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Cashew Growth and Canopy Dynamics as Influenced by Manuring in a Guinea Savanna Agro-Ecology of Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author BAN designed and wrote the manuscript being a part of her PhD thesis. Authors OSOA, IM, SAA, OU, KOO and AFO managed the analyses and literature search used in this manuscript. All authors read and approved the final manuscript.

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ABSTRACT

A two-year experiment was conducted to study the response of manuring on growth and canopy development on three-year-old Cashew trees. The experiment was laid in a randomized complete block design, with three replications. Soil characteristics including the chemical and physical properties were analyzed before and after the experiments. Fecti-plus organic pelletized fertilizer was applied at different rates of 0,750.6 and 1,501.2 kg/ha^{-1} respectively around the circumference of the tree. Before the application, the fertilizer sample was also analyzed. Data collected were plant height, stem girth, canopy dynamics which includes: Canopy diameter, canopy radius, canopy spread (North-South and East-West directions), canopy volume, canopy ground cover and percentage ground cover. The results from the pre soil sample show a relatively low status but

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were significantly enhanced after the application of the pelletized organic fertilizer (Ferti-plus). The soil nutrient composition of Oc, Om, N, K, Na, Ca and Mg^+ was significantly highest in the plots having 1,501.2 kg/ha^{-1} treatments. Generally, there was a significant increase in the soil nutrient with the addition of pelletized fertilizer in respective of the rate of application. Also the results on the canopy dynamic in terms of canopy volume, spread and diameter revealed better development with the use of 1501.2 kg/ha^{-1} pelletized fertilizer and significantly different to 750.6 kg/ha^{-1} and those in the no-manure (control)plots. Meanwhile, the use of pelletized organic fertilizer gave superior growth and canopy development. It also influenced the growth of the Cashew plants, as well as the physical and chemical properties of the soil status.

Keywords: Cashew; canopy; pelletized fertilizer; soil.

1. INTRODUCTION

Cashew (*Anacardium occidentale* L.) tree according to [1] is medium in size, dicotyledonous, with a spreading branches. Its height is up to about 40 inch (100 cm) (but generally 10 - 20' (25-50 cm) at the early stage of growth, with an irregular canopy shape. In older trees, canopy spread may be greater than the plant height, with lower limbs bending to touch the ground. The varying sizes of cashew trees are influenced by the planting geometry and varieties used for its establishment according to [2,3]. These sizes were reported by [2] to be between the ranges of 8 to 14 meters and a canopy diameter of between 15-20 meters in most common cashew trees. [4] in their report classified plant having high canopy to be either tall and straight (Common in area with water) or that with spreading canopies to be large and short (Common where light is not limiting). However, the growth of cashew canopy revolves around the plants morphological and physiological structures. This pattern of growth affects the yield and longevity of the plants directly and indirectly if it is not properly managed. The management of cashew plantations during the early stages of establishment involves costly inputs. But during the productive stage, the cashew biomass (leaf litters) are recycled for nutrients. This method of leaf litters recycling is gradually being replaced by the use of organic fertilizer because of its flammable nature and low rate of its decomposition. According to these authors [5] and [6] organic fertilizer due to the combine resources has disadvantages in term of its volume, weight for transportation but advantages for increases in productivity, sustain and reduces risk of total crop loss. More-so, looking at the time the cashew tree comes into economic importance, soil fertility can be raised over the first two to three years of growth with a slow releasing fertilizer. Slow-release fertilizer has long term effects as well as positive effects on both the health and soil nutrient levels. Fertilizer in its pellet form is among the slow nutrient releasing, uniform and homogeneous materials made for plant use. [7] reported greater P recovery rate compare to non-pelletized compost on buckwheat (*Fagopyrum esculentum* Moench) and komatsuna (*Brassica campestris* L.). Thus this study is aim to understanding how fecti-plus pelletized organic nutrient amendment can enhance the vegetative growth of cashew plant in Nigeria guinea savanna agro ecology.

