Emir. J. Food Agric. 2012. 24 (4): 314-321
http://ejfa.info/

PLANT SCIENCE

Effect of wood ash, poultry manure and NPK fertilizer on soil and leaf nutrient composition, growth and yield of okra (*Abelmoschus esculentus*)

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Abstract

The data on poultry manure (PM), wood ash (WA) and NPK fertilizer are needed to identify strategies for sustainable management of a degraded Alfisol for improving agronomic productivity. Hence field experiments were conducted at Owo in the forest-savanna transition zone of southwest Nigeria to study the effects of organic amendments and NPK fertilizer on the soil chemical properties, leaf nutrient concentrations, growth and pod yield of okra. Seven treatments considered in 2006, 2007 and 2008 were control (no manure/fertilizer), 5.0 t ha^{-1} PM, 10.0 t ha^{-1} PM, 5.0 t hav WA, 10.0 t ha^{-1} WA, 5.0 t ha^{-1} PM + 5. 0 t ha^{-1} WA and NPK 15-15-15 (200 kg ha^{-1}) fertilizer. The treatments were laid out in a randomized complete block design with three replications. Organic amendments (PM and WA) improved soil organic C, N, P, K, Ca and Mg and leaf N, P, K, Ca and Mg concentrations, growth and yield of okra compared with the control. NPK 15-15-15 fertilizer increased soil N, P and K, but did not increase soil organic C, Ca and Mg and leaf Ca and Mg of okra. Combined application of 5.0 t ha^{-1} PM + 5.0 t ha^{-1} WA mostly improved leaf and soil N, P, K, Ca and Mg and soil organic C, growth and okra yield compared with other treatments. The superior performance of 5.0 t ha^{-1} PM + 5.0 t ha^{-1} WA was adduced to increased availability of nutrients following the inclusion of PM which aided faster decomposition and release of nutrients. Relative to the control, using the mean of the 3 years, 5.0 t ha^{-1} WA, 5.0 t ha^{-1} PM, NPK fertilizer, 5.0 t ha^{-1} PM + 5.0 t ha^{-1} WA, 10.0 t ha^{-1} WA and 10.0 t ha^{-1} PM increases pod yield by 23, 64, 68, 255, 41 and 123%, respectively. Combined use of PM and WA is recommended for ameliorating degraded Alfisol of southwest Nigeria and also reduced the quantities of PM and WA required for soil fertility maintenance.

Key words: Poultry manure, Wood ash, NPK fertilizer, Okra (*Abelmoschus esculentus*)

Introduction

Land degradation is regarded as an important global issue for the 21st century as it affects the environment, agronomic productivity and food security (Eswaran et al., 2001). The processes of soil degradation include the loss of top soil by water or wind, chemical deterioration of the natural resource which include among others, the reduction of soil biodiversity (Lal, 2001). According to Kirchhof and Salako (2000) and Salako et al. (2001), the impact of such soil degradation is difficult to reverse, especially if severe. Hence, early intervention in the rehabilitation of degraded soils is very important in achieving quick positive results and reversing the trend of degradation (Agbede and Ojeniyi, 2009). Furthermore, the avoidance of soil loss by improved management of the natural resource is important to combat low agricultural production, food insecurity and the rapid increase in level of poverty (Ehui and Pender, 2005).

The majority of Alfisols available for crop production in the tropics have low organic matter and nutrient status. Consequently, intensive crop production requires high rate of organic and inorganic fertilizers. In the last fifteen years in Nigeria, chemical fertilizers have become very scarce and prices are high for average farmers. Hence, there is the need to search for organic amendments which could be utilized as fertilizer. Such amendments should be readily available, environmentally friendly and cheap. Integrating such amendments with one another might be the key to attaining the good yield. The effects of integrated nutrient supply as opposed to sole application of soil amendments in its effects on soil chemical properties, leaf nutrient concentration, growth and yield of okra has not been investigated,

Received 30 January 2011; Revised 19 October 2011; Accepted 21 December 2011

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although studies were conducted on the responses of okra to sole application of wood ash and poultry manure; For instance, Ojeniyi (2007) found increased in pod yield of okra with application of wood ash up to 8 t ha^{-1}. Likewise, Alasiri and Ogunkeyede (1999) reported that application of poultry manure at the rate of 10 t ha^{-1} gave the optimum seed yield of okra in southwest Nigeria.

