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Maize Grain Yield and Soil Macro Nutrients Dynamics to Varying Rates of Plant Residues Application

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ABSTRACT: Field trials were conducted at Federal University of Agriculture Abeokuta, Farm on the response of maize grain yield and some soil nutrients have influenced by rates of residue application. It was a 6 x 3 factorial experiment in a randomized complete block design (RCBD) in three replicates. The plant residue were: Chromolaena odorata,(CO) Maize stover,(MZ) Banana/Plantain leaves (BN), Leuceana leucocephela,(LL) Neem Clipping(NM) and Panicum maximum (PM) applied at 0, 10 and 20 t/ha rates two weeks before planting. Maize TZEE 1 – Y variety were planted at a spacing of 25 cm x 75 cm and two seeds per hole and thinned to one after two weeks. Data were analyzed for grain yield of maize and some soil properties at harvesting. Data collected was subjected to analysis of variance and the means were compared using the least significant difference at 5% level of probability. The parameters assessed were significantly influenced ($P < 0.05$) by the plant residue and rates of application. LL gave the highest grain yield for all the rates examined (1868.8, 4200.0 and 5337.5kg/ha) for 0, 10 and 20t/ha application rates while MZ gave the least grain yield, 1662.5, 2931.3 and 3850kg/ha for 0,10 and 20t/ha rates of application. LL gave the highest total N and higher OC, P and K compared to others. Optimum maize yield was obtained with application of 20 t/ha of plant residues, therefore, the addition of LL residues at 20t/ha is recommended for maximum maize yield.

KEYWORDS: Maize grain, Yield, Soil nutrients, Plant residues and Soil fertility

INTRODUCTION

Maize (Zea mays L.) is a multipurpose crop which provides food for humans and fodder for livestock and feed for poultry. As a grain crop with high yield potential, maize needs an adequate nutrient supply. Grain yields vary between 2.5 and 9 t/ha; yields more than 20 t/ha; have locally been recorded, representing an excellent conversion of photosynthesis-linked solar radiation into utilizable biochemical energy that is among the highest of all crops. It requires a large quantity of nitrogen (N), and relatively large P and K. The nutrients removed by the yield of 4 tonnes grain/ha are estimated at 200 kg N/ha, 80 kg P_2O_5/ha and 160 kg K_2O/ha thus, the crop responds well to high soil fertility and maximum yield potentials are possible with high fertility (Bello et al., 2015).

Soil in Sub-Saharan Africa is inherently infertile and characteristically low in soil organic matter content and cannot support intensive cultivation due to rapid rate of fertility decline under intensive cultivation (Shiyam et al., 2013).

Among the most considered options for soil fertility improvement is plant and crop residue management. The use of organic inputs such as crop residue and manures has great potential for improving soil productivity and crop yield through improvement of the soil chemical properties and nutrient supply (Abbasi et al., 2009).

Plant residues often exhibit different physical and chemical properties depending on the quality of the residue and therefore affect soil in different ways (Adeleye et al., 2010). The physical properties of plant residue coupled with other factors viz; can affect the rate of its decomposition while the chemical properties can affect the dynamics of nutrient release and mineralization into the soil. The decomposed organic product added to soil can be a good indicator of soil quality and is considered a key measure for ameliorating degraded soil (FAO, 2003). Hence, addition of plant residues has become a pivotal strategy for soil fertility improvement and sustainable land use (FAO, 2003).

Crop residues are also a valuable resource in terms of soil quality (Wilhelm et al., 2007). Research has shown that crop residues are directly related to characteristics beneficial to soil quality and crop yields, including nutrient cycling, soil organic matter (SOM), and soil organic carbon (Blanco-

Canqui and Lal, 2009a). Crop residues are directly related to many soil physical and chemical properties that affect plant growth, and the removal of these residues may adversely affect these soil properties.

Chromolaena odorata (L), Panicum maximum (Jacq), Leucaena leucocephala (Lamk), Neem clippings (L), maize stovers and banana leaves are common plants and crop residues available around many farms in Southwestern Nigeria (located in the derived savanna) but are often burnt, slashed off, pruned or completely removed from the farms.

More data is needed on the benefits that can be derived from the use of these residues as organic amendments in improving the soil for crop production, especially in derived savannah ecology of Abeokuta. Therefore, this research aims to evaluate how the response of maize grain yield and soil NPK dynamics was influenced by plant residues application.

