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Effect of inorganic fertilizer (NPK 15:15:15) and cacao (*Theobroma cacao* L.) leaf litter application rates on maize (*Zea mays* L.) performance in the tropical forest

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Abstract

Effects of inorganic fertilizer (NPK 15:15:15) and cacao leaf litter application rates on maize performance in the tropical forest was studied for 24 months (2016 and 2017) at the 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 maize 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 O t, 10 t and 20 t ha^{-1} which were also represented by L_o, L_1 and L_2 (Factor L), respectively. The result shows that application of either 10 or 20 t ha^{-1} cocoa leaf litter alone or complementary application of either 10 or 20 t ha^{-1} cacao leaf litter plus 500 or 1000 kg ha^{-1} NPK 15:15:15 fertilizer significantly ($p<0.05$) increased the various maize growth and yield components than the fertilizer rates alone in 2016 and 2017. The treatment without fertilizer and leaf litter, i.e. topsoil only (F_0L_0) gave significantly the least maize 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} cacao leaf litter (F_2L_2). The maize 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 maize 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

Maize, Performance, inorganic fertilizer, Cacao leaf litter, Application rates, Tropical forest

Introduction

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. 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).

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).

Kang *et al*., (1985) found that the addition of low rates of N and leucaena prunings in their alley cropping experiments significantly increased maize 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. The authors 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 effect of inorganic fertilizer (NPK 15:15:15) and cacao (*Theobroma cacao* L.) leaf litter application rates on maize (*Zea mays* L.) performance in the tropical forest and how best this leaf litter as organic fertilizer could enhance maize production.

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.

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 April of 2016, 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 maize 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 maize (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 and incubation period of four (4) months was allowed after the application before maize was planted. 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 maize (*Zea mays* L.) was done on a flat harrowed soil surface. Maize 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. Maize was planted in early June. 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 which were randomly selected, tagged and sampled.

a) Maize Plant Growth

i) Leaf area was determined by the method of (Leaf length x Leaf diameter x 0.8(K) Ambasht and Ambasht (2006).

b) At harvest

i) Above ground biomass,
ii) Below ground biomass, total biomass
iii) Cob biomass
iv) Grain yield: per plot and per ha.

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 cobs and their stalks were harvested from each plot, dried, shelled and weighed. The grains were dried at 60^{0}C for 48 hours, whereas the stalk or stover was air-dried in the greenhouse.

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.

Results

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.

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

Effect of fertilizer and cacao (*Theobroma cacao* L.) leaf litter application rates on maize (*Zea mays* L.) leaf area (cm^2) in Ajata - Ibeku, Umuahia

Table 3 summarizes the effects of fertilizer NPK 15:15:15 and cacao leaf litter application rates on the leaf area of maize at 10 weeks after planting (WAP) in both 2016 and 2017. However, at 10th WAP, the applications of the various rates of fertilizer (0, 500 and 1000 kg ha^{-1}) had significant effect on the leaf area of maize. The application of 1000 kg ha^{-1} NPK 15:15:15 gave significantly higher leaf area values in 2016 and 2017 than that of 500 and 0 kg ha^{-1} in the following significant ($P < 0.05$) order : 1000 > 500 > 0 kg ha^{-1}. At the 10th week also, the various application rates of cacao leaf litter i.e. 20, 10 and 0 t ha^{-1}, followed significantly the same trend with those of fertilizer.

Table 3 also shows that fertilizer (F) x leaf litter (L) interaction had significant effects on maize leaf area at the 10th WAP in 2016 and 2017. The application of 20 t ha^{-1} cacao leaf litter complementarily with 500 kg ha^{-1} NPK 15:15:15 (F_1L_2) significantly improved maize leaf area than the zero (0), 500 or 1000 kg ha^{-1} NPK 15:15:15 alone. However, maize plants without cacao leaf litter application gave significantly lower maize leaf area than the plants with cacao leaf litter application. For example in 2016, the application of 500 kg ha^{-1} NPK 15:15:15 (F_1L_0) alone had leaf area value of 340 cm^2, whereas 10 t ha^{-1} (F_0L_1) of leaf litter had leaf area of 373.6 cm^2. The values obtained in 2017 followed the same trend. Therefore, leaf litter alone gave significantly higher leaf area values than fertilizer alone. The relative improvement of the leaf area in both 2016 and 2017 was in the following significant order : $F_1L_2 > F_0L_2 > F_2L_1 > F_1L_1 = F_2L_2 > F_0L_1 > F_2L_0 > F_1L_0 > F_0L_0$.

