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Effects of Number and Rate of Goat Manure Application on Soil Properties, Growth and Yield of Sweet Maize (*Zea mays* L. saccharata Strut)

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Abstract

Alternative sources of plant nutrients have now become highly imperative especially for vegetable crop production in Nigeria. Due to the escalating costs, environmental and health problems associated with excessive use of inorganic fertilizers on continuously cropped fields, there is a need for more research on the use of organic manures and residues. A field experiment was conducted in the late growing season from September to December, 2012 in Calabar, a humid forest agroecology in south eastern Nigeria to evaluate the effects of two types of goat manure (GM) application (single and double split doses), five rates of GM (0, 5, 10, 15 and 20 t ha^{-1}) and 400kg ha^{-1} NPK fertilizer (120:60:60 kg ha^{-1}) rate on soil chemical properties and agronomic performance of sweet maize (*Zea mays* L. saccharata Strut). Factorial combinations of the treatments were fitted into a randomized complete block design with three replications. The application of GM significantly ($P \leq 0.05$) increased soil pH, organic matter (OM) content, total N, available P, exchangeable K, Ca, Mg and the cation exchange capacity (CEC) status of the soil. Soil exchangeable acidity (EA) was reduced from 1.76 to 0.64 cmol kg^{-1} at 20 t ha^{-1} GM rate. The 20 t ha^{-1} also recorded the highest values for soil pH, OM, P, Ca, Mg and CEC, while the values for residual N and K peaked at the NPK fertilizer treatment. The double split application of GM recorded higher values for growth and yield attributes, and increased soil properties than the single application. Growth and yield parameters such as plant height, number of leaves, leaf area index (LAI), total dry matter (TDM), number and weight of grains/ear and total grain yield were significantly ($P \leq 0.05$) increased by GM and NPK fertilizer treatments. The values obtained for all growth and yield parameters except LAI at the 20 t ha^{-1} GM rate were not significantly different from those at the NPK fertilizer treatments. The application of 5, 10, 15 and 20 t ha^{-1} GM, and NPK fertilizer significantly increased TDM by 11.9, 74.3, 91.9, 106.2 and 104.6%; weight of grains/ear by 16.5, 54.6, 61.4, 100.6 and 94.4% and total grain yield by 46.9, 111.7, 121.0, 127.2 and 140.1% respectively, compared with the control treatment. The interactions between number of applications and rates showed that split applying GM at 20 t ha^{-1} maximized TDM, weights of whole and dehusked green ears and total grain yield compared to other GM rates, hence it is recommended.

Keywords: NPK fertilizer, sweet maize, goat manure, rate, soil properties, yield

1. Introduction

Sweet maize (*Zea mays* L. saccharata Strut), one of the maize types containing 13-15% sugar in the immature grains, is a mutant of the dent and flint sub-species (Bhatt, 2012). It is mostly grown in the United States of America, East Asia, and some European countries and has become popular among the higher income groups in African countries (Badu-Apraku & Fakorede, 2006). In Nigeria, sweet maize is gradually becoming an important vegetable crop since it forms a useful ingredient in the preparation of salad, fried rice and other dishes both at home and in restaurants.

The production of sweet maize has intensified in market gardens in the country due mainly to increasing demand and partly to augment the income of peasant farmers dwelling in the outskirts of large cities. Organic matter and nutrient depletion are the major causes of low crop yield under intensive cropping. Continuous cropping as a result of scarcity of land, removal of crop residues after cropping for feeding livestock, nutrient depletion through erosion and leaching leading to increased soil acidity, have generally reduced the productive capacity of the arable land in Nigeria (Akinrinde & Obigbesan, 2000; Brady & Weil, 2008). To achieve food security for the rapidly expanding population in Nigeria will entail making deliberate efforts at promoting the judicious utilization of animal manures and organic residues for crop production. Soil enhancing benefits from these manures in addition to those from macro and micro nutrients supply, are linked to the organic matter that improves soil structure, moisture relations and increases mobility of P, K and micro nutrients and stimulates microbial activities (Maerere et al., 2001; Garg & Bahla, 2008).