Analysis of different organic amendments (Ojeniyi, 2007; Agbede and Ojeniyi, 2009) showed that poultry manure had high N and low K and C:N ratio values, and wood ash had high K and C:N ratio. It is expected that integrating the two organic amendments would have better effect on soil chemical properties, growth and yield of okra than the sole application of either of them. More so, the quantities of the organic amendments available may not be sufficient for large-scale okra production. Based on foregoing, Adediran et al. (2003) suggested the need for the combination of both the poultry manure and wood ash. Therefore this work investigated the sole and combined applications of poultry manure and wood ash compared with NPK-15-15-15 fertilizer on soil nutrient concentrations, leaf nutrient status, growth and yield of okra at Owo, southwest Nigeria.

Materials and Methods

Site description

A 3 year field experiment was carried out at Owo (latitude 7°12'N, longitude 5°35'E) within the forest-savanna transition zone of southwest Nigeria. The soil at Owo belongs to the broad group of Alfisol classified as Oxic Tropuldalf (USDA, 1999) or Luvisol (FAO, 1998) of the basement complex and locally classified as Okemesi Series (Smyth and Montgomery, 1962). The upper horizon (0-15 cm) of the experimental site is of sandy loam textural class. The values of the physical and chemical properties of the surface soil (0-15 cm) prior to experimentation are shown Table 1. This forest-savanna zone has a bimodal pattern of rainfall with first season commencing from April to July and a dry spell in August followed by second season in September to November. The annual rainfall totals were 1241, 1335 and 1442 mm for 2006, 2007 and 2008, respectively. The site of the experiment was fairly degraded and was dominated by Elephant grass (*Pennisetum purpureum*) and Guinea grass (*Panicum maximum*), but was left to fallow for 2 years before the start of the experiment. The same treatment was allotted to each plot for the 3 years of study.

Field experiment and treatments

The trial consists of sole and combined applications of poultry manure (PM) and wood ash (WA), and application of NPK-15-15-15 fertilizer at the rate of 200 kg ha^{-1} . The treatments compared for the 3 years were (a) control, i.e. no application of PM, WA or NPK-15-15-15 fertilizer, (b) 5.0 t ha^{-1} PM, (c) 10.0 t ha^{-1} PM, (d) 5.0 t ha $^{-1}$ WA, (e) 10.0 t ha^{-1} WA, (f) 5.0 t ha^{-1} PM + 5.0 t ha^{-1} WA and (g) NPK-15-15-15 fertilizer at the rate of 200 kg ha^{-1}. The seven treatments were laid out in a randomized complete block design with three replications. After the initial clearing of the site and packing away of debris (no burning was done), manual ridges were constructed with a hoe.

Table 1. Mean ± standard deviation of soil physical and chemical properties (0-15 cm depth) at the experimental site in 2006 before the start of the experiment.

Property	Value
Sand (g kg^{-1})	690 ± 7.4
Silt (g kg^{-1})	130 ± 5.2
Clay (g kg^{-1})	180 ± 3.8
Soil texture	Sandy loam
pH (H_20)	6.2 ± 0.2
Bulk density (Mg m^{-3})	1.54 ± 0.04
Total porosity (%, v/v)	41.9 ± 0.3
Organic C (g $100g^{-1}$)	1.30 ± 0.06
Total N (g $100g^{-1}$)	0.13 ± 0.02
Available P (mg kg^{-1})	6.2 ± 0.08
Exchangeable K (cmol kg^{-1})	0.07 ± 0.08
Exchangeable Ca (cmol kg^{-1})	1.7 ± 0.04
Exchangeable Mg (cmol kg^{-1})	0.12 ± 0.01

Crop establishment

The experimental plot size each year was 6 m x 5 m. Three okra seeds were planted at 60 cm x 60 cm. Okra variety NHAE-47-4 obtained from National Horticultural Research Institute, Ibadan, Nigeria was planted in May each year. Thinning to one plant per stand was done two weeks after sowing (WAS). Sole and combined application of PM and WA and NPK fertilizer was done immediately after thinning by ring method, thoroughly worked into the soil with a hoe. Manual weeding with cutlass was done twice in each experiment. Insect pests were controlled by spraying cypermethrin weekly at the rate of 30 ml per 10 litres of water from 2 WAS till 4 WAS (Adeyemi et al., 2005). The same treatment method was used on each plot for the 3 years of the study.

