Pertanika J. Trop. Agric. Sci. 37 (3): 299 - 310 (2014)

TROPICAL AGRICULTURAL SCIENCE

Journal homepage: http://www.pertanika.upm.edu.my/

Effects of Different Rates of Palm Kernel and Barley Residues as Organic Manures on Growth and Yield of Maize on a Degraded Upland Soil

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ABSTRACT

Effect of organic manures and chemical fertilizers on maize (cv. DMR-ESR-Yellow) was studied in a degraded upland soil. Four levels (0, 1, 3, and 5 t ha^{-1}) of palm kernel and barley residues and a recommended rate of chemical fertilizers were tested in a randomized complete block design with three replications. Plant height, stem diameter, number of leaves, ear leaf area, 1000 grain weight, and grain yield increased with the increase rate of manures, but the increase was higher in palm kernel than the barley residue. The 3 and 5t ha^{-1} rates of palm kernel residue were the best treatments due largely to higher supply of N, P, K, Ca and Mg as. Under high rainfall, grain yield increased likely by reducing days to tasseling and silking and anthesis silking interval (ASI). Under low rainfall, both organic manures, which may have maintained more favourable soil moisture and temperature regimes, gave considerably higher yield than the recomended fertilizer rate (NPK 15:15:15). Organic manure treated plants, especially under palm kernel residue with higher N supply reached 50% tasseling and silking earlier and had shorter ASI and longer grain-filling period than inorganic fertilizer. The use of 3 to 5t ha^{-1} of palm kernel residue manure could substantially increase grain yield in Sierra Leone. However, the increase in yield with application rate showed that the highest rate used was not the optimum. Therefore, higher rates should be included in subsequent trials to obtain maize response curves for both manures.

Keywords: Organic manure, palm kernel residue, barley residue, maize grain yield

INTRODUCTION

Maize is one of the major cereal crops in West and Central Africa, particularly in

ARTICLE INFO

Article history:
Received: 2 April 2013
Accepted: 30 January 2014

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ISSN: 1511-3701

areas with good access to fertilizer inputs and markets (Fakorede *et al*., 2003). In West Africa, Manyong *et al.* (1996) assessed maize as one of the five main crops of the farming systems in about 125 million hectares (about 72%) of the study area. The current on-farm average yield of maize in West Africa is about 2 t ha^{-1} compared with the average yield in the 1970s, which was below 1 t ha^{-1} (Fakorede *et al.,* 2003). Even though the magnitude of the recent gains has been remarkable, there is still a wide yield gap between the research stations and that grown under on-farm conditions. Nevertheless, individual farmers who grow the improved varieties under well-managed, high input conditions usually obtain much higher grain yields. While yield increases achieved by farmers have resulted from the impacts of both genetics and improved crop husbandry, the contribution of improved management to yield increases is likely to be smaller in the next decade due to high cost and non-availability of agro-chemicals, particularly chemical fertilizers and a reduction in soil fertility as a result of human activity (Kamara *et al*., 2004). Therefore, alternative nutrient sources to chemical fertilizers that are environmentally friendly, cheap and readily available need to be investigated for maize.

Organic manures made of natural materials that undergo little or no processing may be a good alternative to chemical fertilizers. Organic inputs play a key role in sustaining soil productivity as they contribute to fertility by adding nutrients such as N, P and K to the soil. They are also major sources of energy and nutrient for soil microbial communities. It improves physical properties of soil such as promoting soil aggregation and nutrient buffering capacity and reducing soil bulk density (Vanlanwe, 1996; Sanchez, 1987). In Sierra Leone, as in other parts of West Africa, where oil palm abounds and have established brewery industries, readily available organic materials in the forms of palm kernel and barley residues, by-products of palm kernel oil processing and brewery industries respectively are usually produced in large quantities annually, and these are normally left to waste. These materials may be used as alternatives to chemical fertilizers in the production of maize. However, little or no research has been reported in this direction for crops. Therefore, this study was initiated to determine the response of maize to different rates of palm kernel and barley residue organic manures on a degraded upland soil in Sierra Leone.

