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Influence of Compost on Incidence and Severity of Okra Mosaic Disease and Fruit Yield and Quality of Two Okra (*Abelmoschus esculentus* L. Moench) Cultivars

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Authors' contributions

This work was carried out in collaboration between all authors. Authors KAF, EAB, DOA and RA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors KAF, EAB and DOA managed the analyses of the study. Author RA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Poor soil fertility, viral diseases and pest infestations are major constraints on the production of okra in Africa. The study was conducted to assess the effectiveness of compost in minimizing okra mosaic disease (OMD), flea beetle infestation and improving the yield and quality of okra. In a pot and two field experiments (conducted in 2014 major and minor seasons), compost was incorporated at 0 kg N ha^{-1}, 100 kg N ha^{-1} and 200 kg N ha^{-1} with three replicates, in a randomised complete block design using *Asontem* and *Enidaso* okra varieties as test crops. Results indicated that compost application yielded significantly higher plant height, and dry matter content and

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nutrients in the harvested okra plants than the control. High levels of compost application significantly improved the soluble carbon, crude fibre and crude fat content of okra fruits but did not significantly affect moisture and protein contents. Application of compost also reduced incidence and severity of OMD, but did not significantly influence the population of flea beetles that infested the okra plants. *Asontem* variety was more susceptible to OMD, recording significantly higher disease incidence and severity than *Enidaso*. The study has demonstrated that the compost application has the potential to enhance the fertility status of tropical soils to increase growth, yield and nutrient composition as well as decreasing incidence of OMD.

Keywords: Compost; soil fertility; okra mosaic disease; yield; fruit quality.

1. INTRODUCTION

Poor soil fertility and viral diseases are major constraints to vegetable production in Africa. Inorganic fertilizer application and synthetic pesticides are the conventional strategies for soil fertility replenishment in low nutrient soils and disease management respectively in many sub Saharan Africa (SSA) countries. Although the use of mineral fertilizers has been shown to increase food production in many areas in Africa [1], this practice suffers several drawbacks due to the inherently low nutrient conversion efficiency in the low activity clay soils in SSA [2]. Furthermore, uncontrolled and indiscriminate use of inorganic fertilizers and pesticides, particularly in vegetable production, have negative impacts on the soil, and water quality, food security and health of farmers and consumers. Owing to these challenges, sustainable, economically feasible and environmentally friendly soil fertility management and pets and disease management options are needed to improve vegetable production on the same available arable land in the face of soil resource scarcity [3] and increasing public concern about the negative effects of pesticides on health and environments [4].

Compost can be produced easily by smallholder vegetable farmers through partial decomposition of locally available organic materials by microbes in a moist, warm and aerobic environment [5]. Use of compost for vegetable production can minimize production cost and thus increase incomes and livelihoods of the smallholder farmers since compost materials are easily accessible and cheap [6]. Furthermore, compost releases nutrients in balanced proportions that prevent excessive gaseous and leaching losses to ensure synchrony between nutrient supply and crop uptake [7]. This in turn ensures healthy growth of plants which can also tolerate pests and diseases attacks, thereby improving yield and quality of produce. Basu et al. [8] reported that, in addition to preserving soil fertility, application of compost also improves food quality.

Okra is an important source of energy, minerals and antioxidants for good health [9]. Owing to its food security and human health improvement potential okra is a popular vegetable in most of sub-Saharan Africa [10]. As a result, vegetables are intensively produced in many rural and urban communities in SSA [11]. However, the inherently nutrient-poor soils in the region and pests and viral diseases do not support sustainable production of this important vegetable crop. Okra mosaic disease (OMD) caused by *Okra mosaic virus* ((OkMV; genus *Tymovirus;* family *Tymoviridae*) is the most common disease viral affecting okra production in West Africa [12,13]. Typical symptoms of OMD include mosaic, vein chlorosis and vein-banding and plant stunting [13]. Yield losses of up to 100% due to OkMV infection has been reported [14]. OkMV is transmitted in a non-persistent manner by flea beetle (*Podagrica* spp) [13,15]. The feeding activity of flea beetles also causes characteristic perforations of leaves leading to irregular holes reducing the photosynthetic surface area of the leaves, resulting in significant yield reductions [13-15].

In this regard, Adewole and Ilesanmi [11] argued that compost application can be a sustainable soil fertility improvement option for okro production to meet its high demand in SSA. It was reported that compost additions increased vegetable yield through changes in soil microbial life and decreased crop diseases through activation and stabilization of beneficial soil microflora, which suppressed plant diseases [16]. Jacques and Mohammed [17] found a reduction of disease infection and a clear decline in death of cucumber sown in compost amended soils compared to the unamended soils, when steamed soil were infected with inoculum of *Pythium ultimum*.