Table 3: Effect of fertilizer and cacao (*Theobroma cacao* L.) leaf litter application rates on maize (*Zea mays* L.) leaf area (cm^2)

NPK Fertilizer (15:15:15) (Kg ha^{-1})	2016 leaf litter rates (t ha^{-1})				2017 leaf litter rates (t ha^{-1})			
	0	10	20	Mean	0	10	20	Mean
0	73.9	373.6	457.1	301.5	71.1	490.8	584.2	382.0
500	340.0	579.2	625.0	514.7	213.0	533.4	598.1	448.2
1000	453.5	580.0	557.5	530.3	397.2	551.9	524.3	491.1
Mean	289.1	510.9	546.5		227.1	525.4	568.9	

	F-LSD$_{(0.05)}$ (cm^2) Year 2016	2017
Fertilizer rates (F)	5.28	3.82
Leaf litter rates (L)	5.28	3.82
Interaction F x L	15.91	11.39

Effect of fertilizer and cacao leaf litter application rates on the various yield components of maize (*Zea mays* L.)

Maize cob weight and grain yield

Table 4 and Figure 1 summarize the effects of NPK 15:15:15 and cacao leaf litter application rates on maize cob weight and grain yields, respectively in 2016 and 2017. The significant performances of the various fertilizer rates were as follows: 1000 > 500 > 0 kg ha^{-1}. Again, the effects of various cacao leaf litter rates on grain yield of maize 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 maize cob dry weight and grain yields, respectively in 2016 and 2017.

There were no significant F x L interaction effect on maize cob dry weight and grain yield in 2017 (Table 4 and Figure 1). However, in 2016, the application of 1000 kg ha^{-1} + 20 t ha^{-1} cacao leaf litter (F_2L_2) gave significantly the highest maize grain yield (2.43 t ha^{-1}), while topsoil only (control) - 0 kg ha^{-1} fertilizer + 0 t ha^{-1} leaf litter (F_0L_0), and 500 kg ha^{-1} NKP 15:15:15(F_1L_0) had similar but the least results, 0.00 and 0.17 t ha^{-1}, respectively. The grain yield values of 2017 followed the same trend. In summary, the application of either 500 or 1000 kg ha^{-1} NPK 15:15:15 + 10 or 20 t ha^{-1} cacao leaf litter significantly improved maize cob dry weight and maize grain yields than the use of zero (0) or 500 kg ha^{-1} NPK 15:15:15 only. The relative improvement of maize grain yield in 2016 was in the following significant order : $F_2L_2 > F_2L_1 = F_1L_2 > F_1L_1 = F_0L_2 = F_2L_0 = F_0L_1 > F_1L_0 = F_0L_0$. However, the values of maize cob weight in 2016 followed same trend.

Table 4: Effect of fertilizer and cacao leaf litter application rates on maize (*Zea mays* L.) cob dry weight (t ha^{-1}) over time

NPK Fertilizer (15:15:15) (Kg ha^{-1})	2016 leaf litter rates (t ha^{-1})				2017 leaf litter rates (t ha^{-1})			
	0	10	20	Mean	0	10	20	Mean
0	0.00	1.04	1.51	0.85	0.00	1.55	1.95	1.17
500	0.34	1.91	3.17	1.81	1.07	2.92	3.10	2.36
1000	2.05	3.28	3.78	3.03	2.15	3.47	3.90	3.17
Mean	0.80	2.07	2.82		1.07	2.65	2.98	

