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ORIGINAL RESEARCH

Response of okra (*Abelmuschus esculenthus* L. Moench) to combined organic and inorganic foliar fertilizers

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Abstract
Aim This study investigated the effects of combined organic poultry manure (PM) and inorganic foliar fertilizer (FF) on growth and yield of okra (*Abelmuschus esculenthus* L. Moench).
Materials and methods Field trials were carried out at Shao and Teaching and Research Farm of Kwara State University, Malete, respectively, in 2013 and 2014 cropping seasons. The treatment consisted of PM at 10.0 t/ha, combinations of FF with 10.0, 7.5, 5.0, or 2.5 t/ha, FF alone and control without fertilizer arranged in a randomized complete block design and replicated three times.
Results Combinations of PM and FF influenced the growth and fruit yield of okra. PM at 10.0 t/ha plus FF produced the highest plant height of 48.40 and 58.50 cm in 2013 and 2014, respectively. Also, highest number of fruits per plant and fruit yield was obtained at the same treatment over the two years. The control, without fertilizer, showed significantly longer days to flower compared with other treatments in the two years.
Conclusion The highest yield obtained at PM 10.0 t/ha +FF was not significantly different from PM 7.5 t/ha +FF. Hence, poultry manure applied at 7.5 t/ha +FF is therefore recommended.

Keywords Foliar fertilizer · Okra fruit yield · Poultry manure · Soil-applied · Yield component

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Introduction

Sustainable soil productivity is one of the major constraints of tropical agriculture. Continuous cultivation is a common practice by poor resource farmers in the tropics. This has resulted in rapid decline of soil nutrients and unstable soil microbial population (ECA 2001). Consequently, there is decline productivity, low farmers income, and increasing poverty (FAO 2006). Hence, the use of organic manure as alternative soil amendment strategy for soil nutrient management has been advocated (Shehu et al. 1997).

Fertilizer plays a major role among cultural practices for increased crop production. However, blanket application of inorganic fertilizer to farmland soils without adequate knowledge of the nutrient status, often leads to increased soil acidity, particularly when nitrogen fertilizers are applied (Akande et al. 2010). Although, inorganic fertilizers, contain high concentrations of nutrients that are rapidly available and released for plant uptake, their use is limited due to scarcity, high cost, nutrient imbalance, and soil acidity (Akande et al. 2010).

Manure provides necessary macro- and micro-nutrients in available form, and improves the physical and biological properties of the soil (Abou El-Magd et al. 2006). Poultry manure (PM) is an excellent source of organic manure. It supplies both macro and micro-nutrients during mineralization, increases the organic matter content of the soil, and consequently enhances the texture, structure, aeration, moisture holding capacity, nutrient retention and water infiltration in the soil (Akinrinde et al. 2006; Dekissa et al. 2008). According to Garge and Bahla (2008), PM supplies phosphorous more readily to plants than other organic sources. In another study, Abd El-Kader et al. (2010) reported that manure from poultry increased okra yield and water use efficiency than composted plant residue.

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Additionally, abattoir waste was found as an excellent organic fertilizer in the cultivation of vegetables and also could promote healthy environment (Roy et al. 2015).

Foliar fertilizers (FF) are applied to the foliage of the plant to boost the nutrient density in the crop. It is a convenient way of applying nutrients to the plant to supplement absorbed soil nutrients. It improves the efficiency of soil-applied nutrients and also acts as a catalyst in the uptake and use of certain macro nutrients (Philips 2004; Fageria et al. 2009). Besides being environmentally safe, it increases crop yield and quality (Fageria et al. (2009). As such, El-Aal et al. (2010), Zodape et al. (2011) have recommended the technique in integrated nutrient management. Paliwal et al. (1999) had earlier reported enhanced development of branches per plant in okra due to foliar fertilization. Similarly, Abasi et al. (2010) reported improved days to 50% flowering, plant height number of branches and fruits per plant and fruit yield in okra using combinations of foliar fertilizer and soil-applied inorganic fertilizer in okra.