2. MATERIALS AND METHODS

The plantation used for this experiment was located in Kogi state of Nigeria at the sub-station of Cocoa Research Institute of Nigeria (CRIN) Ochaja. The town Ochaja lies on latitude 7°46'N - 7°52' and longitudes 6°38'E–6°48' in southern guinea savanna ecology.

Thirty-six physiologically matured 3 years old jumbo cashew trees, planted at a space of 6 m x 6 m were used for the study. Fecti-plus pelletized organic fertilizer was applied at three different levels of 0, 2.7 and 5.4 kg per tree, implied to 0, 750.6 and 1,501.2 kg/ha^{-1} respectively. The manure application was done by spreading at 3 m around from the tree diameter and 5 cm deep into the soil.

The study was a factorial experiment, replicated three times and fitted into a randomized complete block design (RCBD). Prior to the treatments allocation, a uniform agronomic management practices were manually done and above ground tree architecture were measured. Also top soil was collected randomly at the beginning and end of the experiment, air dried before taken for laboratory analysis for routine physical and chemical properties. Starting from four months after treatments application, data on the morphological characteristics were measured on a quarterly based. Among the measurements taken on the cashew trees were stem girth, plant height, canopy spread (E-S, and N-S directions), canopy diameter. These four parameter serves as a metric for the calculation of the canopy radius, canopy ground coverage, canopy volume and canopy ground cover%. The measurements of the cashew vegetative parameter were done according to the method used by [8] as follows:

2.1 Tree Height

The height of the tree was measured vertically in meter from the ground to the highest point of the tree crown tip using a calibrated meter pole.

2.2 Trunk Girth

The circumference of the tree trunk was measured above 30 cm from the base touching the ground and recorded as tree girth in centimeter using a digital calliper.

2.3 Crown Diameter

The diametric length of the ground space occupied by the Cashew tree was measured in two directions ("North-South Spread" and "East-West Spread"). The mean values of diameters measured in the North-South and East-West directions were considered as the crown diameter.

2.4 Canopy Spread

The canopy spread was recorded in meters and is calculated using the multiplication values of the two directions "North-South Spread" and "East-West Spread" of the tree measurements.

$$Cs = NS\ X\ EW$$

(Cs = Canopy spread, NS = North-South, EW = East-West)

2.5 Canopy Volume (M^3)

The Canopy volumes were calculated as: $\mathrm{CV} = \mathrm{Constant} \times \mathrm{H} \times \mathrm{D}$ (CV = Canopy volume (m^3), Constant=0.52, H = Tree height, D = Tree diameter).

2.6 The Ground Coverage

The ground coverage and its percentage of cashew canopy were worked out using the procedure used by [9].

Radius of canopy (m) = $r = \frac{(\mathrm{D1} + \mathrm{D2})}{3}$ (1)

%Ground coverage by canopy (m^2), A= r^2 (2)

D1: Canopy spread in E-W direction (m), Canopy diameter in N-S direction (m), 3: Number of replications.

2.7 Weather Condition

The weather report as presented in Fig. 1 shows sufficient rainfall and temperature pattern suitable for plant growth.

Analysis of variance was used on all data to test the treatments effect on the different parameters measured, using the SAS statistically tools of version 9.4 [10]. Means were separated by Tukey's honestly significant differences (*P<0.05*). This research was conducted for two consecutive years.