MATERIALS AND METHODS

Experimental Site Description

A field experiment was conducted at the east end of Freetown (latitude 8˚, 30'N, longitude 13˚, 17'W and 400 m above sea level) in the Western area of Sierra Leone in 2010 and 2011. Annual rainfall in the Western area ranges from 2000-3000 mm, with an average temperature of 26˚C. The experimental site was cultivated with okra, followed by groundnut before the trial was established. During the trial period, mean temperature and relative humidity were about the same in both years, but rainfall was higher in 2010 than it was in 2011. The soil classified as ultisol (USDA, 1975) was sandy clay loam with a pH of about 4 in both years. The nutrient contents, particularly N, were low (Table 1).

TABLE 1
Weather and soil characteristics of the experimental site during the trial periods

Weather/Soil characteristics	2010	2011
Weather factor		
Rainfall (mm)	1194.3	991.5
Minimum temperature (˚C)	23.3	23.6
Maximum temperature (˚C)	30.6	30.8
Minimum relative humidity (%)	74.5	74.3
Maximum relative humidity (%)	86.8	84.5
Soil characteristics		
pH (H_2O)	4.1	4.0
Sand (%)	56	54
Silt (%)	20	22
Clay (%)	24	24
Organic Carbon (%)	0.36	0.29
N (%)	0.11	0.10
P (mg kg^{-1} Bray 1)	8.91	6.12
K (cmol kg^{-1})	0.54	0.38
Na (cmol kg^{-1})	0.26	0.17
Mg (cmol kg^{-1})	0.13	0.11
Ca (cmol kg^{-1})	0.32	0.24
CEC	6.00	4.70
Soil type	Sandy clay loam	Sandy clay loam

Planting Material

Zea mays L. (cv. DMR-ESR Yellow), obtained from the International Institute of Tropical Agriculture, Ibandon, Nigeria, was used as the planting material.

Experimental Design and Plot

The experiment was laid out in a randomized complete block design with three replications and four factors (palm kernel manure rate, berley manure rate, recommended chemical fertilizer rate and year) after manual land preparation. The plot size was 5 m x 3m with each plot consisting of 4 rows with 10 plant stands per row.

Manure and Fertilizer Rate and Method of Application

Four levels (0, 1, 3 and 5 t ha^{-1}) of palm kernel and barley residues and a recommended rate of chemical fertilizers (NPK 15-15-15) of 200 kg ha^{-1} were used. The organic manures were applied one week before planting using the pocket application method. Inorganic fertilizer was split applied to the appropriate plots, one-half at three weeks after planting and the other half at the onset of tasseling (anthesis). Two-hand weedings were carried out at 3 and 6 weeks after planting.

Seed Sowing and Harvesting

Planting was done on 30th May 2010 and 1st June 2011 at a spacing of 0.75 m x 0.50 m. Four seeds were planted and later thinned to two per stand one week after germination to give a population of 53, 333 plants ha^{-1}. The maize matured around 90 days after planting in both years. Harvesting was done on 29th August 2010 and 30th August 2011 for the first and second year, respectively. The 32 plants in the two middle rows of each plot (excluding the end plants) were harvested. The harvested ears were dried in the sun for two days, shelled and oven-dried at 60^{O}C for

4 days. Grain yield and 1000 grain weight were computed from the shelled dried grain adjusted to 12% moisture level.

Data Collection

Days from sowing to 50% pollen shed (anthesis date) and 50% silk extrusion (silking date) were determined on 40 plants in the two middle rows of each plot. Anthesis-Silking Interval (ASI) was calculated as the difference between days to silking and anthesis. Plant height and stem girth were measured on 10 plants per plot approximately 2 weeks after germination. The area of the leaf below the ear (cob) was measured *in situ* at mid-silking using a portable leaf area meter model LI-3000 A (head-scanner serial no. PAM 1684). The number of leaves per plant was determined at the same time as the ear leaf area.