Boost Xtra is one of the foliar fertilizers that have gained popularity among farmers in Nigeria. It is formulated as soluble granules containing 20% each of nitrogen, phosphorous and potassium along with certain micro-nutrients. Farmers use this fertilizer alone or in combination with soil-applied inorganic fertilizer on various crops to improve growth and yield. However, there is a paucity of information on the combinations of foliar fertilizer and organic manure usage for vegetable crop production. Therefore, this study was initiated to investigate the effects of combined PM and FF on growth and yield of okra.

Materials and methods

Field trials were carried at Shao and the Teaching and Research Farm of Kwara State University, Malete, respectively, in 2013 and 2014 cropping seasons. The two locations are in Moro Local Government Area of Kwara State, Nigeria. The PM was collected from deep liter system of poultry unit in the University Farm and the boost Xtra purchased from the agro chemical outlet in Ilorin, Nigeria. The treatments consisted of PM at 10.0 t/ha, combinations of FF with 10.0, 7.5, 5.0, or 2.5 t/ha, FF alone and control without fertilizer arranged in a randomized complete block design and replicated three times. The nutrient compositions of the PM and FF are shown in Tables 1 and 2.

Table 1 Nutrient composition of foliar fertilizer (Boost Xtra)

Analysis (wt/vol.)		
Nitrogen	N	20%
Phosphorous	P	20%
Potassium	K	20%
Magnesium	Mg	1.5%
Iron (EDTA)	Fe	0.35%
Manganese EDTA	Mn	0.075%
Copper EDTA	Cu	0.075%
Zinc EDTA	Zn	0.075%
Boron	B	0.0315%
Cobalt EDTA	Co	0.0012%
Molybdenum	Mo	0.0012%
pH (10% solution)	4.0–4.5	
Density	1.5SG@18C	

Table 2 Physio-chemical properties of the experimental field (0–15 cm) and nutrient composition of the poultry manure

Soil composition			Poultry manure
Physical properties	Shao	Malete	
Sand (%)	55.28	53.55	
Silt (%)	18.45	19.64	
Clay (%)	28.44	30.23	
Textural class	Sandy-loam		
Chemical properties			
pH (H_2O)	5.88	5.72	5.83
Organic carbon	1.05	1.22	7.10
Available P mg kg^{-1}	6.76	6.85	5.21
Total N	0.18	0.92	8.05
Exchangeable bases			
Ca (mg kg^{-1})	2.62	2.48	0.13
Na (mg kg^{-1})	0.55	0.39	0.22
Mg (mg kg^{-1})	1.15	2.01	0.88
Mn (mg kg^{-1})	0.92	0.88	36.58
Zn (mg kg^{-1})	2.36	2.61	28.94
Cu (mg kg^{-1})	0.33	0.29	4.10
Fe (mg kg^{-1})	3.24	2.98	3.72
K (mg kg^{-1})	0.92	0.88	

Cultural practices

The land was plowed once and harrowed twice. Planting was carried out at the two locations on the flat. Each plot size measured 2.5 m × 3.5 m (8.75 m^2) with 0.5 m between plots and 1.0 m between blocks. Four seeds were planted at inter and intra row spacings of 0.6 and 0.3 m, respectively. Crops were thinned at two weeks after planting (WAP) to two plants per stand. Air-dried PM was applied uniformly at two weeks before planting. Foliar fertilizer was split applied at four and five WAP using knapsack sprayer. Pendimethalin [N-(1-ethylpropyl)-3, 4dimethyl-2, 6 dinitrobenzene amine] was applied two days after planting at the

Table 3 Growth of okra as affected by the combined application poultry manure and foliar fertilizer in 2013 and 2014 cropping seasons

