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Influence of Inorganic Fertilizer (NPK 15:15:15) and Cacao (*Theobroma cacao* L) Leaf Litter Application Rates on Cowpea (*Vigna unguiculata* L.) Performance in the Tropics

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Abstract

Influence of inorganic fertilizer (NPK 15:15:15) and cacao (*Theobroma cacao* L.) leaf litter application rates on cowpea (*Vigna unguiculata* L.) performance in the tropics was studied for 24 months (January, 2017 – December, 2018) at Cocoa Research Institute of Nigeria (CRIN) Ibeku Sub-Station, Umuahia, Nigeria. Three 3 x 3 factorial experiments, each in a Randomized Complete Block Design (RCBD) with three replicates/blocks were used to study the responses of cowpea to three NPK 15:15:15 fertilizer rates 0 kg, 500 kg and 1000 kg ha^{-1} represented by (**Factor F**) $F_{0,}$ F_1 and F_2, respectively, and cocoa leaf litter rates 0 t, 10 t and 20 t ha^{-1} which were also represented by L_o, L_1 and L_2 (**Factor L**), respectively. The results obtained from the study show that the application of either 10 or 20 t ha^{-1} cocoa leaf litter alone or complementary application of either 10 or 20 t ha^{-1} cocoa leaf litter plus 500 or 1000 kg ha^{-1} NPK 15:15:15 fertilizer significantly increased the various cowpea growth and yield components than the fertilizer rates alone. The treatment without fertilizer and leaf litter, i.e. topsoil only (F_0L_0) gave significantly the least cowpea growth and yield components. The highest values were obtained with the application of 1000 kg ha^{-1} NPK 15:15:15 fertilizer with 20 t ha^{-1} cocoa leaf litter (F_2L_2). The cowpea crop performance in terms of growth, yield and yield components over the study periods, 2017 and 2018 were statistically similar. Therefore, the inclusion of leaf litter has greater potential for improving cowpea yield than when fertilizer was used alone. Leaves are potential sources of valuable nutrients providing a high quality of organic matter, which should be returned to the soil.

Keywords: Cowpea, Fertilizer, Cacao Leaf Litter, Application Rates, Performance, Tropics.

1. Introduction

1.1 Background Information

The increasingly dependence of modern agricultural technology on high-value inputs, on the one hand, and the deteriorating economic situation of most of the developing countries, on the other, have led to a renewed awareness of the productive and protective value of trees, and a realization of the potentials of age-old conservation farming techniques (Ojimgba, 2019). Consequently, efforts are now being made to devise the most appropriate ways to integrate trees and other woody species with agricultural crops and/or livestock simultaneously from the same piece of land in a sustainable manner (Fernandes and Chen, 2008). Farmers in tropical West Africa rely mainly on traditional farming system, such as the bush fallow system, for the restoration of soil fertility after a cultivation cycle (Okeke and Omaliko, 1994). To meet the nutrient demand of crops especially for the resource poor farmers, the use of organic materials would be an inevitable practice for a long time to come (Heerendra, 2017). In traditional farming systems in Nigeria, a piece of land is cultivated for a few years and left to fallow in order to regain fertility.

In the farming systems of the tropics, the bush fallow system, cheaply utilized for the maintenance of soil fertility, is still a dominant food production system (Kang *et al*., 1985). Various crop production techniques, including alley cropping, have been tested in the humid tropics to replace the traditional bush fallow in order to increase food production (Kang *et al.*, 1985). However, large quantities of plant nutrients contained in crop residues, plant litter, poultry and cattle manure are often lost by wasteful methods of disposal, such as burning during land preparation (Prabhakaran Nair and Gosh, 1984). Thus, the efficient use of these resources to recycle plant utilizable nutrients, especially in agricultural system of developing countries beset by chronic shortages of fertilizer inputs, has attracted some studies recently (Nordmeyer and Ritcher, 1985; Prabhakaran Nair and Gosh, 1984).

In forest with year's long life cycle, litter is a major source of nutrient systematically enriching the soil. These forest tree leaf litters can be applied as an organic amendment for the production of agricultural crops. To meet the nutrient demand of the crops especially for the resource poor farmers, the use of organic materials would be an inevitable practice for a long time to come (Heerendra, 2017).

Ojimgba (2019) found that the application of 1000 kg ha^{-1} of inorganic fertilizer (NPK 15:15:15) with 20 t ha^{-1} cacao leaf litter gave significantly the highest maize grain yield, while topsoil only (control) - 0 kg ha^{-1} fertilizer + 0 t ha^{-1} leaf litter gave the least yield. Kang *et al*., (1985) also found that the addition of low rates of N and leucaena prunings in their alley cropping experiments significantly increased crop yields, compared to low crop performance where none of these was used. Repeated applications of prunings, they further contended, maintained higher soil organic matter levels and increased soil moisture retention capacity, exchangeable K, Ca, Mg and NO_3 levels. Omaliko and Agbim (1983) also obtained significantly higher yields of forage maize (*Zea mays* L.) with the application of either 75 or 150 t ha^{-1} of incubated rice waste than that with no waste application. They showed that yields of forage maize further increased as the waste was supplemented with N, P and K fertilizers applied together. Similarly, Okeke and Omaliko (1994) found that the incorporation of either 75 or 150 t ha^{-1} of *D.barteri* leaf litter into the soil significantly increased the growth and yield of maize. Okeke and Omaliko (1994), however, cautioned that although the use of litter has potential for improving crop yields, there is yet little information on the various responses of different crops to the rates of incorporating litter in the soil and even the time-lag between the litter incorporation and sowing of the food crop. Therefore, this study looked at the influence of inorganic fertilizer (NPK 15:15:15) and cacao (*Theobroma cacao* L.) leaf litter application rates on cowpea (*Vigna unguiculata* L.) performance in the tropics and how best this leaf litter could enhance cowpea production.