In the light of the beneficial effects of compost application on growth, yield and quality, and disease tolerance of vegetables, the study aimed to examine the effect of compost application on the growth, yield and nutritional quality and incidence and severity of mosaic disease of okra. The choice of compost was on the basis that it is a sustainable and cost-effective, alternative nutrient input for increased okra production.

2. MATERIALS AND METHODS

2.1 Study Site

The study was conducted at the University of Cape Coast, School of Agriculture Teaching and Research Farm during the major and minor cropping seasons of 2014. The area experiences a bimodal rainfall pattern, with a long rainy season, usually between March and July and a short rainy season, usually extending from September to early November. A short dry spell occurs in August and a longer one spans from December to February. The area experiences a mean annual rainfall of 920 mm, a mean annual temperature of 23.5℃ and a mean relative humidity between 70% and 90%.

2.2 Soils

The soil used in the study is a sandy loam, occurring in the middle slope of a top sequence locally designated as Benya Series. The soil, which is developed on sandstones, shales and conglomerates, and dominated by kaolinitic clays and sesquioxides [18] is classified as a *Haplic Acrisol* [19]. Surface soil samples (0-20 cm) were collected randomly from 20 different locations and mixed thoroughly to obtain a composite sample. The soil samples were air-dried and sieved using 2-mm mesh sieve after all debris have been removed. The fine fraction (< 2 mm) was used for the pot trial and laboratory analyses, respectively.

2.3 Soil Analysis

Prior to commencement of the trial, and after harvest, surface soil (0–20 cm) samples were collected from the experimental site and analyzed for some physicochemical properties using standard laboratory procedures [20]. Particle size distribution in the soil was determined by the hydrometer method [21]. Soil pH was measured potentiometrically using a digital pH meter in the supernatant suspension of soil to water ratio of 1:2.5. Percentage organic carbon concentration was determined by the Walkley-Black method [22], while the percentage total nitrogen was determined using the microKjeldahl technique [23]. Available P was extracted by the Bray method and determined colorimetrically [24]. Exchangeable bases were extracted using NH_4 acetate solution buffered at pH 7 [20]. Exchangeable Ca and Mg in the extract were determined by the atomic absorption spectrophotometer and exchangeable K and Na were determined by the flame photometer. Soil exchangeable acidity was extracted with 1 M KCl and determined by titration with NaOH solution. Effective cation exchange capacity (ECEC) was calculated as the sum of basic actions (Ca+Mg+K+Na) and Exchange acidity [20]. Physicochemical composition of the soil used in the study is presented in Table 1.

Table 1. Physicochemical properties of the soil used in the study

Parameter	Value
Bulk density (g cm^{-3})	1.38
pH	6.30
Organic carbon (%)	0.87
Total nitrogen (%)	0.07
Available phosphorus (µg g^{-1})	6.56
Exchangeable bases ($cmol_c$ kg^{-1})	
Ca^{2+}	1.
Mg^{2+}	1.03
K^+	0.10
Na^+	0.04
Exchangeable acidity ($cmol_c$ kg^{-1})	0.47
ECEC ($cmol_c$ kg^{-1})	2.76
Textural class	**Sandy loam**

2.4 Compost Preparation and Characterization

The compost used in the study was prepared from poultry manure, cow dung, *Leucaena leucocephala,* maize husks and household ash using pit method at the Technology Village of the University of Cape Coast. The compost was characterized using standard laboratory methods [20]. pH of the compost was determined with a pH meter in water at a ratio of 1: 2.5; Total N was determined by the microKjedahl method while total P was determined using the ascorbic acid method described by [20]. Total K and available Na contents were measured in an ammonium acetate extract using the flame photometer while available Ca and Mg were determined by EDTA titrimetry [25]. The characteristics of the compost used in the study are presented in Table 2.

Table 2. Chemical properties of the compost used in the study

Parameter	Value
pH	8.93
Organic carbon (%)	14.0
Total nitrogen (%)	1.20
Total phosphorus (%)	0.90
Total potassium (%)	28.80
Available basic cations (%)	
Ca^{2+}	76.00
Mg^{2+}	9.80
Na^{+}	18.40

2.5 Treatments

In the pot experiment, compost was uniformly mixed with soil (< 2 mm) and repacked into 2 L plastic pots at a bulk density of 1.38 g cm^{-3} to supply 0, 100 and 200 kg N ha^{-1}, respectively, based on the percentage N concentration in the compost. The quantities of compost applied in each treatment amounted to 0 tons ha^{-1}, 8.3 tons ha^{-1} and 16.7 tons ha^{-1}, respectively. In the field experiment compost was broadcasted and mixed thoroughly at 20 cm of the surface soil in each bed to supply the same amount of N as in the pot experiment. The amounts of compost applied to the soil in each treatment are summarized in Table 3.