	F-LSD$_{(0.05)}$ (t ha^{-1}) Year 2016	2017
Fertilizer rates (F)	0.26	0.25
Leaf litter rates (L)	0.26	0.25
Interaction F x L	0.45	NS

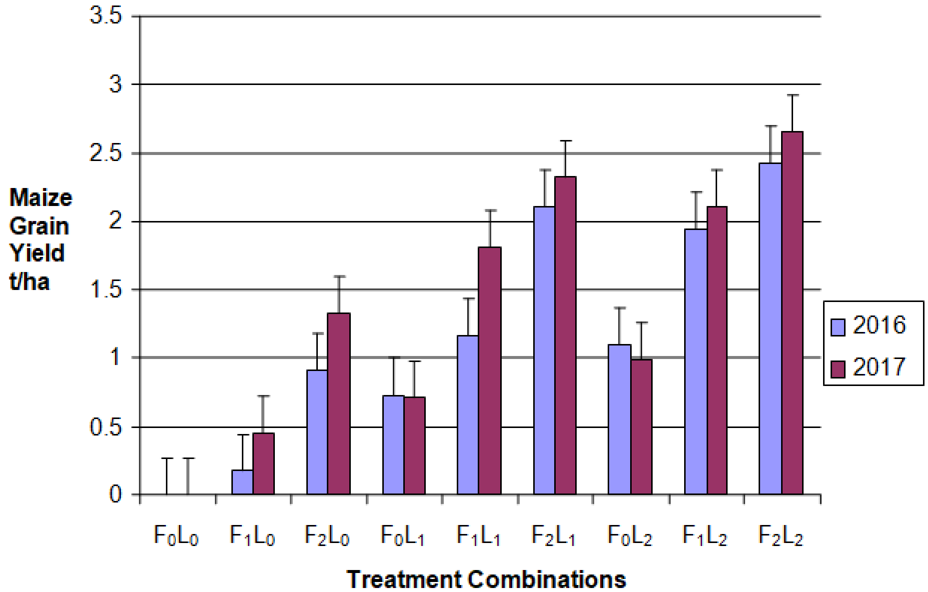

Fig. 1: Effect of fertilizer and cacao leaf litter application rates on maize (Zea mays L.) grain yield in 2016 and 2017

Above ground biomass

Table 5 summarizes the effects of the NPK 15:15:15 fertilizer and cacao leaf litter application rates on the dry weight of above ground biomass of maize in 2016 and 2017. The above ground biomass (stem + leaf + cob dry weight) gave significantly similar trends of results throughout the years of study (2016 and 2017). However, 1000 kg ha^{-1} and 0 kg ha^{-1} fertilizer (NPK 15:15:15) had significantly the highest and least above ground biomass of maize, respectively, in the following order: 1000 >500 >0 kg ha^{-1}. The performance of cacao leaf litter rates on above ground biomass in 2016 and 2017 was in the following significant order: 20>10>0 t ha^{-1}; so that in 2017, 20 and 0 t ha^{-1} gave significantly (P<0.05) the highest (4.22 t ha^{-1}) and least results (0.18 t ha^{-1}), respectively.

In terms of F x L interaction, there was no significant interaction effect on above ground biomass in 2017 (Table 5). However, in 2016, there was significant F x L interaction effect on maize above ground biomass, so that the application of 1000 kg ha^{-1} NPK 15:15:15 + 20 t ha^{-1} cacao leaf litter more significantly improved maize above ground biomass than the topsoil only in the following order in 2016 : $F_2L_2 > F_2L_1 = F_1L_2 > F_1L_1 = F_0L_2 = F_2L_0 > F_0L_1 > F_1L_0 > F_0L_0$.

Below ground biomass of maize

Table 6 summarizes the effect of NPK 15:15:15 and cacao leaf litter application rates on below ground biomass (dry weight) of maize (*Zea mays* L.) at Umudike, Nigeria in 2016 and 2017. In 2016, 1000 and 0 kg ha^{-1} NPK 15:15:15 had significantly the highest and least below ground biomass of maize, respectively. However, in 2017, 500 and 1000 kg ha^{-1} NPK 15:15:15 had statistically similar results that were significantly greater than that of 0 kg ha^{-1} NPK 15:15:15.