2. Materials and Methods

The study was conducted on the experimental research farm of the Cocoa Research Institute of Nigeria (CRIN) Ibeku Sub-station at Ajata - Ibeku, Umuahia, Nigeria. This study area is located on latitude 0.5° 29' N and longitude 07° 33' E in the rainforest ecological zone of South Eastern Nigeria and lies at a mean elevation of 122 metres (400 ft) above sea level (climatic data for National Root Crops Research Institute (NRCRI) meteorological station, Umudike) (Odurukwe, *et al*., 1995) The soil is classified as Ultisol according to USDA and as an Acrisol according to FAO/UNESCO classification schemes, as summarized by Opara-Nadi (2000). The soil is characterized by inherent constraints such as low organic matter, poor structural stability, low nutrient and water holding capacities, low clay activities and high susceptibility to soil erosion and drought stress (Opara-Nadi, 2000; Salau *et al*., 1992). The vegetation of the study area is typical of tropical rainforest vegetation. The secondary bush which dominates the area is the remnant of the tropical rainforests which are fast disappearing in the area.

2.1 Land Preparation and Layout

This study was carried out on the experimental research farm of the Cocoa Research Institute of Nigeria (CRIN) Ibeku Sub-station at Ajata – Ibeku, Umuahia, Nigeria. In early May of 2017, experimental plots were selected at the adjacent bush fallow site of the cocoa plantation. Each of these plots had not been cultivated for at least eighteen (18) months thus ensuring that the topsoil had not been recently disturbed in order to collect soil samples. Thereafter, all the plots were cleared, ploughed and harrowed.

Three 3 x 3 factorial experiments, each in a Randomized Complete Block Design (RCBD) with three replicates/blocks were used to study the responses of cowpea to three NPK 15:15:15 fertilizer rates O kg, 500 kg and 1000 kg ha^{-1} represented by (**Factor F**) F_0, F_1 and F_2, respectively, and cocoa leaf litter rates 0 t, 10 t and 20 t ha^{-1} which were also represented by L_o, L_1 and L_2 (**Factor L**), respectively. Possible treatment combinations are shown in Table 1 below i.e. 9 treatment combinations per replication.

Field Application Rates

1. F_0L_0= No Treatment
2. F_1L_0 = 0.8 kg F + 0 kg L/16 m^2,equivalent to 500 kg F + 0 kg L/ha
3. F_2L_0= 1.6 kg F + 0 kg L/16 m^2, equivalent to 1000 kg F + 0 kg L/ha
4. F_0L_1= 0 kg F + 16 kg L/16 m^2, equivalent to 0 kg F + 10,000 kg L/ha
5. F_1L_1= 0.8 kg F + 16 kg L/16 m^2, equivalent to 500 kg F + 10,000 kg L/ha
6. F_2L_1= 1.6 kg F + 16 kg L/16 m^2, equivalent to 1000 kg F + 10,000 kg L/ha
7. F_0L_2= 0 kg F + 32 kg L/16 m^2, equivalent to 0 kg F + 20,000 kg L/ha
8. F_1L_2= 0.8 kg F + 32 kgL/16 m^2, equivalent to 500 kg F + 20,000 kg L/ha
9. F_2L_2= 1.6 kg F + 32 kg L/16 m^2, equivalent to1000 kg F + 20,000 kg L/ha

Table 1. Treatment Combinations – NPK 15: 15: 15 fertilizer and Cacao leaf litter rates

NPK 15:15:15 Rates (kg ha^{-1})	Leaf litter rates (t ha^{-1})		
	L_O	L_1	L_2
	0	10	20
F_O 0	F_OL_O (1)	F_OL_1 (4)	F_OL_2 (7)
F_1 500	F_1L_O (2)	F_1L_1 (5)	F_1L_2 (8)
F_2 1,000	F_2L_O (3)	F_2L_1 (6)	F_2L_2 (9)

F = fertilizer L = leaf litter

These treatment combinations were randomized within the plots. The experiment was replicated three times. There were, therefore, a total of twenty – seven (27) treatments and plots. Each replicate measured 45 m x 4 m (180 m^2), while the plot measured 4 m x 4 m (16 m^2) each. The total area of the experimental site was 0.063 ha.

Sources of Materials

The cocoa leaf litter was collected from Cocoa Research Institute of Nigeria (CRIN) Ibeku sub-station, Umuahia, Nigeria, while the cowpea (test crop) was obtained from the National Seed Service, Umudike, Nigeria. The fertilizer NPK 15:15:15 was bought from Umuahia main market.

Application of Waste

The cocoa leaf litter was incorporated into the soil in early May and incubation period of four (4) months was allowed after the application before cowpea was planted early August. Inorganic fertilizer treatments were applied in split doses, at planting and one month after planting by incorporation into the soil.

Planting and Observation

Planting of cowpea was done on a flat harrowed soil surface. Cowpea was planted at 1m x 0.5 m spacing, which gave about 20,000 plants ha^{-1} that is 32 plants per plot of 16 m^2. Cowpea was planted in early August each year. This study lasted for a period of 12 weeks each year.

Attributes Studied

Measurements in each plot were done using twelve stands, three stands each from the four inner rows randomly selected, tagged and sampled.

Cowpea Studies with Cacao Leaf litter + Fertilizer rates at 4, 8 and 10 W.A.P.

i)Plant height (ii) No of leaves plant^{-1} (iii) Leaf diameter,(iv) cowpea grain yield plot^{-1} ha^{-1},(v) Leaf length (vi) Leaf area (Leaf length x Leaf diameter x 0.6 i.e. K (Ambasht and Ambasht, 2006)).

Weed Control

No herbicide was applied to control weeds; rather, hand weeding was done using native hoe. The weeds were not thrown away, but were spread within the plot from which they were removed and allowed to decompose to release the absorbed nutrients.

Harvest and Yield Computation

Harvest was done at 12 weeks after planting. The matured pods were harvested from each plot, dried, shelled and weighed. The grains were dried at 60^0C for 48 hours.