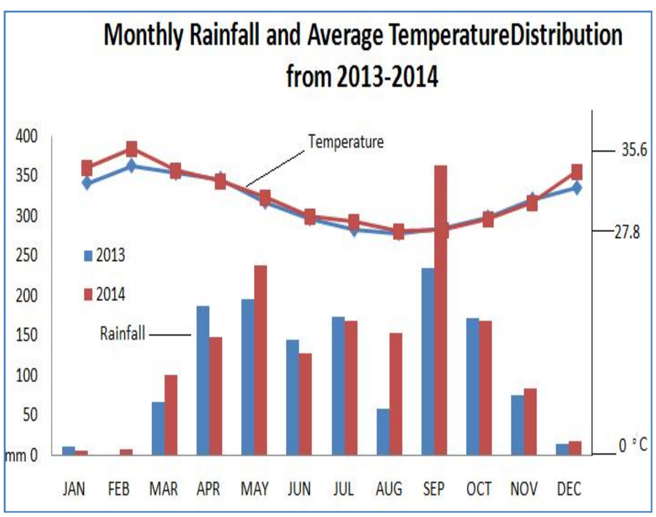

Fig. 1. Distribution of monthly rainfall and average temperature from 2013-2014 at CRIN Ochaja Substation

3. RESULTS

Table 1 shows the chemical composition of the pelletized organic fertilizer material. The contains includes: 88% dry matter, 4.2% total Nitrogen (TN), 3.0% phosphorus (P_2O_5) and 2.8% potassium (K_2O). Other macro nutrients elements present are Magnesium (MgO) and Calcium (CaO). The pelletized organic fertilizer is slightly acidic with a pH value of 6.4. The availability of these essential nutrient elements in the organic material is an indication that it will not only enhance the nutrient status of the soil but improve the soil quality factors.

Table 1. The chemical composition on the label of the pelletized organic material

Dry matter (%)	88
Organic matter	65
Nitrogen Total (N)	4.2
Phosphorus (P_2O5)	3.0
Potassium (K_2O)	2.8
Magnesium (MgO)	1.0
Calcium (CaO)	9.0
C/N	9
PH	6.4

The laboratory result obtained from the initial and post-cropping physicochemical properties of the soil analysed before and after the application of the fertilizer amendments is shown in Table 2. The pre-soil analysis results indicated that the soil is slightly acidic to neutral, with the textural classification as sandy loam (sand content ranges between 78.20-81.83 and low percentage of clay and silt content was recorded and it ranges between 13.61-17.70 and 4.43-7.47 respectively. The soil is also low in organic carbon (OC), potassium (K) and phosphorus (P) contents. The low organic carbon, potassium and phosphorus are an indication that the soil will respond positively to addition of pelletized organic fertilizer (Table 2).

However, the soil Nitrogen (N) is adequate and above the critical level of 0.1%. The post soil analysis revealed a significant (*P>0.05*) increase in soil OC, N, P, Ca^{2+}, Mg^{2+}, K relatively to the no manure (Control) plots. The application of the pelletized fertilizer of 1501.2 kg/ha^{-1} recorded the highest values relative to other rate of application and no manure (Control) (Table 2). No application and pelletized organic fertilizer applied at 7.50.6 kg/ha^{-1} recorded similar effect on soil OM and Ca. While the pelletized organic fertilizer applied at 1501.2 kg/ha^{-1} produced a significant effect on the soil OM and Ca respectively compare to the control and the 750.6 kg/ha^{-1} pelletized fertilized plots. Similar result was exhibited in the soil pH (6.40-6.85). The exchangeable K content falls within the moderate range of 1.59-2.11 and above the soil critical level of 0.12 for Cashew production. Also the cation exchange capacity (CEC) and the water holding capacity (WHC) of the soil used for this experiment were significantly improved by the applied treatments, irrespective of the rates of application. More so, application of 1501.2 kg/ha^{-1} recorded the highest values relative to the control. In Table 3 the results review the ten vegetative parameters which reflected the trend in the growth pattern of cashew trees. The significant least values were in the earliest period of measurement (i.e. last quarter) while the highest significant (*P≤0.05*) values of performance occurred at the fourth quarter.