Treatments	2013				2014			
	Plant height (cm)	Days to 50% flowering	Days to 50% fruiting	Stem girth (cm)	Plant height (cm)	Days to 50% flowering	Days to 50% fruiting	Stem girth (cm)
PM10T +foliar	48.40a	32.77c	43.43b	4.20	58.50a	34.85b	45.62b	4.40
PM7.5t +foliar	46.67b	33.00c	43.40b	3.95	56.10a	34.72b	46.18b	4.18
PM 5.0t +foliar	42.33c	33.47c	43.57b	3.80	55.75ab	35.10b	45.74b	3.60
PM 2.5t +foliar	43,33c	32.50c	41.97b	2.95	48.03c	33.90b	43.39b	3.20
PM 10t alone	45.43b	33.50c	44.00b	3.85	53.50b	34.62b	46.10b	4.25
Foliar alone	38.80d	34.50b	43.80b	2.68	36.36d	35.20b	44.98b	2.62
No fertilizer	30.63e	40.03a	55.00a	2.59 NS	27.50e	39.10a	54.32a	2.55 NS

Values with the same letter(s) under the same column are not significantly different at 5% level of probability by Duncan's Multiple Range Test

rate of 1.5 kg active ingredients per hectare. This was followed by manual weeding at 5 WAP to keep the experimental plot weed free. Insect pests were controlled with cyalothrin [3-(2-chloro-3,3,3,-trifluoropropenyl)-2.2, dimethylclopropanecarboxylate] at the rate of 1 ml of the product per liter of water using knapsack sprayer.

Data collection

Plant height at fruiting, stem girth, number of fruits per plant, fruit length, fruit circumference, and fresh fruit weight at each harvest were measured and days to 50% flowering was observed. Fruits were harvested at four days interval for eight and nine consecutive periods in 2013 and 2014, respectively.

Statistical analysis

Data were subjected to analysis of variance using SAS (1989) package and treatment means compared using Duncan's Multiple Range Test. This was done where results were significant at 5% level of probability.

Results

Soil and poultry manure analysis

Soils at the two experimental sites were sandy-clay loam, slightly acidic with pH 5.88 and 5.72, total nitrogen, 0.18 and 0.92, available phosphorous, 6.76 and 6.85 and exchangeable potassium 0.92 and 0.88, respectively, for Shao and Malete (Tables 1, 2). The PM used was slightly richer in the plant nutrients compared to un-amended experimental soils of the study locations.

Plant growth

Growth of okra was significantly affected with the application of FF in combination with PM (Table 3). The highest plant height of 48.40 cm and 58.50, respectively, in 2013 and 2014 were observed when PM at 10.0 t/ha was combined with FF. Application of PM at 7.5 t/ha combined with FF had similar plant height compared to when PM was applied at 10 t/ha alone. Compared with other treatments, the control without fertilizer had significantly reduced plant height. Days to 50% flowering and fruiting followed similar trends in all the treatments. Where neither of the fertilizer was applied, took longer days to flower and fruit compared with other treatments. It flowered and fruit at 40.03 and 55.00 days in 2013 and 39.10 and 54.32 days in 2014. Although not statistically significant, combination of PM with FF had shorter days to flower and fruit compared with control treatment.

Yield and yield components

Okra fruit yield and yield components were significantly affected by different treatments (Table 4). Plots treated 10.0 t/ha PM mixed with FF produced the highest number of fruits per plant in 2014. Similar number of fruits were produced with application of 10.0 t/ha PM alone and 7.5 t/ha PM mixed with FF in 2014. The least number of fruits were recorded at the control treatments in the two years.

Application of 10.0 t/ha PM mixed with FF significantly produced longer fruits than other treatments, except

Table 4 Effects of combined application of poultry manure and foliar fertilizer (boost Xtra) on yield and yield components of okra in 2013 and 2014 cropping seasons

Treatments	2013				2014			
	No of fruits/plant	Fruit length (cm)	Fruit circum (cm)	Yield kg/ha	No of fruits/plant	Fruit length (cm)	Fruit circum (cm)	Yield (kg/ha^{-1})
PM10t +foliar	23.10a	11.00a	11.81a	1,892.94a	23.65a	10.76a	12.00a	1825.92a
PM7.5t +foliar	20.20a	11.10a	11.60a	1,140.00a	19.37b	9.58ab	11.33a	1549.31ab
PM5.0t +foliar	11.80b	9.30bc	10.95a	796.62b	13.22d	8.13b	10.40a	1057.70cd
PM2.5t +foliar	11.50b	8.50cd	9.61a	720.62bc	11.98d	8.15b	10.20a	958.52cd
PM10t alone	13.20b	10.90ab	11.42a	1092.12a	16.35c	8.23b	11.10a	1307.78bc
Foliar alone	10.00b	8.64cd	9.63a	632.22c	9.57e	8.06b	9.45a	958.33cd
No fertilizer	4.63c	7.10d	9.10a	283.38d	7.30f	6.38c	8.45a	637.40d