The performance of cacao leaf litter rates on below ground biomass in 2016 and 2017 was in the following significant order: 20>10>0 t ha^{-1}. Thus, 20 and 0 t ha^{-1} gave significantly the highest and least below ground biomass of maize, respectively. In terms of F x L interactions, there was no significant interaction effect on below ground biomass of maize in both 2016 and 2017 cropping seasons (Table 6).

Table 5: Effect of fertilizer and cacao leaf litter application rates on maize (*Zea mays* L.) above ground biomass

NPK Fertilizer (15:15:15) (Kg ha^{-1})	2016 leaf litter rates (t ha^{-1})				2017 leaf litter rates (t ha^{-1})			
	0	10	20	Mean	0	10	20	Mean
0	0.09	2.42	3.45	1.98	0.18	2.91	4.22	2.44
500	0.99	4.25	6.17	3.80	2.34	5.94	6.59	4.96
1000	3.98	6.41	7.55	5.98	4.28	6.75	7.75	6.26
Mean	1.69	4.36	5.72		2.27	5.20	6.19	

	F-LSD$_{(0.05)}$ (t ha^{-1}) Year 2016	2017
Fertilizer rates (F)	0.47	0.45
Leaf litter rates (L)	0.47	0.45
Interaction F x L	0.81	NS

*** Above ground biomass = Shoot i.e. Stem + leaf + cob dry weight**

Table 6: Effect of fertilizer and cacao leaf litter application rates on below ground (root) biomass of maize *(Zea mays* L.)

NPK Fertilizer (15:15:15) (Kg ha^{-1})	2016 leaf litter rates (t ha^{-1})				2017 leaf litter rates (t ha^{-1})			
	0	10	20	Mean	0	10	20	Mean
0	0.10	0.78	0.99	0.60	0.09	0.68	1.00	0.59
500	0.30	1.03	1.27	0.87	0.56	1.77	1.91	1.38
1000	1.02	1.39	1.76	1.39	0.79	1.51	1.85	1.38
Mean	0.45	1.07	1.34		0.44	1.32	1.59	

	F-LSD$_{(0.05)}$ (t ha^{-1}) Year 2016	2017
Fertilizer rates (F)	0.16	0.24
Leaf litter rates (L)	0.16	0.24
Interaction F x L	NS	NS

Total biomass (above ground + below ground biomass)

Table 7 shows in 2016 and 2017 that the fertilizer and cacao leaf litter application rates had similar trends of total biomass results as shown below:

a) NPK 15:15:15 fertilizer effects: 1000>500>0 kg ha^{-1}

b) Cacao leaf litter effects: 20>10>0 t ha^{-1}

However, there was no significant effect existed between the total biomass values of the treatments with either 500 or 1000 kg ha^{-1} NPK 15:15:15 + 10 or 20 t ha^{-1} cacao leaf litter in 2016 and 2017 study periods, i.e. there was no significant F x L interactions.

Table 7: Effect of fertilizer and cacao leaf litter application rates on total biomass of maize (*Zea mays* L.) .

NPK Fertilizer (15:15:15) (Kg ha^{-1})	2016 leaf litter rates (t ha^{-1})				2017 leaf litter rates (t ha^{-1})			
	0	**10**	**20**	**Mean**	**0**	**10**	**20**	**Mean**
0	0.12	3.20	4.43	2.58	0.27	3.59	5.21	3.02
500	1.29	5.28	7.44	4.67	2.80	7.71	8.50	6.34
1000	5.01	7.81	9.31	7.38	5.07	8.26	9.61	7.64
Mean	2.14	5.43	9.06		2.71	6.52	7.77	

	F-LSD$_{(0.05)}$ (t ha^{-1}) Year	
	2016	**2017**
Fertilizer rates (F)	0.59	0.60
Leaf litter rates (L)	0.59	0.60
Interaction F x L	NS	NS