Many farmers that apply animal manures lack the scientific knowledge for appropriate rate, timing and number of applications, method of application and storage techniques to retain nutrients. Timing of nutrient application is guided by some basic considerations which include nutrient availability when crops need it, avoiding waste and enhancing nutrient use efficiency (Brady & Weil, 2008). Although goat manure (GM) is readily available on most small holders' vegetable farms and home gardens in south eastern Nigeria, second only to poultry manure in terms of availability its use has received little research attention. There is a dearth of information on appropriate number of applications and the right proportion for optimum performance of sweet maize by farmers. Previous research findings available indicate that farmers still apply GM a week or two before planting or soon after planting or whenever it was available. Also the effects of the inconsistent number and rate of application which may subsequently affect crop performance has not been well documented. Furthermore, most studies on utilization of animal manures emphasize on crop yield without relating the yield to availability of nutrients in the soil.

Increased crop growth rate, yield, ability to tolerate stressful conditions and product quality in relation to application of goat manure have been widely reported (Maerere et al., 2001; Awodun et al., 2007; Akanni & Ojeniyi, 2008; Odedina et al., 2011; Nweke et al., 2013). Ojeniyi and Adegboyega (2003) reported that goat manure significantly increased growth and yield of okra, amaranthus, celosia and maize in south western Nigeria. Goat manure was also found to be an efficient source of N, P, K, Ca, Mg and organic matter for pepper, cassava and okra (Awodun et al., 2007; Odedina et al., 2011; Nweke et al., 2013). Studies by Smith and Ayenigbara (2001) and Ojeniyi and Adegboyega (2003) indicated that GM improved N, P, K, Ca and Mg status of soil. Application of GM to P fixing soils in South Africa was reported to have reduced the sorption of added P and this effect was largely attributed to the liming potential of GM (Gichangi & Mnkeni, 2009). The objective of this study was to evaluate the effectiveness of single and double split applications of ground goat manure at varied rates on some chemical properties of the soil, and agronomic performance of sweet maize in Calabar, a tropical rain forest zone.

2. Materials and Methods

The experiment was conducted under field conditions during the late growing season from September to December 2012 at the Teaching and Research Farm of the Department of Crop Science, University of Calabar. Calabar is located along the humid coastal region of south eastern Nigeria (4º57'N, 8 º19'E; 37m elevation). The region is characterized by a bimodal rainfall distribution ranging from 3000- 3500mm per year with a long rainy season which starts in March while the short rainy season extends from September-November after a short dry spell of one to two weeks in August. The dry spell often marks the end of the early growing season and the subsequent commencement of the late growing season. The dry season is usually from December to February. The mean annual temperature ranges from 27 to 35 ºC (Iloeje, 2001). The soil is acidic and is classified as *Ultisol,* characterized by low pH, and usually deficient in multiple nutrients (Brady & Weil, 2008). The experiment evaluated the response of sweet maize "*Tropical Zea*" (TZ) obtained from International Institute of Tropical Agricultural (IITA) Ibadan, to two types of goat manure (GM) applications (single and double split doses), five rates of GM (0, 5, 10, 15 and 20 t ha^{-1}) and 400kg ha^{-1} NPK fertilizer with recommended rates of 120-60-60 kg ha^{-1}. Factorial combinations of the treatments were laid out in a randomized complete block design with three replicates. Soil samples were collected from the site at 0-30cm depths prior to manure application and analyzed for physico-chemical properties to determine the base line fertility status of the site (IITA, 1982). Composite sample of the manure was air-dried, crushed, sieved and analyzed for chemical properties as described in IITA (1982). Another set of soil sample was taken at the end of the growing season to determine the post-harvest soil chemical properties. The relevant results of the physical and chemical analyses of the soil and manure are summarized in Table 1. The site was cleared of vegetation, ploughed to a depth of 20 cm and demarcated into three blocks of 12 plots each. Each plot size was 1.5 × 4.2 m (6.3 m^2), and the net plot size was 1.0 × 1.8 m (1.8 m^2). Plots were separated by a lane of 1 m while blocks were kept at a distance of 1.5m between them. Sowing was done on tilled flat beds on 16 September 2012. Three seeds were sown per stand at a spacing of 25 × 60 cm and thinning of seedlings to one per stand was carried out two weeks after sowing (WAS) to give 42 stands/plot and 66,666 plants per hectare. The goat manure used was cured by air drying for 30 days, ground with a Wiley Mill and incorporated into the soil of the replicated plots in a single and double split doses per treatment, one week before planting. The second split dose of manure was ring applied 10-15 cm away from each crop at 5WAS. NPK 15:15:15 fertilizer at the rate of 400 kg ha^{-1} was first applied as single dose to all the plots except the control plots one week after crop emergence and urea fertilizer at the rate of 130 kg ha^{-1} was used for top-dressing at 5 WAS. Manual weeding was done twice at 2 and 5 WAS by hand pulling and hoeing. Harvesting took place at two stages – milk or soft dough stage (green harvest) and fully mature stage. Green harvesting was done 74 days after sowing from 6 randomly selected plants in the net plot area as indicated by the dying and browning of the silk, fullness of the tip kennels and firmness of the whole husked green ears. The fully mature ears were harvested 90 days after sowing from the remaining 6 plants in the net plot area and sun-dried to 14% moisture content determined with an Offering Ohaus moisture analyzer model MB54. From these 12 sampled plants, the following parameters were determined: plant height, number of leaves/plant, leaf area index, number of days to 50% tasselling and silking, total dry matter, number of ears/plant, number of grains/ear, weights of whole green and dehusked green ears, weight of grains/ear and total grain yield. Data generated were subjected to analysis of variance using Genstat Release 7.22 DE Statistical software (Lawes Agricultural Trust, 2008). Differences between treatment mean values were compared using the Least Significant Difference (LSD) at 5% level of probability.