2.2 Statistical analysis

The data collected was analyzed statistically and significant differences between treatment means of various experiments were tested at $P < 0.05$ using the Fisher's least – significant differences (F – LSD), standard errors and or Student's "t" – test, according to the procedures of Steel and Torrie (1980). . In all statistical analyses, $P < 0.05$ was used to test for significant differences between the treatments means of the various experiments.

3. Results and Discussion

Chemical properties of the topsoil prior to fertilizer and cacao leaf litter applications at Umuahia, Nigeria

Table 2 summarizes the chemical properties of the topsoil of the study site prior to fertilizer (NPK 15:15:15) and cacao *(Theobroma cacao* L.) leaf litter applications at Umuahia, Nigeria. However, the topsoil of the study site had low pH, total nitrogen, organic carbon and consequently organic matter, available phosphorus, exchangeable cations (K, Na, Ca, Mg) and percentage base saturation. However the percentage aluminium saturation, effective cation exchange capacity (ECEC) and exchangeable acidity (EA) were high. These values are peculiar with soils of tropical rainforest ecological zone of southeastern, Nigeria which requires amendment for effective crop performance.

Table 2. Chemical properties of the topsoil prior to fertilizer and cacao leaf litter applications at Umudike, Nigeria.

Attributes /Statistics	Units of measurement	Mean values
Soil pH and chemical properties		
pH		4.42
Nitrogen	%	0.03
Organic C	%	0.42
Organic matter	%	0.72
Available P	Ppm	3.40
Exchangeable K	C mol (+) kg $^{-1}$	0.06
" Na	"	0.12
" Ca	"	0.70

“ Mg	“	0.50
“ Al	“	2.20
Exchangeable H	“	0.60
Exchangeable Acidity (EA)	“	2.80
Effective cation exchange capacity (ECEC)	“	4.18
Al Saturation	%	62.90
Base saturation	%	39.00
C:N		14:1

Influence of fertilizer (NPK 15:15:15) and cacao leaf litter application rates on plant height of cowpea (*Vigna unguiculata* L.)

Figures 1 and 2 summarize the influence of fertilizer and cacao leaf litter application rates on plant height of cowpea in 2017 and 2018, respectively. At 4 WAP significant differences existed between the application of 1000 kg ha^{-1} NPK 15:15:15 along with cacao leaf litter (0,10,20 t ha^{-1}) treatments over the years. However, the application 1000 kg ha^{-1} NPK 15:15:15 gave significantly higher plant height than the similar values of 500 kg ha^{-1} and 0 kg ha^{-1} in the following order: $F_2 > F_1 = F_0$. Also, the applications of 20 t ha^{-1} of cocoa leaf litter gave significantly higher plant height than the values of 10 t ha^{-1}, while 0 t ha^{-1} had the least result in 2017 and 2018, in the following order 20 > 10 > 0 t ha^{-1}. There were no significant F x L interaction effects on cowpea plant height in both 2017 and 2018 (Figures 1 and 2)

At 8 WAP, the plant height values of 2017 and 2018 followed the same trend. The application of 1000 kg ha^{-1} NPK 15:15:15 gave significantly higher plant height than the similar results of 500 and 0 kg ha^{-1} NPK 15:15:15 . Also, the statistically similar plant height values of 20 and 10 t ha^{-1} cacao leaf litter gave significantly higher results than 0 t ha^{-1} (no leaf litter, L_0). Generally, the application of fertilizer (F) plus leaf litter (L) rates gave similar plant height values at 8 WAP which were significantly greater than the plant height results of F_0L_0 and F_1Lo (i.e. no fertilizer + no leaf litter and no fertilizer application along with 500 kg ha^{-1} NPK 15:15:15, respectively) in 2017. But in 2018, the application of various rates of fertilizer (500, 1000 kg ha^{-1} NPK 15:15:15) along with the cacao leaf litter (10, 20 t ha^{-1}) gave statistically similar plant height values.

However, at 10 WAP, NPK 15:15:15 fertilizer application rates had statistically similar cowpea plant height values in 2018, whereas in 2017 the application of 1000 kg ha^{-1} NPK 15:15:15 gave significantly higher plant height than the statistically similar plant height values of 500 and 0 kg ha^{-1} NPK 15:15:15. The application of various rates of cacao leaf litter followed same trend in 2017 and 2018. The application rates of 20 and 10 t ha^{-1} cacao leaf litter which gave statistically similar plant height values had significantly higher values than that of 0 t ha^{-1}. Generally, the application of higher rates of fertilizer and any of the two litter rates (10 or 20 t ha^{-1}) gave statistically similar plant height values which were ($p>0.05$) significantly higher than the values of fertilizer rates alone. The least plant height was obtained with the application of F_0 and F_1 without leaf litter. The relative improvement of the final plant height of cowpea in 2008 is in the order: $F_1L_2 = F_1L_1 = F_2L_1 = F_2L_2 = F_0L_2 = F_0L_1 > F_2L_0 > F_1L_0 > F_0L_0$. The final plant height values of 2017 followed same trend.