Soil sampling and analysis

Before the start of the experiment (after land clearing), 10 core soil samples, randomly collected from 0-15 cm depth were thoroughly mixed inside a plastic bucket to form a composite which was later analysed for physical and chemical properties. At harvest in 2007 and 2008, another set of composite samples were collected per plot and similarly analysed for routine chemical analysis as described by Carter (1993). The soil samples were air-dried and sieved using a 2-mm sieve before making the determinations. Soil organic C was determined by the procedure of Walkley and Black using the dichromate wet oxidation method, total N was determined by micro-Kjeldahl digestion method, available P was determined by Bray- 1 extraction followed by molybdenum blue colorimetry. Exchangeable K, Ca and Mg were extracted using 1.0 N ammonium acetate. Thereafter, K was determined using flame photometer and Ca and Mg were determined using the EDTA titration method. Soil pH was determined in soil-water (1:2) medium using the digital electronic pH meter. Particle-size analysis was done using hydrometer method. Ten core samples (4 cm diameter, 10 cm high) were collected randomly before the start of the experiment for the determination of bulk density using the core method (Campbell and Henshall, 1991).

Okra leaf analysis

In 2007 and 2008, at 7 weeks after treatment application, leaf samples were collected randomly from each plot, oven-dried for 24 h at 80°C and ground in a Wiley-mill. The samples were analysed for leaf N, P, K, Ca and Mg as described by Tel and Hargarty (1984). Leaf N was determined by the micro-Kjeldahl digestion method. Samples were dry ashed at 500°C for 6 h in a furnace and extracted using nitric-perchloric-sulphuric acid mixture for determination of P, K, Ca and Mg (AOAC, 1990). Phosphorus was determined colorimeterically by the vanadomolybdate method, K was determined using a flame photometer and Ca and Mg were determined by the EDTA titration method.

Preparation and chemical analysis of organic amendments

The wood ash (WA) used for the study was collected from a bakery at Owo and was sieved with 2-mm sieve before application. The poultry manure (PM) used was stacked for 1 week under a shed to allow for mineralization. Small samples from the PM and WA used for the study were taken for laboratory analysis to determine their nutrient compositions. The samples were analysed for organic C, N, P, K, Ca and Mg as described by Okalebo et al. (1993).

Okra growth and yield

Twenty plants were randomly selected per plot for the determination of plant height, leaf area and pod yield. Plant height (by rule measure) and leaf area (by graphical method) were determined at 7 weeks after treatment application. Edible pods were harvested at 4 days interval and weighed. Pod weight was evaluated based on the cumulative number of pods at 8 harvests.

Statistical analysis

The data collected were subjected to analysis of variance and treatment mean were compared using Duncan's multiple range test (DMRT) at $p = 0.05$ probability level (Steel et al., 1997).

Results

The data presented in Table 1 are the results of the physical and chemical analysis of the experimental site before the start of the experiment in 2006. The soil was sandy loam and slightly acidic. The soil organic C and all the essential elements, i.e. N, P, K, Ca and Mg were very low according to the critical levels of 3.0% OM, 0.2% N, 10.0 mg kg $^{-1}$ available P, 0.16 – 0.20 cmol kg^{-1} exchangeable K, 2.0 cmol kg^{-1} exchangeable Ca, 0.40 cmol kg^{-1} exchangeable Mg recommended for crop production in ecological zones of Nigeria (Akinrinde and Obigbesan, 2000). It will therefore unable to sustain crop yield without the addition of external input.