Analysis of the Soil and Plant Samples

About 100g each of the palm kernel and barley residues were oven-dried at 60^{O}C for 4 days, crushed and passed through a 0.5 mm sieve. The organic manure materials were analyzed for N, P, K, Ca, Na and Mg concentrations. In addition, C:N ratio and organic carbon were determined for the manure materials. The Walkley-Black and Macro-Kjeldahl methods were used to analyze for organic C and total N, respectively. Meanwhile, the C:N ratio was calculated as the ratio of organic C to that of total N. Bray I method was used to extract P, while Ca, Mg, Na and K were analyzed after extraction with 1N ammonium acetate at pH 7.0. Ca and Mg were measured using atomic absorption spectrometry and Na and K by flame photometry (IITA, 1982).

The soil samples were collected in three positions in each replication at the depth of 0 – 20 cm with a 0.025 m-diameter Edelman auger. The soil samples were then bulked to make one composite sample. A subsample of 100 g was air dried, crushed and passed through a 0.5 mm and 2 mm sieved for the chemical and mechanical analyses, respectively. Soil pH was measured in 1:1 moisture of soil in deionized water using a glass electrode pH meter. The Walkley-Black and Macro-Kjeldahl methods were used to analyze soil organic C and total N, respectively. The C:N ratio was calculated as the ratio of organic C to that of total N. The Bray I method was used to extract available P. Exchangeable cations were analyzed after extraction with 1N HN_4OAc (ammonium acetate) at pH 7.0. Ca and Mg were measured using absorption spectrometry, and Na and K by flame photometry. The cation exchange capacity was determined by the summation of extractable cations by 1N NH_4OAc. The hydrometer method was used to determine the percentage of sand, silt and clay contents of the soil (IITA, 1982).

Statistical Analysis

The mixed model procedures of the Statistics Analysis System for Microsoft Windows Release 6.10 (SAS Institute, 1991) were used to detect differences between treatments for all the variables. Manure rate and year were the fixed effects and replication the random effect. The residual mean square was used to calculate approximate standard errors.

RESULTS

Nutrient Concentration in Manures

The palm kernel residue had about 3.1, 3.3, 4.1, 4.1, 1.2, 2.0% and 5.0% N, P, K, Na, C, Mg and Ca, respectively while barley residue contained 2.5, 2.9, 3.5, 5.6, 1.7, 1.8 and 3.9% N, P, K, Mg and Ca, respectively. This indicated that concentrations of N, P, K, Mg and Ca were 19, 11, 16, 11 and 21% higher in palm kernel than the barley residue, whereas, Na, C and C: N ratio were 27, 26 and 40% higher in barley than the palm kernel residue (Fig.1).

Grain Yield and Yield Components

Grain yield differed significantly between type ($p< 0.0001$) and rate ($p< 0.0001$) of manure, as well as year ($p< 0.0001$). Within each manure type, grain yield increased with the increase in the rate of manure in both years (Table 2). The palm kernel residue produced higher grain yield than the barley residue. Palm kernel residue treated plants gave about 19 and 28% higher grain yields than those treated with barley residue in 2010 and 2011, respectively. The plants treated with organic manures and NPK 15-15-15 fertilizer produced higher yield than the control. In 2010, only the 3 and 5 t ha^{-1} rates of palm kernel residue yielded higher than the 200kg ha^{-1} NPK 15-15-15 recommended fertilizer rate. In 2011, however, the 1, 3 and 5 t ha^{-1} rates of both manures gave higher grain yield than the NPK 15-15-15 fertilizer. Grain yield was about 39% higher in 2010 than that of 2011. Meanwhile, trends in 1000 grain weight are similar to those in grain yield (Table 2).