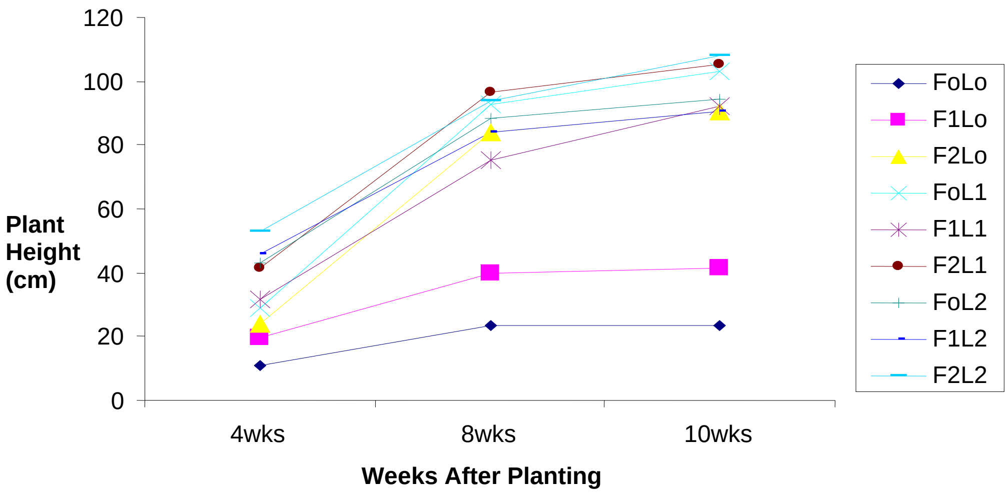

Figure. 1 : Influence of fertilizer and cocoa leaf litter application rates on cowpea plant height in 2017

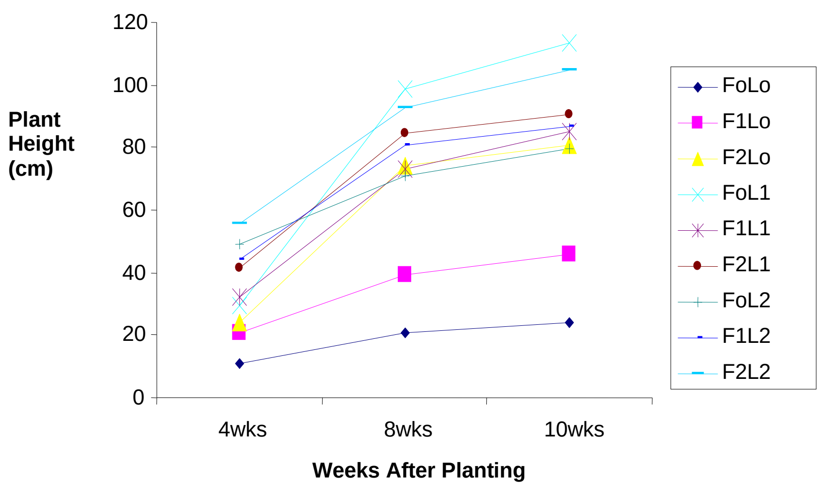

Figure. 2 Influence of fertilizer and cocoa leaf litter application rates on cowpea plant height in 2018

Influence of fertilizer (NPK 15:15:15) and cacao leaf litter application rates on leaf diameter of cowpea (*Vigna unguiculata)*

Tables 3 and 4 summarize the effects of fertilizer, (NPK 15:15:15) and cacao leaf litter application rates on leaf diameter of cowpea in 2017 and 2018, respectively. Table 3 shows that in terms of fertilizer treatments at the weeks after planting (WAP) in 2017, the 1000 kg ha^{-1} NPK 15:15:15 had significantly higher leaf diameter than the 0 kg ha^{-1}. However, at 8 WAP the results of 500 and 1000 kg NPK 15:15:15 were statistically similar. The cacao leaf litter rates significantly influenced cowpea diameter as follows: 10 = 20 > 0 t ha^{-1}. The similar cowpea leaf diameter results of the 20.0 and 10.0 t ha^{-1} were significantly higher than that of the control (0 t ha^{-1}). In 2017, there was no significant fertilizer (F) x leaf litter (L) interaction effects on cowpea leaf diameter in 4 and 8 WAP. However, in 10 WAP, the complementary use of F_2L_2, F_2L_1, F_1L_1 and F_1L_2 had statistically similar cowpea leaf diameter results which were significantly greater than the control (no fertilizer and no leaf litter i.e. F_0L_0), 500 or 1000 kg ha^{-1} NPK 15:15:15 rates without leaf litter. The relative improvement in final leaf diameter values of 2017 was in the order: $F_2L_2 = F_2L_1 = F_1L_1 = F_1L_2 = F_0L_2 > F_0L_1 = F_2L_0 = F_1L_0 > F_0L_0$. Generally, the addition of 10 or 20 t ha^{-1} cocoa leaf litter with or without inorganic fertilizer NPK 15:15:15 rates significantly increased leaf diameter than no leaf litter rates with or without fertilizer application rates.

The results in Table 4 show that the application rates of 1000 and 500 kg ha^{-1} NPK 15:15:15: had significantly higher leaf diameter than the 0 kg ha^{-1} at 4 WAP. However, the results of 500 and 1000 kg ha^{-1} NPK 15:15:15 as well as 0 and 500 kg ha^{-1} treatments were statistically similar at 4 WAP in 2018. The cacao leaf litter rates significantly influenced cowpea leaf diameter. This leaf diameter results at the 4th, 8th and 10th WAP had similar trends of cacao leaf litter treatment as follows: 20 > 10 > 0 t ha^{-1}. There was no significant fertilizer (F) x leaf litter (L) interaction effects on cowpea leaf diameter in 2018.

Table 3. Influence of fertilizer and cacao leaf litter application rates on leaf diameter of cowpea (*Vigna unguiculata)* (2017)

NPK Fertilizer (15:15:15) (Kg ha $^{-1}$)	4 Weeks leaf litter rates (t ha $^{-1}$)				8 Weeks leaf litter rates (t ha $^{-1}$)				10 Weeks leaf litter rates (t ha $^{-1}$)			
	0	**10**	**20**	**Mean**	**0**	**10**	**20**	**Mean**	**0**	**10**	**20**	**Mean**
0	3.57	7.73	9.37	6.89	3.97	8.37	9.77	7.37	4.20	9.00	9.83	7.68
500	5.43	8.80	9.60	7.94	6.20	9.77	10.30	8.76	7.00	10.50	10.43	9.31
1000	7.07	9.73	9.97	8.92	7.07	10.17	10.60	9.28	7.77	10.53	10.80	9.70
Mean	5.36	8.76	9.64		5.74	9.43	10.22		6.32	10.01	10.36	