2.6 Pot and Field Experiments

The pot experiment was done using completely randomized design (CRD) with four replications. Soil moisture content in each pot was kept at 60% water filled pore space (WFPS) and maintained throughout the study period with distilled water by mass balance. Four seeds each of an early maturing *Asontem* okra variety were sown per pot and thinned to one plant one week after emergence.

The field experiments (both major and minor seasons) were done using split-plot design (SPD) with the compost rates as main plots and okra varieties as sub plots. The field trial consisted of 3 blocks of 3 beds each. Each bed was 2 m x 5 m and an interval of 1 m was kept between beds. Each bed was further divided into two subplots of sizes 2 m x 2 m, with an interval of 1 m between subplots. Okra seeds were sown using a planting distance of 60 cm x 60 cm. The test plants in the field trial were early maturing (*Asontem*) and medium maturing (*Enidaso*) varieties. Four seeds were sown per hole and thinned to one plant per stand when they were well established.

2.7 Data Collection

Data was collected on plant height, mature fruit dry mater, proximate analyses, incidence and severity of OMD, and flea beetle populations.

2.7.1 Plant height and fruit yield

In both the pot and field experiments, plant height data was collected from the 2^{nd} to the 7^{th} week after sowing (WAS). Fruits were collected from the 5^{th} week till the 7^{th} week in the early maturing variety and from the 6^{th} to the 8^{th} week in the medium maturing variety. The mean dry weights of the fruits collected were determined using the formula:

Dry weight per fruit = (sum of fruit dry weight per treatment / number of fruits per treatment)

2.7.2 Nutrient concentration in plant parts and proximate analysis of edible pods

In the pot experiment the okra plant in each pot was carefully uprooted at the end of the 7^{th} week. The plants were washed with distilled water and then separated into fruits, leaves, stem and root. These parts were dried in the oven at 60℃ till a constant weight was attained. Oven-dried plant parts were milled separately using Glenson milling machine for laboratory analyses.

Proximate analysis of edible pods was done on the milled dry samples using standard laboratory procedures as outlined by AOAC [26] to determine their crude protein (Kjeldahl protein), crude fat, crude fibre and soluble carbohydrates contents as described [27]. Nitrogen and Phosphorus concentrations in the leaf, stem and roots of okra samples from each plot were also determined using standard laboratory methods [20]. Owing to financial cost constraints, only samples collected in the major season were analyzed.

2.7.3 Insect count and disease severity determination

During the minor season, population of flea beetle (*Podagrica uniformis*) per plant was determined by manually counting insects found

Table 3. Visual scale for rating severity of okra mosaic disease in farmers' okra fields

Disease score	Description
0	Healthy, asymptomatic plant
1	Mild mosaic, mottle or chlorosis on leaves
2	Moderate chlorosis, mottle or mosaic without significant leaf distortion
3	Score 1 or 2 plus leaf malformation
4	Severe chlorosis, mottle or mosaic plus stunting or dwarfing of the whole plant
5	Score 4 plus drying and leaf drop

underneath the leaves of the tagged plants 3, 4, 5, 6 and 7 weeks after sowing (WAS). The plants were scored for severity of Okra mosaic disease (OMD) at 11 WAS based on a 1–5 scale adopted from Alegbejo et al. [28] as indicated in Table 3.

Incidence of Okra mosaic disease (OMD) was determined as a proportion of plants in a plot showing disease symptom according to Asare-Bediako et al. [12].

2.8 Statistical Analysis

All data collected were subjected to analysis of variance (ANOVA) using GenStat statistical package (Discovery version 4). Significant differences among means were separated using least significant difference method at 5% level of probability.

3. RESULTS AND DISCUSSION

3.1 Effect of Compost on Soil Fertility

The soil used in the study (Table 1) was slightly acidic (pH of 6.3) and low in nutrients (total N < 0.13%; available P < 0.20 µg g^{-1}; ECEC < 5 c mol kg^{-1}) [29]. The low soil pH is attributable to continuous cropping and leaching of soil basic cations [30]. The low soil organic carbon content was due to rapid decomposition of organic matter promoted by the prevailing high temperatures and high humidity [31], and continuous cropping without the return of crop residues to replenish the soil organic C stock [32].