Table 1. Physico-chemical properties of the top 0-30 cm depths of the experimental soil and chemical composition of the goat manure used

Composition	**Soil**	**Goat manure**	
Physical composition (%)		**Chemical composition**	
Sand	85.2	pH in (H_2O) (1: 2.5)	8.00
Silt	2.6	Organic matter (g kg^{-1})	484.12
Clay	12.2	Total N (g kg^{-1})	19.8
Textural class	Loamy sand	Av. P (mg kg^{-1})	2001.10
Chemical characteristics		C/N	14.51
pH (H_2O) (1:2.5)	5.50	Ca (cmol kg^{-1})	2600.00
Organic Matter (g kg^{-1})	16.75	Mg (cmol kg^{-1})	677.20
Available P (mg kg^{-1})	32.39	K (cmol kg^{-1})	4310.00
Total N (g kg^{-1})	0.70		
Exchangeable bases (cmol kg^{-1})			
Ca	3.08		
Mg	1.11		
K	0.15		
Na	0.07		
EA	1.76		
CEC	6.16		
BS (g kg^{-1})	715.91		

BS = Base Saturation.

3. Results

3.1 Effects of Number and Rate of GM Applications on Soil Chemical Properties

The post-harvest soil chemical properties as influenced by number and rates of GM application is presented in Table 2. The application of GM significantly ($P \leq 0.05$) increased soil pH, OM content, total N, available P, exchangeable cations (K, Ca and Mg) and cation exchangeable capacity (CEC). Increasing rates of GM equally reduced significantly the exchangeable acidity (EA) of the soil (Table 2). Values of soil pH and OM content were highest at 20 t ha^{-1} GM rate, while the control plots had the lowest, followed by the NPK fertilized plots. The soil pH at 20 t ha^{-1} GM rate, was 32.3% higher than that of the control plots, while increasing the GM rates from 0 to 5, 10, 15 and 20 t ha^{-1}, resulted in corresponding increases in soil OM content by 132.3, 145.6, 249.6 and 275.6% respectively. Nitrogen levels increased from 0.70 g kg^{-1} (initial N status of soil) to 1.8 and 1.9 g kg^{-1} in GM amended plots at 20 t ha^{-1} rate and NPK fertilizer treatment respectively. There was no significant difference in the residual N values at 20 t ha^{-1} GM rate and the NPK treatment. Soil available P increased with each increment in GM rate up to the highest rate (20 t ha^{-1}). The 5, 10, 15 and 20 t ha^{-1} GM rates and NPK fertilizer treatment increased residual P by 13.1, 17.8, 33.7, 54.7 and 52% respectively, over the 0 t ha^{-1} plots. The increase in residual K was more pronounced in NPK fertilized plots which was 10.3% higher than that at 20 t ha^{-1} GM amended plots. Each incremental rate of GM significantly increased residual soil Ca and Mg levels and the CEC up to the highest rate with the control plots recording the lowest value. The magnitude of the reduction in soil exchangeable acidity (EA) increased with increasing rates of GM application and peaked at 20 t ha^{-1} rate. The EA was reduced from 1.76 cmol kg^{-1} (initial soil test value) to 0.6 cmol kg^{-1} at the 20 t ha^{-1} GM rate which was more than 2½ times lower than the initial soil test value (Tables 1 and 2).