Addition of pelletized organic fertilizer at different levels led to a significant (*P≤0.05*) increase in performance of the seven out of the ten traits measured except for plant height, girth and canopy volume (Table 3). Canopy East-West (EW), North-South (NS), crown diameter, canopy spread, canopy radius, ground cover and ground cover percentage had increased significant (*P≤0.05*) performance recorded. In Table 4, the results show a very significant trend for height and highly significant trends for girth, canopy volume, canopy radius, canopy ground cover and canopy ground cover percentage. Year effect was not significant on canopy E-W and N-S, canopy diameter and canopy spread. Fertilizer type effect was highly significant (*≤0.001*) across the measured parameters, apart from canopy radius and canopy ground cover. The interaction between the year and fertilizer was not significant (Table 4). Table 5 shows the means of the ten growth measurement. The highest significant values (*P≤0.05*) were in the last period of measurement performance. Increased amount of organic pelletized fertilizer lead to a significant (*P≤0.05*) increased in performance of all traits measured except plant height and canopy diameter which was similar compare to the control plots. The control plot and that of the 750.6 and 1,501.2kg/ha^{-1} pelletized plot had slight differences (*P≤0.05*) in the growth and canopy measurement performances (Table 5).

Table 2. Pre and post physiochemical analysis of the soil properties

Treatments	Chemical properties					Exchangeable bases				Exchangeable acidity				Physical properties		
	pH. 1:1	OC%	OM%	N%	P mgkg^{-1}	K^{+}cmol kg^{-1}	Na cmol kg^{-1}	Ca cmol kg^{-1}	Mg^{+}cmol kg^{-1}	Al^{3+}cmol kg^{-1}	H^{+}cmol kg^{-1}	CEC cmol kg^{-1}	WHC%	Sand %	Silt %	Clay %
Pre soil sample																
Initial sample	6.10	0.75	0.35	0.35	0.48	0.28	0.93	1.14	1.96	0.42	0.44	3.80	41.24	82.98	11.26	11.08
Post soil sample																
No manure (control)	6.40^{c}	1.06^{b}	1.68^{b}	0.43^{c}	4.00^{b}	1.59^{c}	1.00^{c}	1.24^{b}	1.30^{c}	0.13^{c}	0.10^{b}	6.00^{b}	40.00^{c}	-	-	-
Pf (750.6 kg/ha^{-1})	6.60^{b}	1.07^{b}	1.60^{b}	0.50^{b}	2.92^{c}	1.80^{b}	1.24^{b}	1.26^{a}	1.51^{b}	0.19^{b}	0.18^{b}	7.51^{a}	40.62^{b}	-	-	-
Pf (1501.2 kg/ha^{-1})	6.85^{a}	1.20^{a}	2.00^{a}	0.60^{a}	5.00^{b}	2.11^{a}	1.43^{a}	2.25^{a}	1.65^{a}	0.35^{a}	0.24^{a}	7.60^{a}	40.97^{a}	-	-	-
Textural class	**Sandy loam**															

Means with the same letters along each column are not significantly different at 0.05 level of probability. PF-Pelletized fertilizer

Table 3. Means performances of ten vegetative characters of Cashew at different quarters and fertilizer levels applications

Sources of variation	Height (m)	Girth (cm)	Canopy volume (m^3)	Canopy East-West direction (m)	Canopy North-South direction (m)	Crown diameter (m)	Canopy spread (m)	Canopy radius (m)	Canopy ground cover (m^2)	Canopy ground cover (%)
Quarters										
Last quarter_2013	3.18^{d}	37.99^{d}	10.40^{c}	3.41^{c}	3.36^{d}	5.89^{d}	11.77^{d}	2.26^{d}	4.51^{d}	162.38^{d}
First quarter_2014	4.79^{c}	44.58^{dc}	29.46^{b}	4.65^{b}	4.67^{c}	11.10^{c}	22.20^{c}	6.21^{c}	12.41^{c}	446.25^{c}
Second quarter_2014	5.25^{bc}	51.78^{bc}	38.58^{b}	5.06^{ab}	5.17^{bc}	13.42^{bc}	26.84^{bc}	6.79^{bc}	13.58^{bc}	488.33^{bc}
Third quarter_2014	5.74^{ab}	$56.71b^{a}$	50.91^{a}	5.51^{a}	5.70^{ab}	16.20^{ab}	32.40^{ab}	7.41^{ab}	14.83^{ab}	533.44^{ab}
Fourth quarter_2014	6.21^{a}	65.17^{a}	2.16^{c}	5.84^{a}	6.00^{a}	17.95^{a}	35.89^{a}	7.84^{a}	15.67^{a}	563.69^{a}
Fertilizer Type										
No manure (control)	4.83^{a}	48.48^{a}	22.41^{a}	4.52^{b}	4.56^{b}	11.12^{b}	22.25^{b}	5.60^{b}	11.21^{b}	403.18^{b}
Pf (750.6kg/ha^{-1})	5.22^{a}	52.40^{a}	27.98^{a}	5.19^{a}	5.07^{a}	13.93^{a}	27.85^{a}	6.41^{a}	12.82^{a}	461.28^{a}
Pf (1501.2kg/ha^{-1})	5.04^{a}	52.86^{a}	28.51^{a}	4.96^{ab}	5.30^{a}	13.68^{a}	27.36^{a}	6.28^{a}	12.57^{a}	451.99^{a}