F-LSD$_{(0.05)}$ (t ha^{-1}) Weeks	**4**	**8**	**10**
Fertilizer rates (F)	0.91	0.63	0.72
Leaf litter rates (L)	0.91	0.63	0.72
Interaction F x L	NS	NS	1.25

Table 4. Influence of fertilizer and cacao leaf litter application rates on leaf diameter of cowpea (*Vigna unguiculata)* (2018)

NPK Fertilizer (15:15:15) (Kg ha $^{-1}$)	4 Weeks leaf litter rates (t ha $^{-1}$)				8 Weeks leaf litter rates (t ha $^{-1}$)				10 Weeks leaf litter rates (t ha $^{-1}$)			
	0	**10**	**20**	**Mean**	**0**	**10**	**20**	**Mean**	**0**	**10**	**20**	**Mean**
0	4.17	7.67	9.73	7.19	4.60	8.37	10.37	7.78	4.73	8.77	10.70	8.07
500	5.70	8.43	10.17	8.10	5.93	10.43	10.93	9.10	6.37	11.07	11.40	9.61
1000	6.80	9.63	10.30	8.91	7.43	11.17	12.33	10.31	8.33	12.10	12.83	11.09
Mean	5.56	8.58	10.07		5.99	9.99	11.21		6.48	10.64	11.64	

F-LSD$_{(0.05)}$ (t ha^{-1}) Weeks	**4**	**8**	**10**
Fertilizer rates (F)	0.92	1.09	0.43
Leaf litter rates (L)	0.92	1.09	0.43
Interaction F x L	NS	NS	NS

Influence of fertilizer NPK 15:15:15 and cacao leaf litter application rates on the number of leaves plant^{-1} of cowpea

Tables 5 and 6 also summarize the effect of fertilizer, NPK 15:15:15 and cacao leaf litter application rates on the number of leaves plant^{-1} of cowpea in 2017 and 2018. Generally, the application of fertilizer, NPK 15:15:15 and cacao leaf litter increased the number of leaves plant^{-1} more than the control. However, at 4 WAP in 2017 and 2018, the complementary use of 500 or 1000 kg ha^{-1} plus either 10 or 20 t ha^{-1} leaf litter gave similar number of leaves plant^{-1}. At 8 WAP in 2017, 1000 kg ha $^{-1}$ NPK 15:15:15 gave significantly the highest number of leaves plant^{-1} as follows: 1000 > 500 > 0 kg ha^{-1} NPK 15:15:15. But in 2018, the applications of 1000 and 500 kg ha^{-1} which have similar cowpea number of leaves plant^{-1} were significantly greater than the 0 kg ha^{-1} (no fertilizer). Cacao leaf litter application rates (20, 10 and 0 t ha^{-1}) followed the same trend. However, in 2017 and 2018 study periods, the use of 20 t ha^{-1} leaf litter alone or the complementary use of either 500 or 1000 kg ha^{-1} NPK 15:15:15 with either 10 or 20 t ha^{-1} leaf litter gave similar leaf number plant^{-1} values. These results, however, were significantly higher than those of the other treatments. The control, again gave the least result, At 10 WAP in 2017 and 2018, the number of leaves plant^{-1} values obtained followed the same trend with those of 8 WAP.

Table 5. Influence of fertilizer and cacao leaf litter application rates on the number of leaves plant^{-1} of cowpea (*Vigna unguiculata)* (2017)

NPK Fertilizer (15:15:15) (Kg ha^{-1})	4 Weeks leaf litter rates (t ha^{-1})				8 Weeks leaf litter rates (t ha^{-1})				10 Weeks leaf litter rates (t ha^{-1})			
	0	**10**	**20**	**Mean**	**0**	**10**	**20**	**Mean**	**0**	**10**	**20**	**Mean**
0	3.27	4.40	4.62	4.09	3.83	5.86	6.40	5.36	3.87	6.83	6.68	5.80
500	3.60	4.51	4.72	4.28	4.46	5.86	6.51	5.61	4.83	6.53	6.73	6.03
1000	3.78	4.72	5.06	4.52	5.54	6.48	6.70	6.24	6.61	7.00	7.11	6.90
Mean	3.55	4.54	4.80		4.61	6.07	6.54		5.10	6.79	6.84	

F-LSD$_{(0.05)}$ (t ha^{-1}) Weeks	**4**	**8**	**10**
Fertilizer rates (F)	0.14	0.22	0.26
Leaf litter rates (L)	0.14	0.22	0.26
Interaction F x L	NS	0.38	0.44

Table 6. Influence of fertilizer and cacao leaf litter application rates on the number of leaves plant^{-1} of cowpea (*Vigna unguiculata)* (2018)

NPK Fertilizer (15:15:15) (Kg ha^{-1})	4 Weeks leaf litter rates (t ha^{-1})				8 Weeks leaf litter rates (t ha^{-1})				10 Weeks leaf litter rates (t ha^{-1})			
	0	**10**	**20**	**Mean**	**0**	**10**	**20**	**Mean**	**0**	**10**	**20**	**Mean**
0	3.21	4.32	5.04	4.19	3.83	6.48	5.94	5.42	3.95	6.65	6.19	5.60
500	3.51	4.42	4.86	4.26	5.42	6.21	6.52	6.05	5.75	6.45	6.67	6.29
1000	3.56	4.79	5.19	4.51	5.48	6.35	6.81	6.21	5.72	6.63	6.91	6.42
Mean	3.43	4.51	5..03		4.91	6.35	6.42		5.14	6.58	6.59	

F-LSD$_{(0.05)}$ (t ha^{-1}) Weeks	**4**	**8**	**10**
Fertilizer rates (F)	NS	0.40	0.45
Leaf litter rates (L)	0.34	0.40	0.45
Interaction F x L	NS	0.69	0.78

Influence of fertilizer NPK 15:15:15 and cacao leaf litter application rates on cowpea leaf length