Table 2. Effects of number and rate of goat manure application on soil chemical properties in Calabar

Treatment	**pH**	**OM (gkg^{-1})**	**Total N (gkg^{-1})**	Av.P **($mgkg^{-1}$)**	**K**	**Ca**	**Mg**	**EA**	**CEC**
					←	**c $molkg^{-1}$**			→
GM (tha^{-1})									
0	5.45d	14.53e	0.50e	30.37d	0.12e	2.49e	0.89e	1.88a	6.28f
5	6.95b	33.75d	1.10d	34.34c	0.13e	4.29d	1.68d	0.92c	7.85d
10	7.03b	35.68c	1.35c	35.76c	0.17d	5.34c	2.00c	0.84d	8.92c
15	7.20a	50.80b	1.65b	40.60b	0.24c	5.97b	2.30b	0.73e	9.52b
20	7.21a	54.58a	1.80a	46.98a	0.29b	6.95a	2.60a	0.64f	9.81a
400 kg ha^{-1} NPK	6.02c	33.53d	1.90a	46.16a	0.32a	4.12d	1.60d	1.77b	7.56e
LSD (0.05)	**0.13**	**0.56**	**0.20**	**3.96**	**0.03**	**0.18**	**0.17**	**0.08**	**0.09**
No. of Application									
Single dose	7.11a	42.88a	1.23b	36.02a	0.13a	4.69b	1.68b	1.01a	8.15b
Double dose	7.02b	40.83b	1.53a	33.71b	0.16b	5.03a	2.01a	0.79b	9.25a
LSD (0.05)	**0.07**	**0.32**	**0.10**	**2.13**	**0.02**	**0.11**	**0.10**	**0.01**	**0.02**
Interaction									
GM x NA	NS	**	**	NS	NS	**	**	NS	NS

NS = Not significant.

** = Highly significant at 1% level of probability.

Table 3. Interaction effects between number and rate of goat manure application on organic matter, total N, Ca and Mg contents of the soil in Calabar

Treatment	**Number of application**		**Number of application**		**Number of application**		**Number of application**	
	Single	**Double**	**Single**	**Double**	**Single**	**Double**	**Single**	**Double**
GM (tha^{-1})	**Organic matter (g kg^{-1})**		**Total N (g kg^{-1})**		**Ca cmol kg^{-1}**		**Mg cmol kg^{-1}**	
0	14.73g	14.33g	0.50f	0.50f	2.48h	2.50h	0.88h	0.90h
5	34.11e	33.39f	1.00e	1.20de	3.70g	4.88e	1.48g	1.88ef
10	35.88d	35.48d	1.10e	1.60bc	5.26d	5.42d	1.80f	2.20cd
15	51.40b	50.20c	1.40cd	1.90a	5.79c	6.15b	2.06de	2.54b
20	57.68a	51.48b	1.60bc	2.0a	6.85a	7.05a	2.40bc	2.80a
400 kg ha^{-1} NPK	33.83ef	33.23f	1.80ab	2.0a	4.04f	4.20f	1.48g	1.72fg
LSD (0.05)	**0.79**		**0.30**		**0.26**		**0.24**	

The effect of number of GM application (NA) was equally significant for all the soil attributes determined. The single application of GM and the NPK treatment recorded higher levels of soil pH, OM content, P and EA than the double split doses, while the reverse was the case for residual soil N, K, Ca, Mg and CEC in which the double split application recorded higher values. The double split doses of GM and NPK fertilizer increased soil N, K, Ca, Mg and CEC levels by 24.4, 23.1, 7.3, 19.6 and 13.50%; and lowered the EA by 27.9% over the single application (Table 2).