MATERIALS AND METHODS

The study was carried out at the Teaching and Research Farms of the Federal University of Agriculture, Abeokuta, Ogun State, in the southwest Nigeria (Latitude $7^{0}13^{1N}$, Longitude $3^{0}28^{1E}$). Having altitude of 108m above sea level, mean annual rainfall is 1200 mm. Abeokuta is in a tropical humid and sub-humid climate characterized by distinct wet and dry seasons. The wet season begins in April and continues through October. The rainfall regime is characterized by heavy storms of limited duration, which contributes to the erosion hazard on uncovered soils. The maximum rainfall occurs during the month of July and September with a dry spell in the month of August. The dry season lasts from November to March and is influenced by the hot North Easterly winds blowing from the Sahara Desert. The relative humidity is about 89%, while the temperature range is between 34^{0}C to 24^{0}C. The soil of the experimental site has been classified as Typic U Stipsamment based on the USDA classification.

LAND PREPARATION

The land was manually cleared at the beginning of each planting season with cutlass and hoes. Plant residues and other debris were completely removed leaving bare soil before the application of treatments. Each experimental plot was 4 m x 4 m (16 m^2). Plant residue materials were incorporated manually at the rate of 0, 10 and 20 t/ha to the respective plots two weeks before planting to allow for mineralization of the residues added to the soil. Plant residues were uniformly spread and mixed with the topsoil. The same process was followed for the control plots but no residue was added. Maize TZEE 1 – Y variety sourced from International Institute of Tropical Agricultural (IITA), Ibadan was used as a test crop, the seed is an early maturing improved variety rich in nutrient. Maize seeds were planted at a spacing of 25 cm x 75 cm and at a rate of two seeds per hole. Thinning was carried out to one plant per stand after two weeks of planting.

EXPERIMENTAL DESIGN

The experiment was a 6 x 3 factor in a randomized complete block design (RCBD) in three replicates. The factors included six selected plant residue materials namely: Chromolaena odorata, Maize stover, Banana/Plantain leaves, Leuceana leucocephela, Neem Clipping and Panicum maximum were incorporated at the rate of 5t/ha.

SOURCES OF PLANT RESIDUES AND THEIR ANALYSES

A total of six plant materials were used as residues for the experiment. These were (1) Chromolaena odorata (2) Maize stover (3) Banana residue (4) Leuleana leucocephala Clippings (5) Neem Clipping and (6) Panicum maximum. These plants are parts of the common vegetation found around FUNAAB and Alabata area and were collected locally and sun-dried. Leucena leucocephalais a common shrub used by farmers as hedge plants in their farms around the area. Maize and banana are common crops in the vicinity and maize stovers are left after harvesting while banana leaves are pruned and kept on the land. Neem is a common tree species planted in the area.

PLANT RESIDUE MATERIALS ANALYSIS

Samples of the grinded residue materials were taken to laboratory for analysis. Dry matter was determined by drying at constant weight of 70˚C for 48hrs in an oven and Nitrogen by the micro- Kjeldahl procedure. The macro and trace elements were determined by digesting samples in $HN0_3/HClO_4$ using atomic absorption spectrophotometer to measure Ca, Mg and P. Potassium were determined using flame photometer. Total C was determined as described below.

3.3.4 Soil collection and analyses

Soil samples were collected before and after planting for all the field experiments and air-dried and passed through a 2 mm sieve for the laboratory routine analysis. A portion of the sieved soils were further passed through 0.5 mm mesh for total nitrogen and carbon determination. The pH was determined (1:1 soil: water ratio) using pH meter glass electrode (Mclean, 1982). Organic matter content was determined using the wet – oxidation method. Walkley – Black (1934) method modified by Allison and Moodie (1965). Total nitrogen was determined using Kjeldahl distillation method (Bremner, 1996). Available phosphorus was extracted using Bray 1 procedure (Bray and Kurtz, 1945) and P in solution was determined Colorimetrically using the method of Murphy and Riley (1962). Exchangeable bases were extracted with ammonium Acetate (1N NH_4OAc) buffered at pH 7. Sodium and K^+ in the extract were determined by flame photometer while Ca^{2+} and Mg^{2+} were determined using AAS following the method of Lax et al., 1986. Particle size was determined using the hydrometer method. Bouyoucos, (1962) method and the proportion of sand, clay and silt were used to determine the textural class of the soil using USDA textural triangle.

DATA COLLECTION

Data was taken on grain yield of maize and some soil properties after harvesting. Grain yield was measured by weighing the total number of grains harvested from the net plot and expressed in kilograms per hectare.

STATISTICAL ANALYSIS

Data were subjected to analysis of variance using Statistical Analysis System (SAS, 2003). Means were compared for significant differences using the least significant difference at 5% level of probability and standard error of difference.

RESULTS AND DISCUSSION

The properties of the soil used for the study were shown in Table 1. It revealed that the soil had slightly acidic reaction; the textural class of soil was Sandy loam; organic matter (1.93%), organic carbon 1.12% total N (0.18%), Zn (12.6mg/kg) and Mn (14.97mg/kg). The soil was Temidire series which has been classified as an Alfisol. The low fertility status of the soil has been known to be due to continuous cropping indicating that the nutrient reserve capacity of the soil was minimal. Therefore, the incorporation of crop residues can save and substitute for the use of inorganic fertilizer up to some extent and improve soil health (Aisha et al., 2018).