Tables 7 and 8 summarize the effect of fertilizer NPK 15:15:15 and cacao leaf litter application rates on cowpea leaf length in 2017 and 2018, respectively. The results in the Tables show that the applications of fertilizer NPK 15:15:15 as well as cacao leaf litter significantly influenced cowpea leaf length. At the 4^{th}, 8^{th} and 10^{th} WAP in 2017 and 2018, the application of 1000 kg ha^{-1} NPK 15:15:15 fertilizer significantly gave higher leaf length than either 500 or 0 kg ha^{-1} (control i.e. no fertilizer). In terms of cacao leaf litter treatment, the similar results of 20 and 10 t ha^{-1} gave significantly higher leaf length than the 0 t ha^{-1} as follows; 20 = 10 > 0 t ha^{-1}

However, at 10^{th} WAP in 2017 and 2018, there was no significant fertilizer (F) x leaf litter (L) interaction effects on cowpea leaf length. The 4^{th} and 8^{th} WAP had similar trends of F x L interaction effects on cowpea leaf length. Generally, the addition of 10 or 20 t ha^{-1} cocoa leaf litter with or without inorganic fertilizer (NPK 15:15:15) rates more significantly increased leaf length than no leaf litter rates with or without fertilizer application rates. The complementary use of F_2L_2, F_1L_2 and F_0L_2 had statistically similar cowpea leaf length results which were significantly ($P \leq 0.05$) greater than those of the control treatment (no fertilizer and no leaf litter). The order of improvement in 2018 was as follows: $F_2L_2 = F_2L_1 = F_1L_2 = F_0L_2 = F_1L_1 = F_0L_1 > F_1L_0 = F_2L_0 > F_0L_0$. This means that the use of 10 t ha^{-1} cacao leaf litter without fertilizer gave significantly higher cowpea leaf length than either 1000 or 500 kgha-1 fertilizer when used alone.

Table 7. Influence of fertilizer and cacao leaf litter application rates on leaf length of cowpea (*Vigna unguiculata)* (2017)

NPK Fertilizer (15:15:15) (Kg ha^{-1})	4 Weeks leaf litter rates (t ha^{-1})				8 Weeks leaf litter rates (t ha^{-1})				10 Weeks leaf litter rates (t ha^{-1})			
	0	**10**	**20**	**Mean**	**0**	**10**	**20**	**Mean**	**0**	**10**	**20**	**Mean**
0	4.00	7.50	7.73	6.41	3.90	9.17	7.93	7.00	4.00	8.17	7.97	6.71
500	6.17	7.67	9.67	7.83	7.30	9.80	10.17	9.09	7.50	9.87	10.17	9.18
1000	6.67	10.00	10.83	9.17	7.93	10.63	9.50	9.36	8.37	10.77	10.00	9.71
Mean	5.61	8.39	9.41		6.38	9.87	9.20		6.62	9.60	9.38	

	F-LSD$_{(0.05)}$ (t ha^{-1}) Weeks		
	4	**8**	**10**
Fertilizer rates (F)	0.54	0.84	1.26
Leaf litter rates (L)	0.54	0.84	1.26
Interaction F x L	0.94	1.46	NS

Table 8. Influence of fertilizer and cacao leaf litter application rates on leaf length of cowpea (*Vigna unguiculata)* (2018)

NPK Fertilizer (15:15:15) (Kg ha^{-1})	4 Weeks leaf litter rates (t ha^{-1})				8 Weeks leaf litter rates (t ha^{-1})				10 Weeks leaf litter rates (t ha^{-1})			
	0	**10**	**20**	**Mean**	**0**	**10**	**20**	**Mean**	**0**	**10**	**20**	**Mean**
0	4.43	8.00	9.07	7.17	4.93	9.40	9.77	8.03	5.17	9.53	9.00	7.90
500	6.83	7.33	8.73	7.63	7.67	9.50	10.00	9.06	8.13	9.83	10.63	9.53
1000	6.33	9.33	9.23	8.30	6.93	10.63	10.63	9.40	7.20	11.00	10.87	9.69
Mean	5.87	8.22	9.01		6.51	9.84	10.13		6.83	10.12	10.17	

	F-LSD$_{(0.05)}$ (t ha^{-1}) Weeks		
	4	**8**	**10**
Fertilizer rates (F)	0.41	0.56	1.04
Leaf litter rates (L)	0.41	0.56	1.04
Interaction F x L	0.71	0.96	NS

F_2L_1 F_1L_0 F_1L_2 F_2L_0 F_0L_2

F_2L_2

Cowpea plants at 6 weeks after planting (WAP) treated with various rates of NPK 15:15:15 fertilizer (F) and cocoa leaf litter (L)

Influence of fertilizer NPK 15:15:15 and cacao leaf litter application rates on the leaf area (cm^2) of cowpea in 2017 and 2018

Table 9 summarizes the effects of fertilizer NPK 15:15:15 and cacao leaf litter application rates on cowpea leaf area at the 10th week after planting (WAP) in 2017 and 2018. The results from the table show that the applications of the various rates of fertilizer had significant ($P>0.05$) effect on leaf area of cowpea. However, the application of 1000 kg ha^{-1} NPK 15:15:15 gave significantly ($P>0.05$) higher cowpea leaf area than the 0 or 500 kg ha^{-1} in the following significant order : $F_2 > F_1 > F_0$. Cacao leaf litter application rates followed same trend as that of the fertilizer in the order : $L_2 > L_1 > F_0$.