The NA × GM and NPK fertilizer interaction effects were highly significant for OM, total N, exchangeable Ca and Mg (Tables 2 and 3). The double split application of GM at 20 t ha^{-1}, recorded the highest values for residual soil Ca and Mg while the single application of GM at 20 t ha^{-1} rate produced the highest soil OM content (Table 3).

3.2 Effects of Number and Rate of GM Applications on Sweet Maize Performance

Tables 4 and 5 present the influence of number of GM application and rates on vegetative and reproductive attributes of sweet maize. The effect of GM and NPK fertilizer on all the vegetative attributes, were all significant. Values obtained for plant height and number of leaves/plant were highest at the NPK fertilizer treatment but not significantly different from those obtained at the 15 and 20 t ha^{-1} GM rates (Table 4). Each increment in GM rate, significantly increased the leaf area index (LAI), but the NPK fertilized plots maximized LAI more than any GM treatment. The number of days to 50% tasselling and silking did not differ significantly at 15 and 20 t ha^{-1} GM rates and the NPK fertilized plots, but were all significantly lower than the other treatments. There was no significant difference between the total dry matter (TDM) yield at 20 t ha^{-1} GM rate and NPK fertilizer treatment. For all the variables mentioned above, the 0 t ha^{-1} GM rate recorded the least values (Table 4). The effect of the number of GM application (NA) was equally significant for all vegetative attributes. The double split doses of GM and NPK fertilizer treatment out-performed the single dose application in terms of plant height, number of leaves/plant, LAI, number of days to 50% tasselling and silking and TDM production (Table 4).

Table 4. Effects of number and rate of goat manure application on plant height (cm), number of leaves/plant, leaf area index (LAI), number of days to 50% tasselling and silking and total dry matter (TDM) production of sweet maize in Calabar

Treatment	Plant height (cm)	No of leaves/plant	LAI	Days to 50% tasselling	Days to 50% silking	Total dry matter (g/plant)
GM (tha^{-1})						
0	134.83d	8.50c	2.64e	57.83a	66.18a	102.48e
5	143.33cd	9.50b	2.93d	57.17ab	65.83ab	114.69d
10	146.17bc	9.83ab	2.97cd	56.50bc	65.00bc	178.63c
15	154.17ab	9.83ab	3.08c	56.33bc	64.83cd	196.66b
20	156.67ab	10.17a	3.49b	55.83c	64.17cd	211.30a
400 kg ha^{-1} NPK	163.50a	10.00a	4.32a	55.67c	64.00d	209.69a
LSD (0.05)	**10.83**	**0.56**	**0.12**	**0.88**	**0.84**	**10.59**
No. of Application						
Single dose	142.06b	9.28b	2.87b	65.87a	65.87a	159.82b
Double dose	157.50a	10.00a	3.61a	64.17b	64.83b	177.99a
LSD(0.05)	**6.25**	**0.32**	**0.07**	**0.51**	**0.49**	**6.11**
Interaction						
GM x NA	NS	NS	NS	NS	NS	**

NS = Not significant.

** = Highly significant at 1% level of probability.

Table 5. Effects of number and rate of goat manure application on number of ears/plant, number of grains/ear, weight of grains/ear, weights of whole and dehusked green ears and total grain yield of sweet maize in Calabar

