**	0.041***
Interaction								
A x B	Ns	ns	ns	ns	ns	ns	ns	ns

Note: *†* = weeks after transplanting, * = significant at 5%, ** = significant at 1%, *** = significant at 01%, ns = not significant, PM 1 + NPK 1 = 5t/ha PM + 150kg/ha NPK, PM 2 + NPK 1 = 10t/ha PM + 150kg/ha NPK.

Table 3. Number of Leaves and canopy spread responses of African Star Apple (*Chrysophyllum albidum*) seedlings to different soil type and fertilizer rate

	Number of Leaves				**Canopy spread (cm)**			
	62†	66†	70†	74†	62†	66†	70†	74†
Soil type (A)								
Sandy	7.37	7.15	7.52	8.33	18.98	19.29	19.78	19.96
Loamy	7.81	7.41	8.48	10.67	17.73	19.27	21.76	23.67
Clay	7.48	7.07	8.07	10.33	16.30	18.24	20.13	22.07
LSD	Ns	ns	Ns	1.89*	ns	ns	ns	Ns
Fertilizer Type (B)								
Control -0 t/ha	8.11	8.00	7.11	9.33	16.92	17.37	18.38	19.08
5t/ha PM	7.00	6.56	6.78	8.56	17.13	18.86	21.33	23.44
10t/ha PM	7.00	5.44	6.11	7.67	15.21	15.29	16.08	16.11
15t/ha PM	6.78	4.67	5.67	7.11	12.81	12.78	14.75	15.72
150kg/ha NPK	8.33	8.89	11.00	13.22	19.53	23.39	24.22	26.17
250kg/ha NPK	9.56	10.22	10.67	12.00	25.02	26.64	28.26	29.83
500kg/ha NPK	7.56	7.56	9.44	12.44	16.61	18.77	20.92	22.44
PM 1 + NPK 1	6.78	7.11	8.78	10.22	16.33	17.58	21.22	23.72
PM 2 + NPK 1	6.89	6.44	6.67	7.44	19.46	19.72	19.83	20.58
LSD	Ns	3.27*	2.88**	3.28**	ns	7.91*	7.57*	7.14**
Interaction								
A x B	Ns	ns	ns	*	ns	ns	ns	Ns

Note: *†* = weeks after transplanting, * = significant at 5%, ** = significant at 1%, *** = significant at 01%, ns = not significant, PM 1 + NPK 1 = 5t/ha PM + 150kg/ha NPK, PM 2 + NPK 1 = 10t/ha PM + 150kg/ha NPK.

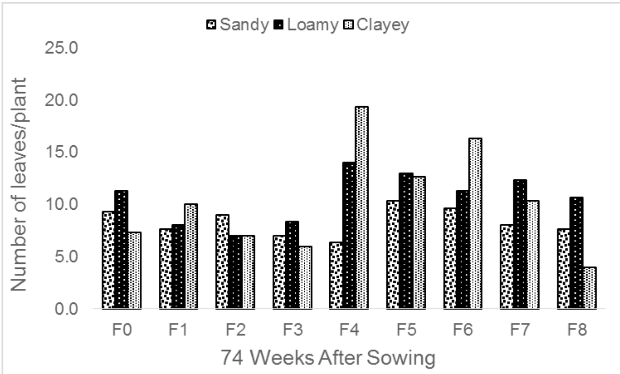

Figure 1. The soil type x fertilizer rate interaction effect on number of leaves production in African Star Apple (*Chrysophyllum albidum*) at 74WAS

Note: F0 = control-1 (unfertilized plot), F1 = 5 t/ha PM, F2 = 10 t/ha PM, F3 = 15 t/ha PM, F4 = control-2 (150 kg/ha NPK), F5 = 250 kg/ha NPK, F6 = 500 kg/ha NPK, F7 = 5 t/ha PM + 150 kg/ha NPK, F8 = 10 t/ha PM +250 kg/ha NPK.