Table 9 also shows that fertilizer NPK 15:15:15 (F) x cacao leaf litter (L) interaction had significant effects on cowpea leaf area at the 10th week after planting (WAP) in 2017 and 2018. However, cowpea plants with leaf litter application gave significantly higher leaf area than those without leaf litter application. Also, cowpea plants treated with 1000 kg ha^{-1} NPK 15:15:15 plus 20 or 10 t ha^{-1} cacao leaf litter (i.e. F_2L_2 or F_2L_1) gave higher leaf area than the rest treatments. The treatment without fertilizer and leaf litter, i.e. the topsoil only (F_0L_0), gave significantly the least leaf area values in 2017 and 2018. The relative improvement of the leaf area in 2018 was in the following significant order : $F_2L_2 > F_2L_1 > F_1L_2 > F_1L_1 > F_0L_2 > F_0L_1 > F_2L_0 > F_1L_0 > F_0L_0$.

Table 9. Influence of fertilizer and cacao (*Theobroma cacao* L.) leaf litter application rates on cowpea (*Vigna unguiculata)* leaf area (cm^2)

NPK Fertilizer (15:15:15) (Kg ha^{-1})	2017 leaf litter rates (t ha^{-1})				2018 leaf litter rates (t ha^{-1})			
	0	10	20	Mean	0	10	20	Mean
0	10.1	44.1	47.0	33.7	14.6	50.2	57.8	40.9
500	31.5	62.2	63.6	52.4	31.1	65.3	72.7	56.4
1000	39.0	68.1	64.8	57.3	36.0	79.9	83.7	66.5
Mean	26.9	58.3	58.5		27.2	65.1	71.4	

	F-LSD$_{(0.05)}$ (cm^2) Year	
	2017	**2018**
Fertilizer rates (F)	0.55	0.27
Leaf litter rates (L)	0.55	0.27
Interaction F x L	1.70	1.24

Influence of fertilizer NPK 15:15:15 and cacao leaf litter application rates on cowpea grain yield in 2017 and 2018

Figure 3 summarizes the influence if various NPK 15:15:15 fertilizer and cacao leaf litter application rates on cowpea grain yield in 2017 and 2018. The significant performances of the various fertilizer rates were as follows;

a. 1000 = 500 > 0 kg ha^{-1} for 2017 and
b. 1000 > 500 > 0 kg ha^{-1} for 2018.

However, the influence of various cacao leaf litter rates on grain yield of cowpea for 2017 and 2018 were as follows: 20 > 10> 0 t ha^{-1}. Thus, the 20 and 0 t ha^{-1} cacao leaf litter gave significantly the highest and least cowpea grain yield, respectively in 2017 and 2018.

There was no significant F x L interaction effects on cowpea grain yield in 2017 (Figure 3). However, in 2018 the application of 1000 kg ha^{-1} NPK 15:15:15 + 20 t ha^{-1} cocoa leaf litter (F_2L_2) gave significantly the highest cowpea grain yield than the control – 0 kg ha^{-1} fertilizer plus 0 t ha^{-1} leaf litter. Again, the application of 20 t ha^{-1} leaf litter with either 1000 kg ha^{-1} or 500 kg ha^{-1} NPK 15:15:15 gave significantly higher cowpea grain yield than those of the 10 t ha^{-1} leaf litter plus either 1000 kg ha^{-1} or 500 kg ha^{-1} NPK 15:15:15 . However, the applications of various rates of NPK 15:15:15 (1000, 500 and 0 kg ha^{-1}) with no cacao leaf litter application rates, that is F_2L_0, F_1L_0 and F_0L_0, gave significantly lower cowpea grain yield results than those of the fertilizer application rates plus either 20 or 10 t ha^{-1} cacao leaf litter (F_2L_2, F_2L_1, F_1L_2 or F_1L_1).

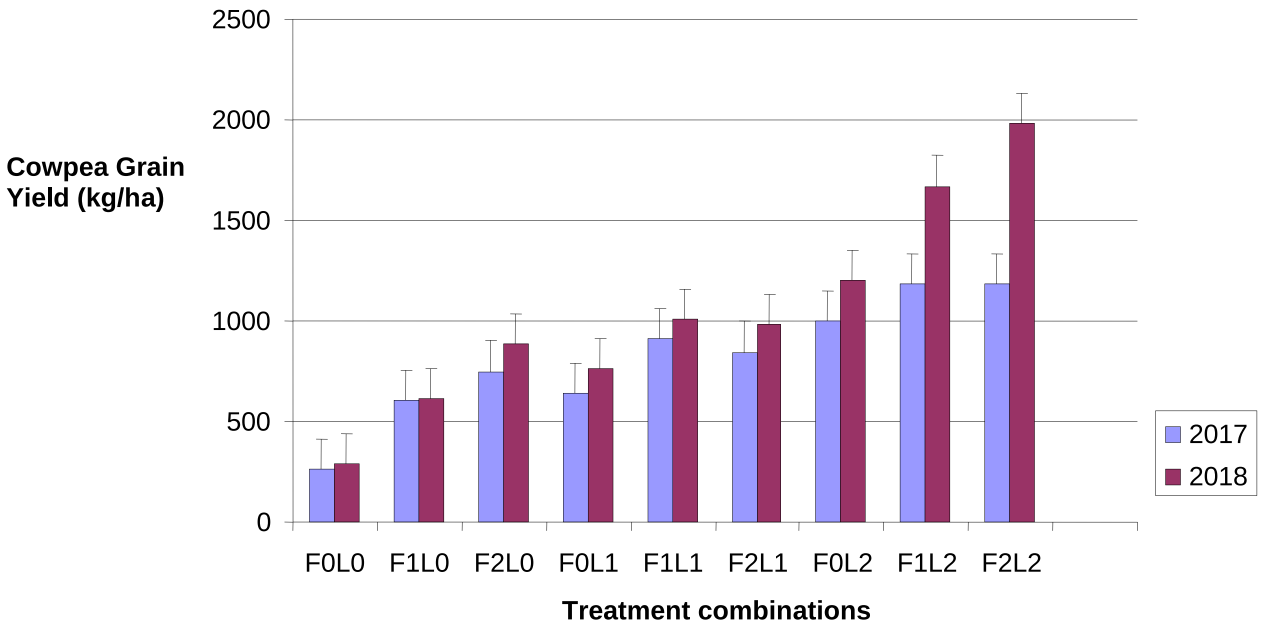

Figure.3 Influence of fertilizer and cacao leaf litter application rates on cowpea grain yield in 2017 and 2018