Treatment	No. of ears/plant	No. of grains/ear	Wt. of whole green ear (g)	Wt. of dehusked green ear (g)	Wt. of grains/ear (g)	Total grain yield (tha^{-1})
GM (tha^{-1})						
0	1.01b	238.5d	113.69d	72.04d	45.86c	1.62b
5	1.02b	278.00c	245.00c	86.85c	53.44c	2.38b
10	1.17b	284.33c	315.18b	90.72c	70.91b	3.43a
15	1.17b	340.50bc	383.56a	111.35b	74.03b	3.58a
20	1.33ab	395.17ab	395.22a	144.52a	92.01a	3.68a
400 kg ha^{-1} NPK	1.67a	430.33a	422.58a	154.61a	89.17a	3.89a
LSD (0.05)	**0.45**	**75.67**	**43.23**	**10.80**	**8.38**	**0.86**
NA						
Single dose	1.11	277.33b	299.04b	101.48b	76.76b	2.90b
Double dose	1.33	329.83a	326.04a	118.55a	92.97a	3.30a
LSD (0.05)	**NS**	**43.69**	**24.96**	**6.24**	**4.84**	**0.37**
Interaction						
GM x NA	NS	NS	**	*	NS	**

NS = Not significant.

** = Highly significant at 1% level of probability.

* = Significant at 5% level of probability.

The highest number of ears/plant, grains/ear and heaviest dehusked green ear (1.7, 430.3 and 154.6 g) were obtained from maize crop at the NPK treatment which however, was not significantly different from the 20 t ha^{-1} GM rate (Table 5). The NPK fertilized plots equally maximized weight of whole green ear even though this was not significantly different from those obtained at 15 and 20 t ha^{-1} GM rates. Weight of grains/ear peaked at 20 t ha^{-1} GM rate but did not differ significantly from the value obtained at the NPK treatment. Total grain yield obtained at 10, 15 and 20 t ha^{-1} GM rates with that of NPK treatment did not differ significantly but the value at the NPK fertilized plots were however the highest. The NPK fertilizer treatment gave grain yield increases of 5.7, 8.7, 13.4, 63.5 and 140.1% above the 20, 15, 10, 5 and 0 t ha^{-1} GM rates respectively, which was in the order of NPK treatment >20>15>10>5>0 t ha^{-1} GM rates. The effect of number of GM applications was significant for number of grains/ear, weights of whole and dehusked green ears, weight of grains/ear and total grain yield. The double split doses of GM rates significantly increased these variables above the sole application. The number of grains/ear, weight of grains/ear, weight of dehusked green ear and total grain yield obtained with the double split application of GM were 18.9, 21.1, 16.8 and 13.8% respectively, higher than those of the single application of GM (Table 5).

The NA x GM and NPK fertilizer interaction effects were significant (P = 0.05) for weight of dehusked green ear and highly significant (P = 0.01) for total dry matter, weight of whole green ear and total grain yield (Tables 4 and 5). The double split application of NPK fertilizer, gave the highest values for the attributes mentioned but these values were not significantly different from those obtained at 15 and 20 t ha^{-1} GM rates when split applied twice for TDM, weight of whole green ear and total grain yield (Table 6).

Table 6. Interaction effects between number and rate of goat manure application on total dry matter (g/plant), whole and dehusked green ear weights (g) and total grain yield (tha^{-1}) of sweet maize in Calabar

Treatment	**Number of application**		**Number of application**		**Number of application**		**Number of application**	
	Single	**Double**	**Single**	**Double**	**Single**	**Double**	**Single**	**Double**
GM (tha^{-1})	Total dry matter		Wt. of whole green ear		Wt. of dehusked green ear		Total grain yield	
0	93.65e	111.31cd	115.85f	111.53f	72.60f	71.47f	1.46f	1.78ef
5	103.68de	125.70c	237.81b	252.18e	78.01f	95.69e	2.11e	2.65d
10	172.01b	185.24b	289.67de	340.68cd	80.37f	101.07e	3.18c	3.68b
15	181.18b	212.13a	370.79dc	396.33abc	99.57e	123.13d	3.43bc	3.73ab
20	205.92a	216.69a	378.83bc	411.61ab	136.73c	152.31b	3.57bc	3.79ab
400 kg ha^{-1} NPK	202.49a	216.88a	401.26abc	443.90a	141.57bc	167.64a	3.63b	4.15a
LSD (0.05)	**14.97**		**61.13**		**15.28**		**0.45**	