Table 2. Chemical composition of the organic amendments used for the experiment.

Parameters	Wood ash	Poultry manure
pH	11.1	6.8
Organic C (%)	18.0	29.5
Nitrogen (%)	1.72	4.31
C : N	10.5	6.8
Phosphorus (%)	0.86	0.83
Potassium (%)	3.6	2.2
Calcium (%)	8.6	1.4
Magnesium (%)	1.9	0.58

Table 2 shows the chemical composition of organic amendments used for the experiment. The pH of WA was very strongly alkaline and that of PM was slightly acidic. Except for organic C, N and P, WA has higher values of nutrients compared to PM. Poultry manure (PM) have low C:N ratio compared with WA. The amendments have higher values of organic C, P, N and cations than the soil used for the experiment. Hence, it is expected that the soil amendments used would improve the fertility of the soil and okra yield.

Effects of organic amendments and NPK-15-15-15 fertilizer on soil chemical properties

The effects of organic amendments and NPK-15-15-15 fertilizer on soil chemical properties in 2007 and 2008 are shown in Table 3. In the 2 years considered and relative to the control, sole applications of WA and PM increases and decreases soil pH linearly with rates of WA and PM applied respectively. There were no significant differences between the pH values of control, 5.0 t ha^{-1} PM and NPK-15-15-15 fertilizer and between 5.0 t ha^{-1} WA and combined applications of PM and WA (5.0 t ha^{-1} PM + 5.0 t ha^{-1} WA).

Relative to the control, sole and combined applications of PM and WA significantly increased (p = 0.05) soil organic carbon (SOC) with 10.0 t ha^{-1} PM producing the highest value. NPK-15-15-15 fertilizer did not increase SOC. Relative to the control and using the mean of the 2 years, 10.0 t ha^{-1} PM, 5.0 t ha^{-1} PM + 5.0 t ha^{-1} WA, 5.0 t ha^{-1} PM, 10.0 t ha^{-1} WA and 5.0 t ha^{-1} WA, increased SOC by 241, 192, 113, 102 and 47%, respectively. Sole application of PM significantly gave higher SOC than the sole WA.

Compared with the control, organic amendments (PM and WA) significantly increased (p = 0.05) soil N, P, K, Ca and Mg concentrations. Whereas, NPK fertilizer significantly increased (p = 0.05) soil N, P and K, but did not increase soil Ca and Mg. Combined application of 5.0 t ha^{-1} PM + 5.0 t ha^{-1} WA produced the highest values of P, K, Ca and Mg concentrations. Phosphorus values of NPK fertilizer and 10.0 t ha^{-1} PM were not significantly different. Likewise, K values of NPK fertilizer and 10.0 t ha^{-1} WA were not significantly different. Sole application of PM and WA increased the concentration of organic C, N, P, K, Ca and Mg compared with the control. The values of these nutrients increased with increases in amount of WA and PM. Comparing the same sole rate of PM and WA, poultry manure (PM) significantly increased soil organic C, N and P concentrations relative to wood ash (WA). Wood ash (WA) significantly increased K, Ca and Mg concentrations relative to poultry manure (PM).

Effects of organic amendments and NPK fertilizer on leaf nutrient concentrations of okra

Compared to control, organic amendments significantly increased (p = 0.05) leaf N, P, K, Ca and Mg concentrations. Whereas NPK fertilizer significantly increased (p = 0.05) leaf N, P and K, but did not increase leaf Ca and Mg (Table 4). However, there were no significant differences in the leaf N of NPK fertilizer and 10.0 t ha^{-1} WA, and between 5.0 t ha^{-1} PM + 5.0 t ha^{-1} WA and 10.0 t ha^{-1} PM. Combined use of PM + WA produced the highest values of leaf K, Ca and Mg concentrations compared with other treatments.