PHYSICAL AND CHEMICAL PROPERTIES OF THE SOIL USED

Table 1: Pre-soil analysis of the experimental site

Parameter	Unit	Value
pH (H_2O)		6.2
Organic matter	%	1.93
Organic carbon	%	1.12
Total Nitrogen	%	0.18
Available Phosphorus	mg/kg^{-1}	22.4
Exchangeable – Ca	cmolkg^{-1}	1.25
Exchangeable – K	cmolkg^{-1}	0.08
Exchangeable – Mg	cmolkg^{-1}	2.5
Exchangeable – Na	cmolkg^{-1}	0.22
ECEC		3.80
Cu	mgkg^{-1}	1.63
Zn	mgkg^{-1}	12.6
Fe	mgkg^{-1}	10.6
Mn	mgkg^{-1}	14.97
Particle size		
Sand	g kg^{-1}	862
Clay	g kg^{-1}	120
Silt	g kg^{-1}	18
Textural classes		Sandy Loam

The properties of plant residues used in this experiment are shown in Table 2. Leuceana leucocephala had the highest C and N % content compared to others. Similarly, Nitrogen, Phosphorus, Potassium, Calcium and Mg were higher in % for L. leucocephala compared to other plant residues. Chromolaena odorata followed nutrient quality values to Leuceana leucocephala in N, Ca and Mg than others. Maize stover had the least N, P, K and Ca percentage compared to others but had the highest C:N ratio. The nutrient content shown from the residues indicated that Leuceana leucocephala and Chromolaena odorata indicated that both had a better quality than the remaining plant residues (Neem clipping> Panicum maximum > Banana/Plantain >Maize stover) in the order listed. This shows that there was variation in the plant residues with regards to the quality. Hence, it can be deduced that each crop residue has potential with variation between them as a source of soil amendment (Adekunle et al., 2013).

Table 2: Mean **Nutrient content (% dry matter) of the six plant residues used for the experiment**

Plant residue	C %	N %	P mg/kg	K Cmol/kg	Ca Cmol/kg	Mg Cmol/kg	C:N ratio
Neem clippings	30.96	1.80	0.38	1.00	1.61	0.33	17.2
Banana/Plantain	18.87	1.06	0.37	1.53	1.45	0.20	17.8
Maize stover	22.17	0.99	0.21	0.41	0.12	0.19	22.4
Chromoleana odorata	17.20	1.92	0.22	0.75	0.41	0.28	18.7
Panicum maximum	32.98	1.52	0.68	1.71	0.27	0.11	21.7
Leuceana leucocephela	33.66	1.98	0.36	1.19	0.34	0.15	17.0

Grain yield of maize was significantly affected by the rate of application of residue (Table 3). The grain yields at 10t/ha and 20t/ha of application were significantly higher than that of the control. Residue types also have significant effect on the grain yield of maize. Control plot for Maize stover (MZ) residue plot had the lowest grain yield and was more than 100%lower than plot incorporated with 20 t/ha of Maize stover (MZ) residue.

Also, Table 3 showed that all the treatments used were highly significant on the yield of maize cultivated. However, from the result the use of L. leucocephela gave the highest grain yield (t/ha) for all the rates of application (0, 10 and 20 t/ha) considered. This was followed by C. odorata with higher yield at 0 and 10 rates of application respectively. Also, Neem clipping followed L. leucocephela at 20t/ha rate of application in terms of yield performance compared to others. However, P. maximum followed C. odorata in terms of yield performance for both 0 and 10 rates of application compared to others while Banana followed L. leucocephela at 0 rate of application given 1837.5kg/ha yield. Generally, the use of Banana gave a better yield response compared to that of maize stover at 10 and 20 t/ha rates of application respectively. Generally, for all the rates of application considered (0, 10 and 20 t/ha) the use of maize stover gave the least response for the grain yields recorded (1662.5, 2931.3 and 3850.0kg/ha) on the maize stover plots.

The better performance of 20t/ha over 10t/ha and 0t/ha, ascertained (Osundare and Fawole, 2018) work that large amount of manure supports slow longer period of storage in the soil thereby ensuring a long residual effect. The superior grain yield observed in the Leucaena leucocephala and Neem clipping plot can be explained by the higher amount of nutrients in the residue especially N and P than the control. Similar results were observed by Ray, (2007) and Asha et al., 2018) reported that residues of Gliricidia sepium and Chromolaena odorata increased the organic Carbon, total nitrogen, potassium, available P content of the soil as well as the yields of crops.