The C: N ratio in the compost used in the study was less than 14:1 (Table 2). Such compost material can stimulate microbial activity and supply of plant nutrients [33,34]. According to Whalen et al. [35], the ideal C: N ratio of compost ranges from 25 to 30:1.

Compost application significantly increased soil pH (by up to 0.4 units) compared to the unamended control (Table 4 and 5). The increased soil pH observed in the compost-amended soils can be attributed mainly to addition of basic cations, and possibly, production of NH_3 during decomposition of the added compost [36]. Soil pH is one of the deciding factors affecting plant nutrient uptake and movement and many soil attributes and reactions [37]. However, the effect of compost on soil pH is not well understood because compost can both increase and decrease soil pH depending on compost feedstock, amount and time of application and soil type [38].

During both the major and minor seasons, Effective Cation Exchange Capacity (ECEC) concentrations in the compost treatments were greater than in the control (Tables 6 and 7). ECEC in the compost amended soils followed the order 200 kg N ha-1 > 100 kg N ha-1 > control. Incorporating compost at 100 and 200 kg N ha^{-1} increased ECEC by up to 20% and 28 %, respectively. Furthermore, the pooled data revealed that soil pH strongly correlated positively with ECEC (R^2= 0.97, P < 0.05). Pocknee and Sumner [39] explained that soluble carbon released during compost decomposition caused temporary reducing conditions through increased microbial activity while organic acids released from the compost displaced hydroxyls from sesquioxide surfaces, thereby lowering soil pH.

In the study, compost application significantly increased exchangeable Ca, Mg and K, but not exchangeable Na concentration in the soils. There were however, no significant differences between the exchangeable cation concentrations in the 100 kg N ha^{-1} and 200 kg N ha^{-1} treatments (Table 6 and 7). Studies have shown that compost application has the potential to enhance the exchangeable cations of soil through improved cation exchange capacity (CEC) [40].

The increases in ECEC, and Mg, K and Mg concentrations in the compost treatments could be due to the high concentrations available cations in the compost as well as the creation of supplementary negative exchange sites on the soil surface by the compost, which would have led to easy and rapid sorption of more cations [41]. White [42] found that compost increased cation exchange capacity through increased negative charges on the soil colloidal surface due to increased organic matter content in compost amended soils. This could have contributed significantly to the increased phosphorus concentration in the compost amended soils [43].

Application of compost at 100 kg N ha^{-1} increased soil N and soil P concentrations by 87 to 125% and 98-99%, respectively, while at 200 kg N ha^{-1}, compost application increased soil N and P concentrations by 150 to 163% and 121-133%, respectively (Table 4 and 5). Studies have shown that incorporation of composts from cattle manure, biogenic household and garden waste all increased soil C and total N concentrations [44]. According to Butler et al. [38] application of municipal solid waste and dairy manure composts to soil can significantly increase concentrations of N, P and other nutrients in soil even several years after compost application. However, Dombreville et al. [45] argued that increased microbial activity in compost amended soils can increase the rates of soil N mineralization and potential denitrification leading to N loss via leaching volatilization and denitrification [46]. In contrast, Larney et al. [47] argued that most essential nutrients from compost are in organic forms hence they are released slowly and are less subject to leaching compared to inorganic fertilizer. This has important implications for replacing inorganic fertilizers with compost in organic vegetable production systems. Thus, compared to manure and fresh crop residues, compost C is only partly decomposable in the short term, indicative that compost may be useful for C sequestration in soils. This is in agreement with Lynch et al. [48] who reported that two years after the last application of compost from dairy manure and sewerage sludge, 37-67% of applied C was still retained in the soil. Previous authors have noted that compost addition counteracts organic matter depletion [49]. According to McConnell et al. [50] application of compost at rates of 18 to 146 ton ha^{-1} resulted in 6 to 163% increment in soil organic matter content.

Our advocacy for compost as a sustainable alternative source of soil nutrient is supported by Topliantz and Bollof [51] who argued that stabilization of soil organic matter and slow release of nutrients in compost amended soils promotes a balanced nutrient supply for proper crop development and yield, thus reducing environmental pollution [52]. Willer and Yousseffi [53] explained that the clay-humus complexes formed in compost amended soils enhances porosity and root penetration, and easy water and nutrients absorption. Ayoola and Adeniyan [54] concluded that compost addition offers a means of ensuring long-term soil fertility to improve crop production [55] without the need for mineral fertilizers.