Effects of organic amendments and NPK fertilizer on growth and yield of okra

The effects of organic amendments and NPK fertilizer on growth and yield of okra is shown in Table 5. All the soil amendments significantly increased (p = 0.05) plant height, leaf area per plant and pod yield of okra relative to control. Combined use of 5.0 t ha^{-1} PM + 5.0 t ha^{-1} WA gave the highest values of growth and yield parameters. There were no significant differences in the plant height, leaf area and pod yield of 5.0 t ha^{-1} PM and NPK fertilizer. Sole application of PM significantly recorded better plant height, leaf area and pod yield compared with sole WA. Likewise, the growth and yield parameters increases with amounts of PM and WA applied. Relative to the control, using the mean of the 3 years, 5.0 t ha^{-1} WA, 5.0 t ha^{-1} PM, NPK fertilizer, 5.0 t ha^{-1} PM + 5.0 t ha^{-1} WA, 10.0 t ha^{-1} WA and 10.0 t ha^{-1} PM increases pod yield by 23, 64, 68, 255, 41 and 123%, respectively. Compared with NPK fertilizer, 10.0 t ha^{-1} PM and 5.0 t ha^{-1} PM + 5.0 t ha^{-1} WA improved pod yield of okra by 32 and 111%, respectively.

Discussion

The increase in soil organic C, N, P, K, Ca and Mg concentrations due to the application of organic amendments and NPK fertilizer is consistent with the analysis recorded for the PM and WA in the present work and the use of PM, WA and NPK fertilizer for improving soil fertility in crop production (Patterson et al., 2004; Nottidge et al., 2005; Adenawoola and Adejoro, 2005). The decrease in pH with amount of PM could be due to the humic acid developed and $C0_2$ evolved in the process of decomposition of poultry manure. Chang et al. (1991) also found that pH in the surface 60 cm of non-irrigated and 90 cm of irrigated soil decreased with increased manure rates. Likewise, the findings that WA led to increase in soil pH is consistent with the analysis recorded for the pH of the wood ash used in the present study (pH of 11.1). Hence wood ash being a calcium-containing mineral raised the soil pH. The increase in soil pH observed in this treatment could be attributed to increased availability of calcium ions released into the soil solution during the microbial decarboxylation of wood ash which is known to buffer change in soil pH. This confirmed that wood ash improved the base status of the soil to which it is applied.

Table 3. Effects of organic amendments (PM and WA) and NPK fertilizer on soil chemical properties (0-15 cm depth) in 2007 and 2008.

Treatment	pH (H_20)			Organic C(g $100g^{-1}$)			N (g $100g^{-1}$)			P (mg kg^{-1})			K (cmol kg^{-1})			Ca (cmol kg^{-1})			Mg (cmol kg^{-1})		
	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean
Control	6.1d	6.1d	6.1d	1.00f	0.92f	0.96f	0.09e	0.08e	0.09e	4.3f	4.2f	4.3f	0.06g	0.05g	0.06g	1.21f	1.00f	1.11f	0.10f	0.10f	0.10f
5.0 t ha^{-1} PM	5.8d	5.8de	5.8de	2.00c	2.08c	2.04c	0.38c	0.38c	0.38c	5.9d	5.9d	5.9d	0.26f	0.26f	0.26f	2.40e	2.60e	2.50e	0.14e	0.15e	0.15e
10.0 t ha^{-1} PM	5.3f	5.3f	5.3f	3.20a	3.33a	3.27a	0.71a	0.72a	0.72a	11.1b	11.1b	11.1b	0.48d	0.49d	0.49d	4.40c	4.45c	4.43c	0.26c	0.27c	0.27c
5.0 t ha^{-1} WA	7.3b	7.3b	7.3b	1.40e	1.41e	1.41e	0.21d	0.23d	0.22d	5.4e	5.4e	5.4e	0.37e	0.38e	0.38e	2.95d	3.01d	2.98d	0.23d	0.24d	0.24d
10.0 t ha^{-1} WA	8.1a	8.2a	8.2a	1.90cd	1.98cd	1.94cd	0.48b	0.46b	0.47b	8.6c	8.5c	8.6c	0.73b	0.75b	0.74b	5.61b	5.83b	5.72b	0.41b	0.41b	0.41b
5.0 t ha^{-1} PM + 5.0 t ha^{-1} WA	7.0bc	6.9bc	7.0bc	2.75b	2.85b	2.80b	0.68a	0.70a	0.69a	12.5a	12.5a	12.5a	0.85a	0.86a	0.86a	6.42a	6.60a	6.51a	0.47a	0.47a	0.47a
NPK 15-15-15 (200 kg ha^{-1})	6.0d	5.9de	6.0d	0.96f	0.90f	0.93f	0.47b	0.47b	0.47b	11.0b	11.6b	11.3b	0.67bc	0.69bc	0.68bc	1.26f	1.03f	1.15f	0.09g	0.09g	0.09g