Phenology

Days to 50% anthesis and silking, as well as Anthesis-Silking Interval (ASI),

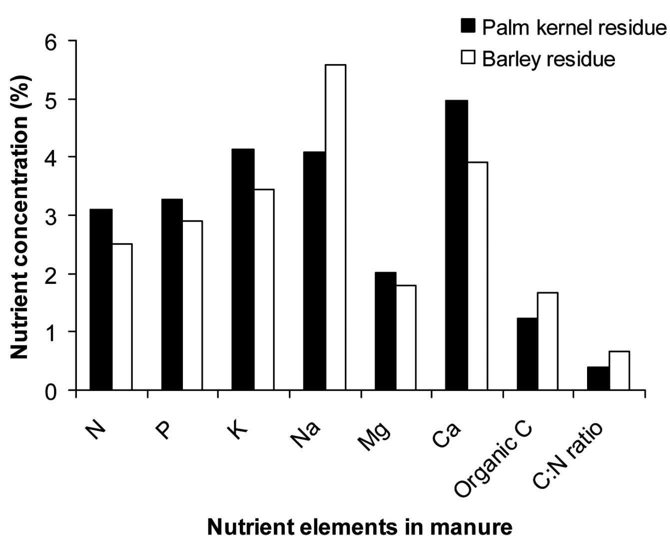

Fig.1: Concentration (%) of nutrient elements and C: N ratio in palm kernel and barley residue organic manures.

varied significantly (p< 0.0001) among rate and type of manure and year. In general, flowering (anthesis and silking) and ASI decreased as the rates of both manures increased in both years (Table 2). The plants treated with palm kernel residue reached 50% anthesis and silking about 2 and 3 days earlier than those plants treated with barley residue in 2010 and 2011, respectively. Anthesis-Silking Interval was the same for the plants treated with both manures in 2010. In 2011, ASI was 1 day shorter for the plants subjected to palm kernel manure than those of the plants treated with barley residue manure. Plants with no manure application had higher number of days to flowering and ASI than the manure and fertilizer treated plants in both the years. NPK 15-15-15 fertilizer treated plants flowered later and had higher ASI than the organic manure in both the years. The plants tasseled and silked were about 3 and 4 days, respectively, earlier in 2010 than in 2011. ASI was also lower in 2010 than in 2011 (Table 2).

TABLE 2
Yield and yield components and days to anthesis and silking of maize (cv. ‘DMR-ESR-Yellow) as influenced by different rates of palm kernel and barley residue organic manures and NPK 15:15:15 fertilizer in 2010 and 2011 on the upland soil

Treatment		Grain yield (kg ha^{-1})		1000 grain weight (g)		Days to 50% silking		Days to 50% anthesis		Anthesis-silking internal (days)	
Manure type	Rate	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
No manure	0 t ha^{-1}	1826de	860f	189d	142f	57.7a	67.0a	51.7a	61.0a	6.0a	6.0a
NPK 15:15:15	200 kg ha^{-1}	2136bc	945ef	194cd	147de	54.7c	61.0b	49.7c	56.3b	5.0b	4.7d
Palm kernel residue	1 t ha^{-1}	1763e	1171cd	190cd	147de	54.0c	55.0de	49.7c	50.3de	4.3c	4.7d
Palm kernel residue	3 t ha^{-1}	2174b	1577b	202b	154c	53.0d	54.3e	49.3c	50.0e	3.7d	4.3e
Palm kernel residue	5 t ha^{-1}	2826a	1982a	222a	161a	52.7d	54.3e	49.0d	50.0e	3.7d	4.3e
Barley residue	1 t ha^{-1}	1683e	974def	190cd	146e	56.3b	58.7bc	51.7d	53.0c	4.6bc	5.7b
Barley residue	3 t ha^{-1}	1849de	1080de	195c	150d	54.7c	58.0c	51.0b	53.0c	3.7d	5.0c
Barley residue	5 t ha^{-1}	1969cd	1343c	195c	160a	54.3c	57.0cd	51.0b	52.3cd	3.3d	4.7d
Year mean		2028a	1241b	197a	151b	54.7b	58.2a	50.4b	53.2a	4.3b	4.9a

Treatment means in a column and year means in row for each variable followed by a common letter are not significantly different at 5% level determined by LSD test

Plant height, stem girth, leaf production and ear leaf area were significantly varied among manure type and rate, as well as year (Table 3). For both types of manure, plant height increased with the increase in rate of manure in both the years. Comparing the residues, palm kernel residue showed taller plants than the barley residue. The plants were also taller in the organic manure treated plots than the control. In 2010, both manures at the rate of 5 t ha^{-1} produced significantly taller plants than the 200 kg ha^{-1} NPK 15-15-15. In 2011, the plants treated with both types of organic manure at all application rates were taller than those treated with NPK-fertilizer. The plants were 17% taller in 2010 than those in 2011 (Table 3).