***Total biomass = above + below ground biomass**

Evaluation of the performance of yield and yield components of maize as influenced by fertilizer and cacao leaf litter over time

Table 8 summarizes the evaluation of the performances of growth, yield and yield components of maize (*Zea may* L.) as influenced by NPK 15:15:15 fertilizer and cacao (*Theobroma cacao* L.) leaf litter application rates in 2016 and 2017. The Table shows that fertilizer NPK 15:15:15 and leaf litter application had statistically similar results with those of the 2017. Generally, the maize crop performances in terms of yield and yield components over the study periods, 2016 and 2017 were statistically similar.

Table 8: Evaluation of the performance of growth, yield and yield components of maize as influenced by NPK 15:15:15 fertilizer and cacao leaf litter application rates over time (2016 and 2017)

Plant variables	Unit of assessment	Fertilizer NPK 15:15:15 (F) Mean values Year			Cocoa leaf litter (L) mean values Year		
		2016	**2017**	**t – cal (L)$^{+}$**	**2016**	**2017**	**t-cal (L)$^{++}$**
	Yield and	**Yield**	**Components**				
Cob dry weight	(t ha^{-1})	1.90	2.23	0.38^{NS}	1.90	2.23	0..40^{NS}
Grain yield	(t ha^{-1})	1.17	1.37	0.35^{NS}	1.17	1.38	0.36^{NS}
Above ground biomass	(t ha^{-1})	3.92	4.55	0.39^{NS}	3.92	4.55	0.35^{NS}
Below ground biomass	(t ha^{-1})	0.95	1.12	0.48^{NS}	0.95	1.12	0.39^{NS}
Total biomass	(t ha^{-1})	4.88	5.67	0.40^{NS}	4.88	5.67	0.38^{NS}

t – table $_{(0.05)}$ for fertilizer and leaf litter rates for 2016 and 2017 = 4.30
+ = t – calculated (F): calculated "t – test value for fertilizer application rates
++ = t – cal (L) calculated "t = test values for leaf litter rates
NS = Not significant when t = cal < t – table $_{(0.05)}$.

Maize plants at 8 WAP without fertilizer and cocoa leaf litter application (F_0L_0).

Maize plants at 4 WAP treated with 500 kg ha^{-1} NPK 15:15:15 fertilizer and 20 t ha^{-1} cocoa leaf litter (F_1L_2).

Discussion

However, the soil pH value (4.42) of the study site was acidic. Ojimgba and Mbagwu (2007) observed that there was a problem of exposure of very acidic subsoil due to erosion. They attributed this low value partly because the soils were heavily leached of the basic cations due to very heavy rainfall associated with the rainforest zone. The organic matter content (0.72%) was low which is typical of most tropical soils which have been exposed to hot weather and constant cultivation. As erosion increased, organic carbon is reduced (Ojimgba and Mbagwu, 2007). Opara-Nadi (2000) concluded that, these soils being an Ultisol constitute the bulk of the upland soils of southeastern Nigeria. He added that these soils are rich in free iron but have a lower mineral reserve and lower fertility than the ferruginous tropical soils. Their cation exchange capacity and base saturation were very low.

The differential performance of this fertilizer NPK 15:15:15 and cacao leaf litter application rates on maize leaf area, cob weight, grain yield, below and above ground biomass are shown in the results above for the two cropping seasons. The values of the 2016 and 2017 cropping seasons followed similar trend. The fertilizer and cacao leaf litter enhanced maize performance significantly ($P< 0.05$) than the unamended control i.e. plot without fertilizer or cacao leaf litter. Heerendra (2017) confirmed that forest tree leaf litters can be applied as an organic amendment for the production of agricultural crops. Ojimgba, *et al.*, (2010) added that the addition of cacao leaf litter to the degraded soils of Umuahia increased the values of organic matter more than the control and fertilizer alone. This increase in organic matter values due to leaf litter could be the reason for the increase in maize growth and grain yield in the eroded soils.