3.2 Effect of Compost Application on Plant Height and Dry Matter Yield

In agreement with Ofosu-Anim et al. [41] compost application significantly increased the height and dry matter yield of okra in the pot experiment (Table 8). However, it did not significantly influence the dry matter yield in the minor and major season field trials (Figs. 1 and 2). However, no significant difference was found between the yields and heights of okro in the 100 kg N ha^{-1}and 200 kg N ha^{-1}compost treatments on the field. This agrees with Uwah et al. [56] who stated that okra requires about 80 kg N ha^{-1} for optimum yield. Inthe study, varietal effect on dry matter was not observed, since there was no significant difference in dry matter yield between the Enidaso and Asontem varieties (Figs. 1 and 2). This finding disagrees with that of Amanullah et al. [57] who reported that in addition to nutrient supply, okra height and yield are genetically influenced. Bisht and Bhat [58] also reported that crop yields in compost amended soils depend mostly on the cultivar used, moisture content and soil type.

Table 4. Soil physicochemical properties after compost application for okra production in a pot experiment

Compost (kgN ha^{-1})	Organic C (%)	Total N (%)	pH	Available P (ug g^{-1})
0	1.49^{c}	0.09^{c}	6.2^{ns}	12.12^{c}
100	1.54^{b}	1.14^{b}	6.3	20.78^{b}
200	1.59^{a}	1.22^{a}	6.35	22.63^{a}
LSD (P<0.05)	0.03	0.05	-	1.02

Ns=not significant (P>0.05), Means in the same column bearing different letters are not significantly different (P<0.05). ANOVA did not show any significant difference in the soil properties between the two okra genotypes (P>0.05)

Table 5. Soil physicochemical properties after harvesting of okra from the field experiments

Compost (kgN ha^{-1})	Moisture content (%)	Total N (%)	Organic C (%)	Available P (ug g^{-1})	pH
0	13.4^{c}	0.07^{ns}	1.605^{ns}	12.27^{c}	6.2^{b}
100	16.0^{b}	0.165	1.79	24.23^{b}	6.5^{a}
200	20.5^{a}	0.205	1.835	28.12^{a}	6.55^{a}
l.s.d.(P<0.05)	0.93	-	-	3.15	0.01

ns=not significant (P>0.05); Means in the same column bearing different letters are significant different (P<0.05). ANOVA showed no significant difference between the two okra varieties in the various parameters indicated in the Table (P>0.05)

Table 6. Soil properties after harvest two seasons (major and minor seasons) of okra production

Compost	Exchangeable cations (c mol.kg^{-1})				Exchange	ECEC
(kgN ha^{-1})	Ca	Mg	Na	K	acidity	(cmol$_c$ kg^{-1})
0	1.22^{b}	0.60^{b}	0.10	0.235^{b}	1.23^{a}	3.38^{b}
100	1.47^{ab}	1.10^{a}	0.10	0.495^{a}	0.85^{b}	4.05^{a}
200	1.57^{a}	1.26^{a}	0.10	0.58^{a}	0.81^{c}	4.27^{a}
l.s.d. (p<0.05)	0.29	0.20	-	0.11	0.10	0.23

ECEC= Effective cation exchange capacity; ns=not significant (P>0.05); Means in the same column bearing identical letters are not significantly different (P>0.05). ANOVA did not show any significant difference between the two okra varieties in the various parameters indicated in the Table (P>0.05)

Table 7. Exchangeable cations concentrations in soils after harvest following compost application at different rates in a pot experiment

Compost	Exchangeable cations (cmol.kg^{-1})				Exchange	ECEC
(kgN ha^{-1})	Ca	Mg	Na	K	acidity	(cmol$_c$ kg^{-1})
0	1.08^{c}	0.63^{c}	0.11^{c}	0.11^{ns}	0.78^{ns}	2.69^{c}
100	1.25^{b}	1.03^{b}	0.18^{b}	0.19	0.71	3.39^{b}
200	1.36^{a}	1.08^{a}	0.22^{a}	0.19	0.64	3.45^{a}
l.s.d. (P<0.05)	0.09	0.04	0.02	-	-	0.02

ECEC= Effective cation exchange capacity; ns=not significant (P>0.05); Means in the same column bearing different letters are significantly different (P<0.05). ANOVA did not show any significant difference between the two okra varieties in the various parameters indicated in the Table (P>0.05)