The stem girth increased with the increase in rate of organic manures, but at each rate the palm kernel residue treated plants produced bigger stems than those of plants treated with barley residue in both years (Table 3). In 2010, plants treated with organic manure had bigger stems than the control and the recommended fertilizer rate of 200 kg ha^{-1} NPK 15-15-15. On the contrary, in 2011 only plants treated with 5 t ha^{-1} palm kernel residue had bigger stems than those treated with NPK-fertilizer. In all cases the control (0 t ha^{-1}) produced the smallest stem size.

Leaf production increased as the rates of two manure types increased in both years (Table 3). At each manure rate, the palm kernel residue produced higher number of leaves than the barley residue. In 2010, NPK-fertilizer treatment plants produced more leaves than the control, but in 2011 both treatments had similar number of leaves. In 2010 and 2011, 200 kg ha^{-1} NPK 15-15-15 and the control treatments produced lower number of leaves than the manure treatments. On average, plants produced more leaves in 2010 than in 2011 (Table 3).

In each type of manure, ear leaf area increased with the increase in rate of manure. At each rate, plants treated with palm kernel residue produced larger ear leaf area than those plants treated with barley residue. Plants treated with palm kernel residue at all rates and at 5 t ha^{-1} for barley residue had significantly large ear leaf area than those of 200 kg ha^{-1} NPK 15-15-15 fertilizer, while the control had the least ear leaf area. In 2011, irrespective of the rate and type, the manure treated plants had larger ear leaf area than the 200 kg ha^{-1} NPK 15-15-15 ferilizer and the control. In both years, the chemical fertilizer treated plants produced larger ear leaf area than the control. The ear leaf area was about 12% larger in 2010 than in 2011 (Table 3).

DISCUSSION

Maize showed significant differences for grain yield and its components under different rates of palm kernel and barley residue manures. Grain yield and 1000 grain weight increased with the increase in the rate of both organic manures. The results are consistent with Kamara (1998) who reported that an addition of organic materials is important in maize production. Mugendi *et al*. (1994), and Sanginga and Swift (1992) reported that positive role is

TABLE 3
Effect of different rates of palm kernel and barley residue organic manures and NPK 15:15:15 fertilizer on morphological characters of maize (cv. 'DMR-ESR-Yellow) in 2010 and 2011 on a degraded upland soil

Treatment		Plant height (cm)		Stem girth (cm)		No. of leaves plant^{-1}		Ear leaf area (cm^2)	
Manure type	Rate	2010	2011	2010	2011	2010	2011	2010	2011
No manure	0 t ha^{-1}	162.4d	121.3e	1.8d	1.9c	15.3d	13.6d	223.8e	186.8d
NPK 15:15:15	200 kg ha^{-1}	175.5bc	130.1d	1.9cd	2.1b	16.0d	13.7d	286.4c	198.8d
Palm kernel residue	1 t ha^{-1}	172.2c	144.5c	2.2b	2.0bc	16.6cd	16.7b	290.2c	261.1c
Palm kernel residue	3 t ha^{-1}	176.1b	155.3b	2.4a	2.1b	19.7a	17.6b	326.4b	295.6b
Palm kernel residue	5 t ha^{-1}	185.4a	167.0a	2.5a	2.8a	19.8a	18.8a	385.3a	345.5a
Barley residue	1 t ha^{-1}	173.0bc	130.6d	2.0c	2.0bc	15.5d	15.4c	253.1d	258.5c
Barley residue	3 t ha^{-1}	173.5bc	149.2bc	2.2b	2.0bc	16.3cd	16.7b	280.7c	262.6c
Barley residue	5 t ha^{-1}	177.8b	153.4b	2.2b	2.1b	17.0c	17.1b	302.9bc	262.8c
Year mean		174.5a	143.9b	2.2a	2.1a	17.0a	16.2a	293.6a	259.0b

Treatment means in a column and year means in row for each variable followed by a common letter are not significantly different at 5% level determined by LSD test

played by N released from decomposing organic materials. A similar trend in the grain yield as that in 1000 grain weight suggests that the manures increased yield by partly increasing the individual grain weight. This is supported by Kamara *et al*. (2003) who reported that maize genotypes with higher individual kernel weight gave higher yields than those of lower kernel weight.