Higher yields were also reported for other crops because of crop residue incorporation into the soil compared to crop residue removal (Paul et al., 2014). Yield of maize were more than double when 20 t/ha application of each residue was compared to the control in the first planting of the year one experiment.

Table 3: Effect of Plant Materials Incorporation on grain yield of maize

Residue	Planting rate & Grain yield (kg/ha)		
	Rate (t/ha)		
	0	10	20
Banana	1837.5b	3150.0d	4095.8d
C. odorata	1837.5b	3718.8b	4295.8c
L. leucocephela	1868.8a	4200.0a	5337.5a
Maize stover	1662.5e	2931.3e	3850.0e
Neem clipping	1683.3d	2493.8f	4550.0b
P. maximum	1822.9c	3325.0c	3675.0f

Means of residues on rate with same letter within column are not significantly different by DMRT

Effect of residue application on some soil macro nutrients after planting

The analyses of soil properties after harvesting revealed significant effect of the residue type on the soil nutrients considered (Table 4). These properties were also affected by the rate of application of residue. The plot incorporated with Leucaena leucocephala (LL) and Panicum maximum (PM) had significantly higher org. C than the other residues incorporated. Banana leaves (BN), Leucaena leucocephala (LL), and Panicum maximum (PM) residue incorporated plots had significantly higher Total N than maize stover (MZ), Chromolaena odorata (CO) and Neem clipping (NM) residue incorporated plots. However, the K content of Chromolaena odorata (CO) incorporated plot was significantly higher than those of Banana leave (BN), Leucaena leucocephala (LL), and Maize stover (MZ).

The application rate of 20t/ha significantly increased the organic C of the soil compared to 10 and 0t/ha. Also, 10t/ha had significantly higher organic C than 0 t/ha. The total N was significantly increased by the rate of application of residue when compared to zero application rate. The K content observed in control plot were significantly lower when compared to 10 and 20t/ha. In fact, 20t/ha was more than 3fold higher in K content than the 0t/ha. The rate of application of 20t/ha was significantly higher in K content than 10t/ha rate. The pH and Exchangeable P were not significantly affected by the residual type and rate of application.

Incidentally, Leucaena leucocephala had the highest total C and N which also influenced its C:N ratio and made its residue a high-quality residue. This result further confirmed the work of Babayemi et al. ,2006 who affirmed that Leucaena leucocephala is a widely acceptable plant for nitrogen fixation and browsed legume for livestock feeding in the tropics. Similarly, the response of the soil properties with regards to variation in the plant residues incorporated corroborated with the work of Paul et al., 2014 who concluded that better plant nutrition, better soil physical and hydraulic properties, and better moisture retention through organics application are possible reasons for greater productivity.

Table 4: Effect of residue incorporation on some soil chemical properties

Residue	OC	pH_2	TOTAL N	P	K
Banana	1.5b	6.55	11.84a	30.48	0.68bc
C. odorata	1.43b	6.75	9.14b	31.31	1.05a

L. leucocephala	1.94a	6.48	11.74a	32.39	0.61bc
Maizestover	1.42b	6.47	9.67b	27.3	0.68bc
Neem clippings	1.41b	6.73	8.49b	29.67	0.92ab
P. maximum	2.09a	6.58	11.5a	41.45	0.83abc
Control	1.01c	6.03	4.24c	10.26	0.3d
Rate					
20	1.76a	6.71	11.07a	33.55	0.92a
10	1.51b	6.58	9.72a	30.65	0.67b
0	1.01c	6.13	4.25b	10.27	0.3c
ANOVA					
RES	*	Ns	*	Ns	*
RAT	*	Ns	*	Ns	*
RES x RAT	Ns	Ns	Ns	Ns	*

* and ns represent significant at $P<0.05$ and not significant respectively
Means of residues on rate with same letter within column are not significantly different by DMRT

CONCLUSION

From the results obtained, the nutrient release was significantly enhanced by the type of residue and their chemical compositions. The nutrient release, especially N. P and K, were higher in Leucaena leucocephala and neem clippings. All the residues used in the study improved the organic matter content of soil after their application and they showed prospects of sustaining soil fertility for immediate and subsequent crop production. Leucena leucocephela gave the best result of all the six residues applied in the experiment in terms of soil improvement and grain yield of maize. All the residues improved the organic matter content of soil after their application, and they showed prospects of sustaining soil fertility for immediate and subsequent crop production. The study also revealed the impact of the residues on maize yield with the addition of 10 and 20 t ha^{-1} of each residue leading to a better performance of the maize plants. Also, the major benefit of application of organic materials to crop field is the residual effect and this was shown on soil properties evaluated. Hence, the use of 20 t ha^{-1} Leucaena leucocephala and either C. odorata or neem clippings could be considered for maize production in the region of investigation.

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