4. Discussion

The increases in soil nutrients due to GM application were probably due to the OM and nutrient contents of the manure (Table 1). The high Ca content of the GM was probably responsible for the relatively high pH in amended plots (Mbah & Mbagwu, 2006). In addition, during microbal decomposition of incorporated manures, basic cations are released which would raise the initial pH of the soil to a more favourable level for crop production (Pucknee & Summer, 1997). The increase in soil available N, P, and K with application rates of GM could be attributed to increased microbial activitiy as a result of enhanced decomposition of the organic forms of N, P, and K. Earlier studies by Smith and Ayenigbara (2001); Ano and Ubochi (2007) had shown that GM improved N, P, K, Ca, Mg and CEC status of soil and also reduced the exchangeable acidity (EA) of soil. Positive changes in soil contents of K, Ca and Mg and reduction in values of EA accompanied by increases in CEC upon application of animal manures have been documented by other workers (Ano & Ubochi, 2007; Uwah et al., 2012).

All the growth and yield parameters were significantly and positively responsive to increasing rates of GM and NPK fertilizer split applied twice. The low fertility status of the site which was in continuous cropping without fertilizer application made the response of sweet maize to GM and NPK fertilizer treatments apparent. Goat manure at higher rates (15 and 20 t ha^{-1}) promoted better growth probably as a result of higher uptake of inherent nutrients in the manure as compared to lower rates. The highest values for the vegetative attributes recorded for the inorganic fertilizers relative to GM are attributable to the fact that GM generally contains low quantities of plant nutrients which are usually released slowly. These nutrients triggered the vigorous growth of plant, thereby achieving higher LAI and further boosted the dry matter production and hastened the flowering and maturity period. Dry matter yield was highly related to soil availability of N, P and K and the narrow C/N ratio suggested quicker mineralization of organic forms of N, P and K (Maerere et al., 2001). These results therefore, suggest that the observed response was largely due to increased availability of nutrients supplied by GM which resulted in enhanced root growth. Superior growth attributes obtained with high rates of GM in this study, have been reported by other workers (Ojeniyi & Adegboyega, 2003; Awodun et al., 2007; Akanni & Ojeniyi, 2008; Odedina et al., 2011; Nweke et al., 2013).

The increase in grain yield with increasing rates of GM up to 20t ha^{-1}, was as a result of significant increases in almost all yield contributing characters especially number of ears/plant, number of grains/ear and weight of grains/ear. The increase in grain yield could also be due to the significant increases in number of leaves/plant and LAI which enhanced greater photosynthetic activity and translocation of assimilates. Therefore, the improved nutrient availability as a result of GM application, must have led to the significant enhancement of growth and yield of sweet maize. This result is in conformity with the findings of Ojeniyi and Adegboyega (2003) that GM increased yield of celosia, Bala and Manga (2009) who worked on cabbage and Nweke et al. (2013) on okra.

This study however, found that the NPK fertilizer increased growth and yield of sweet maize better than any GM treatment even though, the increase in values obtained for the various attributes were not significantly different from those at the 20 t ha^{-1} GM rate. This is attributable to the quicker release of these N, P and K nutrients from the inorganic fertilizers (Smith & Ayenigbara, 2001). Comparison of the number of applications (single and double-split) indicated that for all the growth and yield attributes, the double-split application produced higher response than the single. This was probably because in single application, most of the soluble nutrients may have been used up by the plant early in the season, volatilized or leached out from the root zone. The split application of the fertilizers and GM however, made the nutrients more beneficial to the plant at various stages of its growth and hence the superior performance recorded. This is in support of the ascertain by Havlin et al. (2006) that nutrients should be applied at a time that will maximize recovery by the crop and reduce potential loses to the environment.

5. Conclusion

The study showed that GM improved the chemical properties of the soil and enhanced the growth and yield of sweet maize. The application of GM at 20 t ha^{-1} was the most effective among the rates investigated in terms of boosting the residual soil nutrients and agronomic performance of sweet maize. Double application of GM and NPK fertilizer were more beneficial to the soil and crop than the single application as indicated by higher growth and yield values obtained. Even though higher values were obtained from NPK treatment for most of the agronomic attributes, these however, were not significantly different from values obtained at 20 t ha^{-1} GM rate. Double-split application of ground GM at 20 t ha^{-1} is therefore recommended for sweet maize production in this agro-ecology.

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