While the palm kernel residue at the rates of 3 and 5t ha^{-1} were the best treatments in both years, the 200 kg NPK 15-15-15 ha^{-1} yielded higher than barley residue at 1 and 3t ha^{-1} in 2010. In 2011, there was a 27-57% and 19-56% increases in yield with the application of 1-5t ha^{-1} palm kernel residue compared to the control and the recommended 200 kg ha^{-1} NPK 15-15-15. The corresponding figures for barley residue were 9-36% and 0.2-30%. This indicates that the use of both organic manures, particularly at 5 t ha^{-1}, has substantial yield advantage over the inorganic fertilizer. The results of this study corroborate with those of Kamara (1998) who observed that organic materials obtained from *G. sepium* and *L. leucecophala* gave higher maize yield than the inorganic N fertilizer at 90 kg ha^{-1}.

The barley and palm kernel residues contained about 2.5 and 3.1% N, respectively, which translated to 25 and 31 kg N for each ton of manure, respectively. The ability of plant residues to decompose and release nutrients is determined by their litter quality which is a function of the chemical composition of the plant materials. Plant residues with high N content show high decomposition rates and nutrient release (Swift *et al*., 1979; Kamara, 1998). Therefore, the higher yield obtained from palm kernel residue application than that of barley residue could largely be due to higher N content, faster decomposition rate and nutrient release by the palm kernel than barley residue (Swift *et al*., 1979; Kamara, 1998). After oil extraction, the palm kernel residue is left in the form of fine particles, which might have contributed to its faster rate of decomposition and nutrient release. Thus, the use of barley residue as manure should be supplemented with inorganic nutrients to accelerate nutrient release as recommended by Mugendi *et al*. (1994) for pruning from tree leaves with low N content. Palm kernel residue could do without inorganic fertilizer.

Grain yield increased with the increase in rates of organic manures, due largely to increase in N supply, as was also observed by Mugendi *et al*. (1994) and Kamara (1998). The 200 kg of NPK 15-15-15 fertilizer had 30 kg N, indicating that at 3 and 5t ha^{-1}, the palm kernel residue contained about 3 and 5 times, while the barley residue had 2½ and 4 times more N than the chemical fertilizer treatment. Hence, the higher grain yields at these rates (3 and 5t ha^{-1}) for both organic manures than the 200 kg of NPK 15-15-15 fertilizer. The low availability and high cost of inorganic fertilizers put them out of the reach of many small farmers in West Africa (FAO, 1992). Also, leaching of nutrients in the soil reduces the efficiency of inorganic fertilizers in the tropics (Sanchez *et al*., 1997). Organic inputs have an important advantage over inorganic fertilizers with regard to fertility replenishment; they provide a carbon source for microbial utilization resulting in the formation of soil organic nitrogen. Inorganic fertilizers do not contain such carbon sources. Therefore, most of the fertilizer nitrogen not used by the crops is subject to leaching and de-nitrification losses, while much of the nitrogen released from organic inputs and is not utilized by the crops can build soil organic nitrogen capital (Sanchez & Palm, 1996). Hence, the use of 3-5t ha^{-1} of both manures, particularly palm kernel residue with higher nutrient content compared with barley residue, could substantially increase maize grain yield in Sierra Leone.

The 5t ha^{-1} rate contained about 125 and 155 kg N ha^{-1} for barley and palm kernel residues, respectively. Thus, the increase in grain yield and its components as the application rate of both manures increased showed that the highest rate used was not the optimum as maize has been reported to respond to up to 200 kg N ha^{-1} in Sierra Leone (George, 1986). Therefore, rates higher than 5t ha^{-1} should be included in subsequent trials in order to obtain maize response curves for both manures. Grain yield was about 39% higher in 2010 than in 2011, likely and partly due to higher rainfall (1615.5 mm) in the first than the second year (941.2 mm), which might have reduced drought stress in the first year (Table 1). During the period of lower rainfall, plants treated with both organic manures gave considerably higher grain yield than the chemical fertilizer compared with the yield under high rainfall. The organic manures might have maintained more favourable soil moisture and temperature regimes during low rainfall thereby substantially increasing yield. Consistent with our results, Martinez *et al*. (2009) observed 50% increases in yield of quinoa with the addition of organic matter even under conditions of low irrigation.