Means followed by similar letters are not significant different according to Duncan's multiple range test (DMRT); PM = Poultry manure; WA = Wood ash

Table 4. Effects of organic amendments (PM and WA) and NPK fertilizer on leaf nutrient concentrations of okra in 2007 and 2008.

Treatment	N (g $100g^{-1}$)			P (g $100g^{-1}$)			K (g $100g^{-1}$)			Ca (g $100g^{-1}$)			Mg (g $100g^{-1}$)		
	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean
Control	1.40e	1.39e	1.40e	0.09f	0.08e	0.09f	1.00f	1.09f	1.00f	0.30f	0.30f	0.30f	0.09f	0.08f	0.09f
5.0 t ha^{-1} PM	2.55c	2.56c	2.56c	0.13d	0.12c	0.13d	1.15d	1.15d	1.15d	0.51e	0.51e	0.51e	0.11e	0.11e	0.11e
10.0 t ha^{-1} PM	4.90a	4.95a	4.93a	0.28a	0.29a	0.29a	1.98c	1.98c	1.98c	0.79c	0.81c	0.80c	0.15c	0.15c	0.15c
5.0 t ha^{-1} WA	1.66d	1.69d	1.68d	0.11e	0.10d	0.11e	1.30e	1.31e	1.31e	0.61d	0.61d	0.61d	0.13d	0.12d	0.13d
10.0 t ha^{-1} WA	3.60b	3.60b	3.60b	0.15c	0.16b	0.16c	2.50b	2.55b	2.53b	1.00b	1.00b	1.00b	0.21b	0.21b	0.21b
5.0 t ha^{-1} PM + 5.0 t ha^{-1} WA	4.80a	4.95a	4.88a	0.29a	0.28a	0.29a	2.82a	2.96a	2.89a	1.28a	1.26a	1.27a	0.25a	0.25a	0.25a
NPK 15-15-15 (200 kg ha^{-1})	3.70b	3.60b	3.70b	0.26b	0.28a	0.27b	2.45b	2.47b	2.46b	0.30f	0.30f	0.30f	0.09f	0.08f	0.09f

Means followed by similar letters are not significant different according to Duncan's multiple range test (DMRT); PM = Poultry manure; WA = Wood ash.

Table 5. Effects of organic amendments (PM and WA) and NPK fertilizer on plant height, leaf area and pod weight of okra in 2006, 2007 and 2008.

Treatment	Plant height (m)				Leaf area per plant (m^2)				Pod weight (t ha^{-1})			
	2006	2007	2008	Mean	2006	2007	2008	Mean	2006	2007	2008	Mean
Control	0.32f	0.34f	0.33f	0.33f	0.70f	0.74f	0.72f	0.72f	2.4f	2.2f	2.1f	2.2f
5.0 t ha^{-1} PM	0.48c	0.49c	0.50c	0.49c	1.11c	1.18c	1.10c	1.13c	3.6c	3.6c	3.5c	3.6c
10.0 t ha^{-1} PM	0.52b	0.58b	0.59b	0.56b	1.25b	1.31b	1.28b	1.28b	4.8b	4.9b	4.9b	4.9b
5.0 t ha^{-1} WA	0.39e	0.41e	0.40e	0.40e	0.90e	0.92e	0.91e	0.91e	2.7e	2.8e	2.6e	2.7e
10.0 t ha^{-1} WA	0.44d	0.46d	0.47d	0.46d	0.99d	1.04d	1.00d	1.01d	3.0d	3.1d	3.2d	3.1d
5.0 t ha^{-1} PM + 5.0 t ha^{-1} WA	0.59a	0.64a	0.65a	0.63a	1.60a	1.66a	1.52a	1.59a	7.7a	7.8a	7.9a	7.8a
NPK 15-15-15 (200 kg ha^{-1})	0.49c	0.51c	0.50c	0.50c	1.11c	1.19c	1.10c	1.13c	3.7c	3.7c	3.6c	3.7c

Means followed by similar letters are not significantly different according to Duncan's multiple range test (DMRT); PM = Poultry manure; WA = Wood ash.