Values with the same letter(s) under the same column are not significantly different at 5% level of probability by Duncan's Multiple Range Test

combinations of 7.5 t/ha PM with FF. There was no difference in fruit length between 10.0 t/ha PM alone, as well as 7.5, 5.0, and 2.5 t/ha PM combined with FF. Shorter fruit length was observed at the control treatments.

Okra fruit yield was highest (1182.94 kg/ha in 2013 and 1825.92 kg/ha in 2014) with the integrated application of PM at 10.0 t/ha plus FF. Recorded fruit yield in this treatment was not statistically different from those obtained with application of 7.5 t/ha PM mixed with FF in the two years. Application of 7.5 t/ha PM integrated with FF had similar fresh fruit weight with applied 10.0 t/ha PM alone in the two cropping seasons. Over the two years, there was no significant different between combinations of FF with PM at 2.5 t/ha and when boost Xtra was applied alone. The yield was minimum, 283.38 kg/ha and 637.40 kg/ha in 2013 and 2014, respectively, at the control treatment without fertilizer. There was no significant difference in fruit yield between application of FF alone and the control.

Discussion

The inherent low nutrient status of the two locations suggests the need for external soil amendment for optimum crop yield. In overall, result of the study indicated that growth and yield attributes of okra were enhanced with combinations of PM and FF. The improved growth and yield observed in this study was due to balanced nutrient in the PM that was synergistically complemented with nutrient present in the FF. This was evident by the earlier commencement of flowering and fruiting in the treatments where FF was combined with high tonnage of PM. The higher values in all the parameters with the combinations of FF with PM at 7.5 t/ha compared to 10.0 t/ha PM alone also corroborated this observation. Earlier commencement of flowering and fruiting, growth, and yield parameters as observed in the study could also be due to excellent macro- and micro-nutrients in the poultry manure that was complemented with the nutrient that was supplied through the foliage. Garge and Bahla (2008) reported that poultry manure readily supply phosphorous to plants than other organic sources. Similarly, Tu et al. (2006) observed that microbial biomass and activity were higher in organically managed soils compared to conventional soil amendment with synthetic inorganic fertilizer. In a more recent study, Roy et al. (2013) reported rapid released of available plant nitrogen in organic fertilizer produced from bovine-rumen-blood-digesta mixture (BBRD).

It is possible that the combined application favored increased production of photosynthates during the growth stages and consequently partitioning and allocation of the dry matter at the developmental stages of okra. This finding is consistent with the observation of earlier researchers on the integration of organic manure with inorganic soil-applied fertilizer for okra (Akande et al. 2010; Abd El-Kader et al. (2010) and other crops such as maize (Makinde and Ayoola 2008), rice (Satyanarayana et al. 2007), sorghum (Bayu et al. 2006), and sweet maize (Uwah et al. 2011). Foliar fertilizers are fast acting because the nutrients are absorbed at the site where they are readily utilized. Apart from supplying micro-nutrients, this method of fertilizer application has also been reported to act as catalyst in the uptake and utilization of certain macronutrients (Philips 2004). In another study, Selvi and Rani (2000), found higher yield, income, and benefit cost ratio in okra when FF was mixed with inorganic NPK fertilizer than when NPK was applied alone.

Conclusion

In the present study, combinations of PM applied at 10 t/ha and FF produced the highest fruit yield. However, there was no significant difference in the obtained yield and integration of PM at 7.5 t/ha plus FF. Poultry manure at 7.5 t/ha mixed with foliar fertilizer is therefore recommended.

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