Table 8. Height (cm) and dry matter (g/ fruit) of okra at maturity

Compost	Minor season	Major season	Pot experiment	
(kgN ha^{-1})	Plant height (cm)	Plant height (cm)	Plant height (cm)	Dry matter (%)
0	0.60^{b}	0.65^{b}	52.2^{a}	0.51^{c}
100	0.71^{a}	0.78^{a}	54.2^{b}	0.57^{b}
200	0.72^{a}	0.82^{a}	58.8^{c}	0.63^{a}
l.s.d. (P<0.05)	0.05	0.06	0.11	0.02

Means in the same column bearing different letters are not significantly different (P<0.05). ANOVA did not show any significant difference between the two okra genotypes (P>0.05)

3.3 Effect of Compost on Plant N and P Content

Both N and P concentrations in the okra leaf increased with increasing compost application rates (Table 9). Total N concentration followed the order leaf > stem > root. Similarly, total P concentration was greater in the leaf than in the other parts of the plants, but concentrations in the stem and the root were not significantly different from each other. No varietal effect on N and P concentrations was observed (Table 9). Furthermore, both soil N and soil P concentrations and leaf N and P concentrations strongly correlated positively with okra yield (R^2= 0.65 and 0.88, *P*< 0.05, for soil N and soil P concentrations, respectively) and (R^2= 0.80 and 0.84, P < 0.05, *P*< 0.05 for plant N and plant P concentrations, respectively) in both the major and minor season. According to Porter [59], compost application improves plant growth and nutrient uptake through enhance microbial activity, which stimulate nutrient mineralization and uptake. Kawasaki et al. [60] demonstrated that compost application can increase plant nutrient availability, nutrient uptake and hence root development and plant growth [61].

Odlare et al. [46] reported plant N and P uptake from compost amended soils may be lower than that from inorganic fertilizer amended ones because organic N in compost has to be mineralized before it can be taken up by plants. Passoni and Borin [62] found that after 2-years only 36-44% of compost N gets mineralized partly due to microbial N immobilization. This has implication for food quality in terms of nitrate accumulation in plant biomass. Again, slow mineralization of compost N is likely to sustain N supply by promoting synergy between compost N release from compost and crop uptake.

3.4 Proximate Analysis

The proximate analysis data indicated that compost application did not significantly influence moisture content nor crude protein content among the different treatments (Table 10). However, soluble carbon concentration, crude fibre and crude fat increased with increasing compost application rates in either variety. Soluble C concentration was higher in the early

Table 9. Percentage N and P in plant parts following compost application at different rates

Compost	Percentage N			Percentage P		
(kgN ha⁻¹)	Leaf	Stem	Root	Leaf	Stem	Root
0	2.67^c	0.79^b	0.73^c	0.34^c	0.28^c	0.25^b
100	3.24^b	1.08^a	0.97^b	0.46^b	0.35^b	0.31^a
200	3.54^a	1.04^a	1.14^a	0.50^a	0.37^a	0.31^a
l.s.d. (P<0.05)	0.09	0.08	0.12	0.03	0.01	0.03

Means in the same column bearing different letters are not significantly different (P>0.05)