Park et al. (2004) also found that WA significantly increased soil pH in the 0-10 cm soil layer from 6.1 in the control to 6.9 and 7.1 in the 10 and 20 Mg ha^{-1} plots, respectively.

The findings that combined application of PM and WA (5.0 t ha^{-1} PM + 5.0 t ha^{-1} WA) gave the highest values of P, K, Ca and Mg is attributable to release of nutrients from both the WA and PM. The integration of the PM with the WA should have enhanced faster decomposition and release of nutrients from the WA due to low C:N ratio of the PM. The lower soil nutrient concentrations of NPK fertilizer in spite of its high nutrient value could be adduced to leaching and erosion. The findings that sole PM significantly increased soil organic C, N and P and low K, Ca and Mg concentrations compared with WA is consistent with the analysis of nutrients for PM and WA.

The significant increase in leaf N, P, K, Ca and Mg concentrations of okra by the application of either sole or combined PM and WA is attributable to increased availability of nutrients in soil by the application of the soil amendments leading to increased uptake by okra plant. It was found that 5.0 t ha^{-1} PM + 5.0 t ha^{-1} WA produced significantly higher values of leaf K, Ca and Mg concentrations compared with other treatments. This could be attributed to increased microbial activities and mineralization of nutrients induced by poultry manure addition. NPK fertilizer increased leaf N, P and K, but did not increase leaf Ca and Mg, hence the fertilizer and control gave similar leaf Ca and Mg concentrations.

The findings that all amendments and NPK fertilizer increased plant height, leaf area and pod yield of okra is consistent with the low soil organic C, N, P, K, Ca and Mg status of the soil before the start of the experiment. This observation confirmed the importance of fertilizer or organic amendments in promoting okra performance in a degraded Alfisol of the humid tropics. The findings that 5.0 t ha^{-1} PM + 5.0 t ha^{-1} WA produced better growth and pod yield of okra is adduced to the fact that the PM with low C:N ratio tended to decompose fast and release nutrients for crop uptake. It also improved microbiological activity and enhanced soil fertility status. Therefore its addition to WA would have reduced nutrient immobilization due to high C:N ratio and enhanced released of nutrient from the WA. The superior plant height, leaf area and pod yield of okra given by 5.0 t ha^{-1} PM + 5.0 t ha^{-1} WA compared to other treatments could also be attributed to the increased in N and K concentrations of the okra plant. Majanbu et al. (1986) had shown that N and K are the most important macronutrients that okra required for proper growth and pod production. Poultry manure is known to have high concentrations of N and P and low C:N ratio while WA is high in K with high C:N ratio, this attribute of PM would have enhanced faster decomposition of WA and quicker release of nutrients for okra plant uptake, hence better growth and yield of okra with 5.0 t ha^{-1} PM + 5.0 t ha^{-1} WA than either sole WA or PM application and NPK fertilizer.

Conclusion

Sole and combined applications of WA and PM and NPK fertilizer improved soil fertility status of a degraded Alfisol as indicated by increase in soil organic C, N, P, K, Ca and Mg and leaf N, P, K, Ca and Mg concentrations of okra plant. Combined applications of WA and PM mostly improved soil fertility and leaf K, Ca and Mg, growth and pod yield of okra. Plant (WA) and animal (PM) wastes could be combined and used as organic amendments and be well substituted for expensive and scarce NPK fertilizer in improving the fertility status of a degraded Alfisol in the forest-savanna transition zone of southwest Nigeria.

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