Means with the same letters along each column are not significantly different at 0.05 level of probability. PF-Pelletized fertilizer

Table 4. Interval responses and analysis of variance summary for Cashew characters and canopy structure performances as influenced by rates of manure applications

Sources of variation	DF	Height (m)	Girth (cm)	Canopy volume (m^3)	Canopy East-West direction (m)	Canopy North-South direction (m)	Crown diameter (m)	Canopy spread (m)	Canopy radius (m)	Canopy ground cover (m^2)	Canopy ground cover (%)
		1.92	493.25	729.29	4.16	1.26	94.61	383.44	2.74	10.96	14179.93
Year	1	5.68**	17175.67***	7902.89***	17.41	19.86	553.71	2209.30	387.05***	1548.21***	2003278.72***
Error(a)	2	0.01	65.69	114.95	0.17	0.14	12.26	49.71	0.97	3.88	5020.68
Fertilizer Type	2	10.92***	1795.23***	11519.10***	20.63***	31.88***	828.79***	3299.76***	21.99	87.98	113833.40***
Year*Fertilizer Type	2	0.055	166.58	38.30	0.65	0.47	6.67	27.27	0.79	3.15	4074.49
Error (b)	8	0.15	90.23	634.14	1.69	2.03	61.40	247.532609	1.98	7.93	10261.77
Mean		5.52	42.55	53.36	5.45	5.82	17.25	34.49	5.74	11.47	412.67
Coefficient of Variation (%)		17.69	19.99	44.31	24.26	26.59	42.57	42.52	24.99	24.99	24.99

*Means with the same letters along each column are not significantly different at 0.05 level of probability. **-and *** significant at P ≤0.01, and -≤0.001. PF-Pelletized fertilizer*

Table 5. Means for Cashew characters and canopy structure performances as influenced by rates of manure applications

	Height (m)	Girth (cm)	Canopy volume (m^3)	Canopy East-West direction (m)	Canopy North-South direction (m)	Crown diameter (m)	Canopy spread (m)	Canopy radius (m)	Canopy ground cover (m^2)	Canopy ground cover (%)
2013	5.24^b	27.11^b	42.88^b	4.96^b	5.30^b	14.48^b	29.95^b	3.42^b	6.84^b	245.86^b
2014	5.81^a	58.00^a	63.83^a	5.94^a	6.35^a	20.03^a	40.03^a	8.05^a	16.11^a	579.47^a
Fertilizer Type										
No manure (control)	4.75^b	33.55^c	33.12^c	4.61^b	4.70^b	12.14^b	24.28^b	4.82^b	9.64^b	346.89^b
Pf ($750.6 kg/ha^{-1}$)	5.81^a	43.31^b	50.32^b	5.29^b	5.77^b	15.95^b	31.89^b	6.73^a	11.31^b	406.84^b
Pf ($1501.2 kg/ha^{-1}$)	6.01^a	50.80^a	76.62^a	6.44^a	7.00^a	23.67^a	47.29^a	6.73^a	13.46^a	484.26^a

Means with the same letters along each column are not significantly different at 0.05 level of probability. PF-Pelletized fertilizer

4. DISCUSSION

Organic fertilizer from plant or mixture of plant and animal origin is well known for the maintenances of soil nutrient properties and for the sustainability of crop production. However, very little information is available about the use of pelletized organic fertilizer on tree crops especially to the Cashew plant. The pH values of 6.10 acidic nature of the soil could be attributed to high rainfall experience in the study site which may have leached out the basic cations from the soil surface, in accordance to the works of [11].