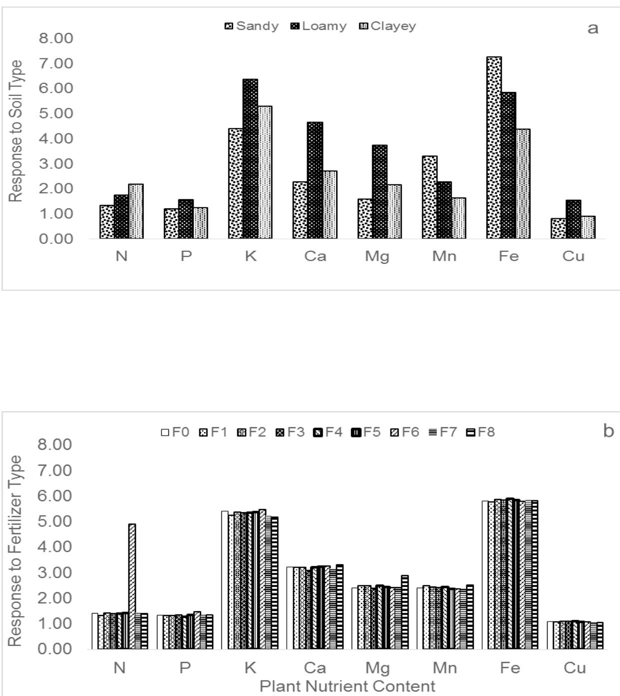

Figure 2. Plant tissue analysis showing nutrient uptake of *Chrysophyllum albidum* in response to soil type and applied fertilizer rate

Note: F0 = control-1 (unfertilized plot), F1 = 5 t/ha PM, F2 = 10 t/ha PM, F3 = 15 t/ha PM, F4 = control-2 (150 kg/ha NPK), F5 = 250 kg/ha NPK, F6 = 500 kg/ha NPK, F7 = 5 t/ha PM + 150 kg/ha NPK, F8 = 10 t/ha PM +250 kg/ha NPK.

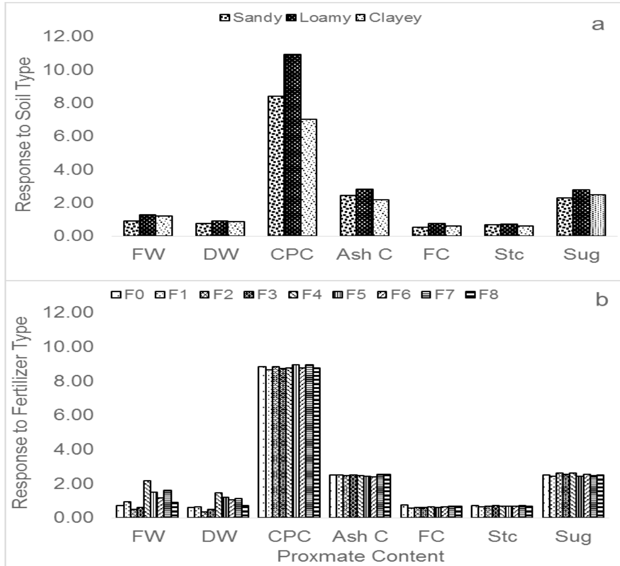

Figure 3. Proximate analysis showing proximate content of *Chrysophyllum albidum* in response to soil type and applied fertilizer rate

Note: F0 = control-1 (unfertilized plot), F1 = 5 t/ha PM, F2 = 10 t/ha PM, F3 = 15 t/ha PM, F4 = control-2 (150 kg/ha NPK), F5 = 250 kg/ha NPK, F6 = 500 kg/ha NPK, F7 = 5 t/ha PM + 150 kg/ha NPK, F8 = 10 t/ha PM +250 kg/ha NPK.

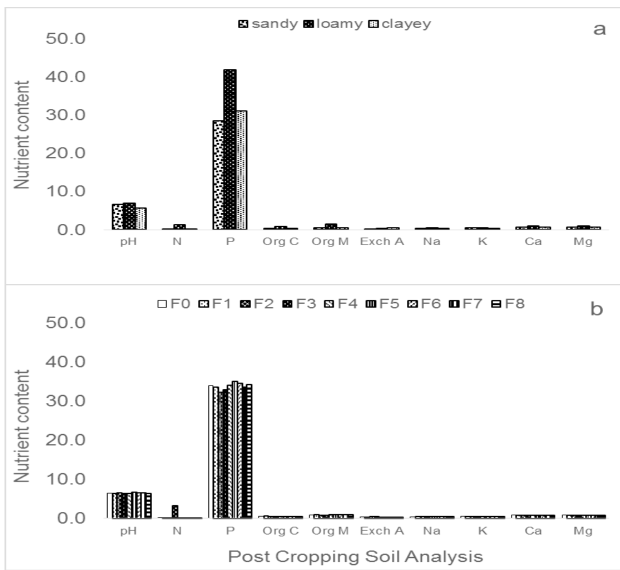

Figure 4. The post cropping soil analysis under soil type and fertilizer application in African Star Apple (*Chrysophyllum albidum*)

Note: F0 = control-1 (unfertilized plot), F1 = 5 t/ha PM, F2 = 10 t/ha PM, F3 = 15 t/ha PM, F4 = control-2 (150 kg/ha NPK), F5 = 250 kg/ha NPK, F6 = 500 kg/ha NPK, F7 = 5 t/ha PM + 150 kg/ha NPK, F8 = 10 t/ha PM +250 kg/ha NPK.

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