Generally, the application of either 10 or 20 t ha^{-1} cacao leaf litter alone or the complementary application of either 10 or 20 t ha^{-1} cacao leaf litter and 500 or 1000 kg ha^{-1} NPK 15:15:15 significantly improved the various maize growth parameters than the fertilizer rates namely; zero (0), 500 and 1000 kg ha^{-1} NPK 15:15:15 alone. However, plants without cacao leaf litter application gave significantly lower maize growth attributes than plants with leaf litter. The treatment without fertilizer and leaf litter, i.e. topsoil only (F_0L_0), gave significantly the least maize growth components. Ojimgba *et al*., (2008) confirmed that addition of amendments improved the growth of maize relative to unamended control. They also added that the variation in response of maize to treatments may be due to the amount of nutrients supplied and mineralization rates. Mbagwu (1992) also reported similar results. However, the increase in maize yield components may be attributed to the higher organic matter contents of the soils treated with cocoa leaf litter (Ojimgba *et al*. 2010). Muller-Samann and Johannes, (1997) reported that the tree's greatest virtue is its ability to improve the soil. That its leaves, falling at the beginning of the rainy season, supply the soil with nutrients and organic matter, especially *Acacia albida* . They added that trials showed that soil organic matter, pH value, microbiological activity and cation exchange, as well as the supply of macro-nutrients, were markedly higher under *Acacia albida* than on open land. The deep taproot of trees means that nutrients from the deeper soil layers can be accessed. These are deposited on the soil surface when the leaves are shed. Thus the tree acts as a nutrient pump. Hence, raising the organic matter and nutrient status of the soil would increase the maize over those control plots.

The application of either 500 or 1000 kg ha^{-1} NPK 15:15:15 complementarily with 10 or 20 t ha^{-1} cacao leaf litter more significantly improved maize yield components (cob dry weight, grain yield, above ground biomass and below ground biomass) than the control or 500 kg ha^{-1} NPK 15:15:15 only in 2016 and 2017 cropping seasons. The highest values were obtained with the application of 1000 kg ha^{-1} NPK 15:15:15 with 20 t ha^{-1} cocoa leaf litter (F_2L_2). Young (1989) confirmed that grain yields under crown can be substantially higher than in the open field, with increases of between 36 and 178% noted in trials in Ethiopia and Senegal. 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 yield of maize. 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.

The results presented here also showed that maize cob dry weight and grain yields of the control plots (F_0L_0) recorded no yields or values, while the above ground biomass and below ground biomass had significantly the least values. The main causes of yield reduction by erosion are lowering of fertility through loss of organic matter and associated nutrients (Ojimgba and Mbagwu, 2007). Several researchers like Mbagwu *et al.,* (1984) have concluded that erosion reduced to great extent maize yields. The poor results of the yield components may be attributed to the acidity of the soil which Sierra *et al.,*(2003) confirmed that soil acidity reduces maize yields on about 8 million hectares, mostly in tropical developing countries. Gaume *et al.,* (2001) added that aluminum toxicity due to high exchangeable Al, reduced P uptake is the main factors affecting maize growth and yield on acid soils. The high exchangeable Al and low available soil P of the control plots of the study site confirmed the above findings.

Conclusion

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 maize (*Zea mays* 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 yield and yield components of maize. Therefore, the application of either 500 or 1000 kg ha^{-1} NPK 15:15:15 complementarily with 10 or 20 t ha^{-1} cacao leaf litter significantly improved maize yield components (cob dry weight, grain yield, above ground biomass and below ground biomass) than the control or 500 kg ha^{-1} NPK 15:15:15 only in 2016 and 2017 cropping seasons., whereas the control had zero yield. Also, application of leaf litter alone performed better than the control.

Recommendations

The following recommendations are made based on the results of the studies.

i) This type of study on leaf litter and inorganic fertilizer effect 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) Leaf litter could be used for the rehabilitation of the eroded soils (Ultisols) of the South-eastern Nigeria.
iii) Also farmers should plant cacao 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 maize with little or no inorganic fertilizer application.

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