The soil OC had a low value of 0.75% which indicated that the water holding capacity and nutrients retentively will be low, which is similar to the report of [12]. Hence the need to improve the soil organic matter, for optimal and sustainable cashew production. At the early stage of Cashew growth before the canopy closes, increases in the growth of branches are severe because its goal is on having a lot of sunlight for growth enhancement. When the canopy is closed, however, the requirements for soil nutrient becomes rapid as the growth rate of the tree as a whole change. Thus for maximum productivity, Panda H. [13] advocated the need for regular fertilization. It is worthy to state here that fruit trees like Cashew plants are considered to have a positive influence on the soil nutrient content because of its tap root system and the presence of un-pack leaf litters from the plants. It is probable that these litter dropping are being converted to manure that may remain in the soil and act as additional manure to the plant. Since no fertilizer has been applied to the soil before the time of commencement of this experiment, it was no surprise that the P was significantly higher after the application of pelletized fertilizer treatments because its boost up the P contents above the soil critical level as recommended by [11]. The results on the soil properties were also consistent to that of [14] who reported slow Nitrogen (N) release from organic fertilizer and concluded that these nutrients may not only improve soil structure but its water content.

The reduction of the soil pH before the application of the pelletized fertilizer may not be attributed to the K, Mg, Ca higher contents in the pelletized treated plots but to the time the soil sample was collected and the magnitude of change in the soil structure for the study periods. However, the results from the post soil had increase in the soil pH and this may be probably because of greater mineralization and subsequent release of basic cations contained in the pelletized materials [15]. Our results on the N nutrient content is consistent with the earlier work of [16] that most Africa soils are impoverished and the low N contents maybe due to intense rainfall, leaching, rapid microbial activities amongst others. Similar report was obtained from [17] and [18] apart from intense weathering and high temperature. Its worthy to state here that one of the options given to small Cashew farmers in Nigeria experiencing low nutrient soil status was the use of organic manure/fertilizer after soil testing. These organic fertilizer according to [19] and [20] is less concentrated than chemical fertilizers but it is cheap and has the ability to release nutrient slowing, with a significant improvement in the soil nutrient composition [21]. More so, in the northern part of Nigeria, farmyard manure for soil amendment is a common practise [22] being used. The results obtained from this study was in consistence with [23] who demonstrated that regular application of nitrogen, potassium and phosphorus is beneficial for obtaining healthy trees. Similarly, to the agreement with [24] that canopy growth is a determinant factor and it determines how rapidly a Cashew plant can enter into a better economic production phase. Others researchers of the likes of [25,26,27] opium the existence of a relationship between the canopy and the size of the tree was positive to our obtained results.

5. CONCLUSION

In order to reduce the weight of organic fertilizer, it can be converted to pelletized form for ease of transportation. Cashew Farmers can use pelletized organic fertilizer because of its ability to gradually release available nutrients for the plant to utilized throughout the growing season. The spread of the canopy associated to the use of fertilizer is an expansion though which yield capacity are measured. Thus this study shows that at the early year the cashew canopy was well spread and developed. However, a call for proper canopy management is necessary to understand the role of branch architecture of the plant. More so the Cashew canopy need to be pruned after each harvesting, to shape the architecture of the plant for better yield production. The recycling of organic manure produced from pruning could be a strategy for sustainable soil management. We recommended that the use of pelletized organic fertilizer be utilized in nursery of Cashew seedling soil, with an understanding of the nutrient up-take.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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