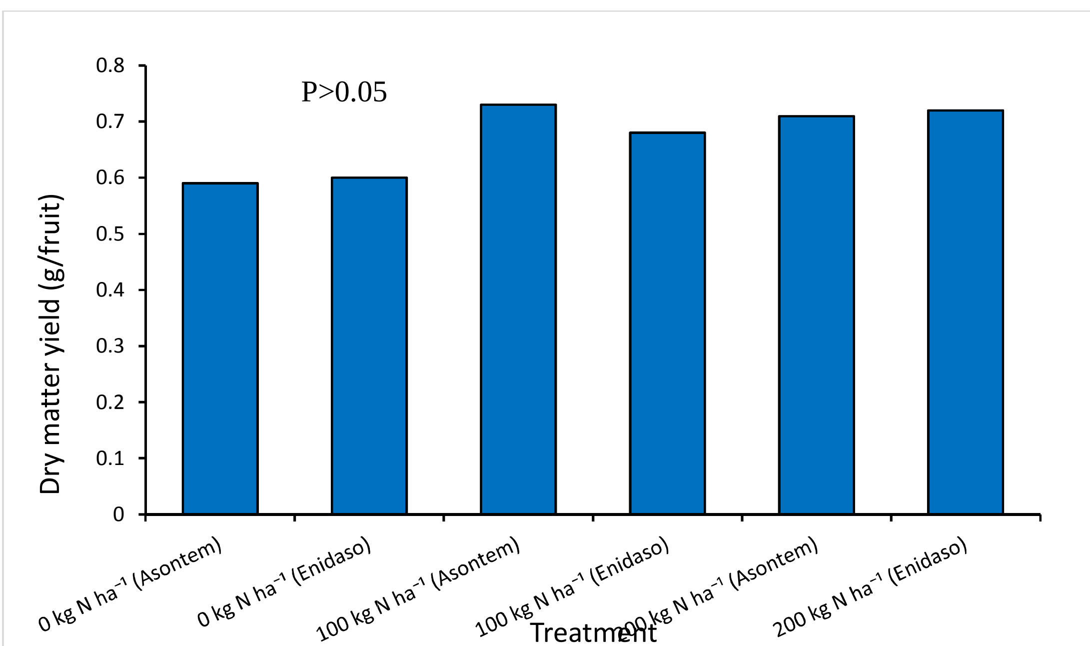

Fig. 1. Dry matter yield of okra (g/ fruit) at maturity during major season field trial
ANOVA did not show significant difference (P>0.05) among the treatments

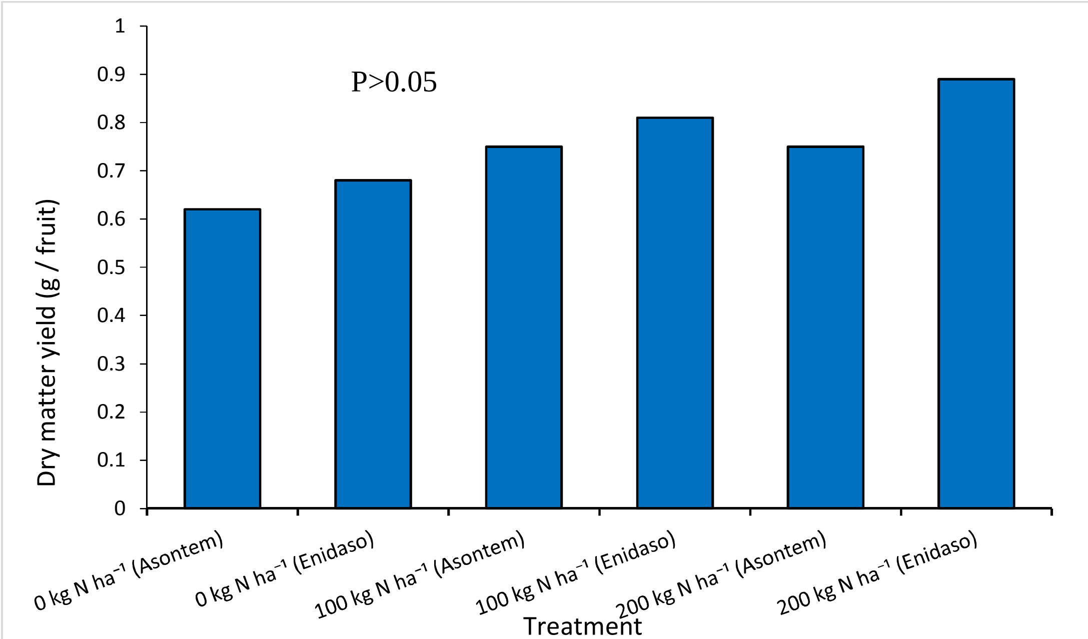

Fig. 2. Dry matter yield of okra at maturity (g / fruit) during minor season field trial

ANOVA did not show significant difference (P>0.05) among the treatments

Table 10. Proximate analysis of edible okra pods following compost application at different rates

Compost (kg ha^{-1})	Moisture content	Crude protein	Soluble carbohydrate	Crude fibre	Crude fat
0	87.6^{ns}	17.6^{ns}	23.3^{c}	9.3^{b}	1.3^{c}
100	87.9	19.4	25.2^{b}	9.2^{c}	1.9^{b}
200	88.0	19.3	26.5^{a}	10.5^{a}	2.1^{a}
l.s.d. (P<0.05)	-	-	0.24	0.06	0.06

ns=not significant (P>0.05); Means in the same column bearing different letters are significantly different (P<0.05). ANOVA did not show any significant difference between the two okra varieties in the various parameters (P>0.05)

maturing variety than in the medium maturing variety. Crude fat content was greater in the compost treatments compared to the control (Table 10). This suggests that application of compost improved the quality of okra fruit, at least in terms of soluble C, crude fibre and crude fat. It has also been reported that, in addition to preserving soil fertility, application of compost also improves food quality [8].