Plants treated with both organic manures reached 50% pollen shed and silk emergence earlier and had shorter ASI than those of plants treated with inorganic fertilizer and no manure application, with plants treated with palm kernel residue having shorter days to reproductive development than those of plants treated with barley residue. However, all the treatments attained physiological maturity at about 90 days. The reduction in days to silking and ASI likely resulted in effective pollination and longer grain-filling period, which might have contributed to the increased in yield for especially plants treated with palm kernel residue. The results of this study are consistent with the observation that delayed silking is associated with barrenness (Herrero & Johnson, 1981) and appear to reflect reduced partitioning of assimilates to the developing ear at flowering (Edmeades *et al*., 1993; Kamara *et al*., 2003). Environmental stress such as N-deficiency delays reproductive development (Bolanos & Edmeades, 1993; Kamara *et al*., 2005) and reduce ear biomass at flowering (Lemcoff & Loomis, 1986). The increased supply of N to the maize plants with increasing manure rate might have contributed to the early tasseling and silking and also to shorter ASI as the rates of both organic manures increased. Delay in reproductive development under inorganic fertilization and barley residue as compared to palm kernel residue, respectively, could largely be attributed to lower N supplied by the former than the latter nutrient sources. The plants had shorter days to tasseling and silking and lower ASI in 2010 than in 2011. This could partly be attributed to the higher rainfall in 2010 than in 2011, which could have reduced drought stress in the first year, as drought stress has been reported to delay reproductive development in maize (Edmeades *et al.*, 1993).

Plant height, stem diameter, number of leaves and ear leaf area increased as the rate of both organic manures increased, but the increases in these growth parameters were higher under palm kernel than the barley residue. Kamara *et al*. (2005) showed that plant height, ear height and total dry matter increased with increasing rates of N application. The increase in nutrient availability, particularly N with increasing rate of manuring, may have contributed to the increase in growth parameters as the rate of both manures increased. This is supported by the fact that palm kernel residue with higher N, P, K, Ca and Mg produced taller plants that had bigger stems and higher number of leaves and ear leaf area than barley residue treated plants. Kamara *et al*. (2003) showed that maize genotypes with extended green leaf area duration have longer grain filling periods and higher kernel yields and also noted remobilization of assimilates from the stem to the ears. The manure treated plants with bigger stems and higher number of leaves and ear leaf area, especially those under palm kernel residue likely had longer grain filling periods and more assimilates for remobilization to the developing ears and therefore higher grain yield than the recommended chemical fertilizer and the control.

CONCLUSION

Maize exhibited significant differences for growth parameters and yield under different rates of palm kernel and barley residue manures. These parameters increased with the increase in the rate of manures, but the increases were higher in palm kernel than the barley residue. Organic manure treated plants, especially under palm kernel residue, flowered earlier and had shorter anthesis silking interval (ASI) than those plants treated with inorganic fertilizer. High rainfall reduced days to tasseling and silking and ASI and increased yield. Under low rainfall, both organic manures yielded considerably higher than the inorganic fertilizer when compared with the yield under high rainfall. The use of 3 and 5t ha^{-1} of particularly, palm kernel residue could substantially increase grain yield without the use of inorganic fertilizer. However, the increase in yield with application rate showed that higher rates should be included in subsequent trials to obtain maize response curves for both manures.

ACKNOWLEDGEMENTS

The authors are grateful to Mr. Braima Sinneh Turay, Miss Jane F. Kabba-Sei, Miss Lucy Lahai and the field staff of the Department of Crop Science for data collection and to Dr. Melvin George for calculation of grain nutrient content.

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