(a) Cowpea Growth Parameters

Generally, the cowpea growth components followed the same trend with those of maize growth components as indicated by Ojimgba (2019). The addition of 10 or 20 t ha^{-1} cacao leaf litter with or without inorganic fertilizer NPK 15:15:15 rates more significantly increased the cowpea plant height, leaf diameter, number of leaves $plant^{-1}$, leaf length and leaf area than no leaf litter rates with or without fertilizer application rates. This improvement according to Young (1989) could be as a result of the return in litter and pruning of some 100 – 300 kg N/ha/yr under cocoa and coffee plantations with shade trees. Ouda and Mahadeen (2008) added that shoot fresh and dry weights of broccoli plants tended to increase by increasing dose of organic manure. They further stated that number of leaves per plant showed a little increase with increased organic manure dose. That each increase in inorganic fertilizer dose tended to increase number of leaves per plant compared with control. They confirmed that plots receiving a combination of organic and inorganic fertilizers produced slightly higher ($P>0.05$) fresh and dry weights of shoot. These results are in accordance with Magnusson (2002) on chinensis cabbage (*B. chinensis*) and Abdelrazzag (2002) on onion (*Allium cepa*). Furthermore, organic manure activates many species of living organisms, which release phytohormones and may stimulate the plant growth and absorption of nutrients (Arisha *et al*., 2003). Such organisms need nitrogen for multiplication. This is plausible reason that use of organic manure with inorganic fertilizer showed a beneficial effect on dry matter accumulation. Organic manure can serve as alternative practice to mineral fertilizers (Naeem *et al*., 2006) for improving soil structure (Dauda *et al*., 2008) and maize growth Mbagwu, 1992). However, the litter fall is major recognized avenue for addition of organic matter (nutrients) to the soil from the trees. Therefore, the increase in cowpea growth components might be due to the combinations of the cacao leaf litter with high organic matter status and inorganic fertilizer NPK 15:15:15, nitrogen being one of the major nutrient elements.

(b) Cowpea Grain Yield

The results contained in Figure 3 shows that the applications of various rates of NPK 15:15:15 fertilizer (i.e. 1000, 500 and 0 kg $^{-1}$) without cacao leaf litter application rates gave significantly lower cowpea grain yield results than those of the fertilizer application rates plus either 20 or 10 t ha^{-1} cacao leaf litter. However, the applications of the highest dose of inorganic fertilizer (1000 kg ha^{-1}, F_2) with the highest dose of cocoa leaf litter (20 t ha^{-1}, L_2) (i.e. F_2L_2) which produced the highest yield of cowpea grain yield was similar to results obtained by Ouda and Mahadeen (2008) and Ojimgba (2019). They confirmed that the application of the highest dose of inorganic fertilizer (60 kg ha^{-1}) with the highest dose of organic manure (80 t ha^{-1}) produced the highest yield of main heads of broccoli and maize, respectively. Furthermore, Anikwe *et al*., (2003) added that the cumulative results of maize plots amended with manure + NPK had an over 8-fold increase in grain yield relative to the control. They added that other treatments (mulch + NPK and NPK alone) did not statistically affect grain yield of maize relative to the control (unamended plots). According to them, in groundnut plots amended with manure + NPK, cumulative data show that grain yield also increased ($P<0.05$) by 123% relative to the control. Ojimgba *et al.*, (2008) reported similar results and concluded that the reason for this is that organic wastes had about 90% higher mineralization rate than the unamended control or inorganic fertilizer.

The poor yield obtained in unamended control plots may be associated with the acidity which is a major problem in many tropical soils (Ojimgba and Mbagwu, 2007). Muller-Samann and Johannes (1997) confirmed this statement that on soils with pH values under 5, the exchange particles elements are coated with hydrogen and nutrient cations (Mg, K, Ca) and often also with aluminum (Al) ions which may lead to aluminum toxicity and phosphate fixation through the formation of Al-phosphates. Also, only at pH values exceeding 5 does aluminum become hydroxide, so that toxicity is no longer a problem. The signs of aluminum toxicity are reduced, stunted growth and disrupted Ca and P metabolism, which was the problem with the control and fertilizer treated plots as well as their high Al saturation. The little yield of the unamended control plots of cowpea might be due to nitrogen fixed by the cowpea which is the characteristics of all leguminous crops.

4. Conclusion and Recommendations

The research has documented basic information about the potentials and uses of cacao in an agroforestry farm at the Cocoa Research Institute of Nigeria (CRIN) Ibeku Sub-station, Umuahia, Nigeria. The study also revealed that cowpea (*Vigna unguiculata* L.) can be successfully grown with cacao leaf litter incorporated in the soil without the use of costly inorganic fertilizers. The results also pointed to the fact that the leaf litter improved highly the grain yield of cowpea in the eroded soils, whereas inorganic fertilizer had no such effect.

The following recommendations are made based on the results of the study:

i) Studies on litter production and decomposition effects on crop growth and yield should be carried out in different agroforestry ecosystems of the humid and sub-humid (including the arid and semi-arid) zones of West Africa.

ii) I, also recommend that farmers should plant cocoa trees along the contour bunds or boundaries as alley, prune them periodically or allow the leaves to fall and decay to improve the nutrient status and structure of the soils.

It is hoped that the results of this study will encourage farmers embark on the establishment of cacao plantations using economically viable landuse management system such as agroforestry. The results will encourage greater production of cocoa beans as well as encourage the establishment of small-scale industries to process the products. The establishment of cocoa plantations and the processing of the products from the plantations could boost the income of farmers and the nation's foreign exchange reserve via exportation of the processed products. It is also hoped that the results of the study will encourage the farmers to profitably grow cowpea with little or no inorganic fertilizer application.

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