3.5 Disease and Pest Incidence and Severity and Disease Suppression

A significant difference occurred between the okra varieties in respect of incidence of the OMD (Table 11). *Asontem* variety showed a significantly higher incidence (59%) than *Enidaso* (39.6%). This indicates that *Asontem* was more susceptible to OkMV infection than *Enidaso*. This suggests a varying host-virus interaction effect, as was observed by Sergius and Dibua [64] when they screened different okra varieties for resistance to OkMV under field condition in Nigeria.

The study also revealed a significant difference (*P*<0.05) among the compost treatments with respect to the mean incidence of OMD (Table 11). Plants growing on soil with no compost amendment (0 kgha-^{1}) had significantly higher incidence of OMD (64.2%) than those planted on soils amended with 100 kgha-^{1} and 200 kgha-^{1} with mean disease incidences of 42.5% and 40.9% respectively. This suggests that compost application resulted in a reduction of incidence of OMD. According to Badejo and Togun [7], compost releases nutrients in balanced proportions that prevent excessive gaseous and leaching losses to ensure synchrony between nutrient supply and crop uptake. This in turn ensures healthy growth of plants which improves the resistance and / or tolerance of the plants to viruses and pests attacks.

Effect of compost application on the mean severity of OMD on two okra varieties is shown in Table 12. The overall mean severity score for *Asontem* variety (3.89) was significantly higher (P<0.05) than *Enidaso* variety. This suggests that *Asontem* was more susceptible to OMD than *Enidaso*. Varying degrees of susceptibility of different okra genotypes to OMD has also been reported by Sergius and Dibua [63] when they screened different genotypes of *Abelmoschus* spp in Nigeria. The study also showed a significant difference among different compost application rates in respect of mean OMD severity scores. Okra plants grown in the soil without compost (control) had significantly higher severity score (4.17) than those grown in the soil amended with 100 kg ha^{-1} and 200 kg ha^{-1} with mean severity scores of 3.17 and 3.00 respectively. Addition of compost to soil has been shown to eradicate and inactivate plant pathogens [64].

Mean populations of flea beetle infesting okra plants from 3 WAS to 7 WAS are shown in Table 13. No significant difference was observed among the treatments at any of the growth stages. This suggests that compost application did not reduce the insect populations. On the contrary, studies conducted by Chau and Heong [65] and Akambi et al. [66] clearly demonstrated the insecticidal properties of compost.

Table 11. Mean incidence of Okra mosaic disease (OMD) on two okra varieties treated with different rates of compost

Compost (kgha-^{1})	Mean incidence (%) of OMD		Mean incidence (%) across varieties
	Asontem	Enidaso	
0	68.2	60.2	64.2^a
100	51.5	34.1	42.5^b
200	57.5	24.3	40.9^b
Mean	59.0^a	39.6^b	49.3

Compost means in the same column bearing identical letters at not significantly different from each other by l.s.d. of 10.74 at P<0.001. Okra variety mean in the same row having different letters are significantly different from each other by l.s.d. of 8.72 at P<0.001

Table 12. Mean severity scores of okra mosaic disease (OMD) recorded for two okra varieties at 11 weeks after sowing (WAS)

Compost (kgha-^{1})	Mean severity score of OMD		Mean
	Asontem	Enidaso	
0	4.33	4.00	4.17^a
100	3.67	2.67	3.17^b
200	3.67	2.33	3.00^b
Mean	3.89^a	3.00^b	

Means in the same column bearing identical letters are not significantly different by l.s.d. of 0.559 at P=0.002. Variety means in the same row are significantly different by l.s.d. of 0.456 at P=0.001

Table 13. Mean flea beetle population recorded on okra plants growing in soil amended with different rates of compost

Compost(kgha-^{1})	Mean population of flea beetle (Weeks after sowing)				
	3	4	5	6	7
0	14.2^{ns}	8.67^{ns}	13.67^{ns}	6.17^{ns}	10.50^{ns}
100	16.7	8.50	12.50	6.17	11.67
200	10.5	8.17	14.67	5.83	8.50
Mean	13.8	8.44	13.61	6.06	10.22

ns= Not significant (P>0.05)

4. CONCLUSIONS

The study indicated that compost application increased soil nutrient availability and plant uptake by improving soil exchangeable Ca^{2+}, K^{+} and Na^{+}, soil pH and soil available phosphorus concentrations. Additionally, soil total nitrogen, organic carbon concentrations and ECEC were improved. Furthermore, the study demonstrated that application of compost improved plant height and fruit yield and also improved soluble C, crude fibre and crude fat contents of the edible okra fruit but did not affect the protein content. In addition, compost application reduced the incidence and severity of OMD, but did not have any significant influence on the population of flea beetle that infested the okra plants.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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