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ORIGINAL ARTICLE

Physiological growth, yield and quality responses of okra to sole and combined soil application of green biomass, poultry manure and inorganic fertilizers

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Abstract Agronomic practices using different organic materials helps in improving soil fertility and quality of produce. Experiments were conducted to determine the effects of different sole and combined application of organic manures and inorganic fertilizers on the physiological growth, yield and quality of okra. Treatments consisted two green biomass viz- *Gliricidia sepium* leaves (5 and 10 t ha^{-1} Gs), *Chromolaena odorata* leaves (5 and 10 t ha^{-1} Co), poultry manure (5 and 10 t ha^{-1} Pm), zinc sulphate (0 and 10 kg ha^{-1} Zn) and NPK fertilizer (200 kg ha^{-1} NPK) in a Randomized Complete Block Design (RCBD) with four replications. Application of 5 t ha^{-1} Co + 5 t ha^{-1} Pm (T_2), 10 t ha^{-1} Pm + 0 kg ha^{-1} Zn (T_8) and 10 t ha^{-1} Pm + 10 kg ha^{-1} Zn (T_9) increased vegetative growth, number of fruits and quality of okra fruits similar to application of NPK except fruit weight per hectare while 5 t ha^{-1} Gs + 5 t ha^{-1} Pm (T_1) improved all the parameters including fruit weight. Effects of treatments had significant influences on the proximate composition. The average concentrations of the heavy metals (Pb, Zn, Cu and Fe) detected in the samples were all below the safe limit. Incorporation of 5 t ha^{-1} Gs + 5 t ha^{-1} Pm (T_1) will be adequate for growth, yield and quality characteristics of okra without the addition zinc sulphate fertilizer. Further increase in the amendments may therefore not be economical.

Keywords Okra · Growth rate · Organic materials · Chemical fertilizers · Yield and proximate

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Introduction

Food insecurity and hunger are persistent social and public health issues; vegetable production has been a part of the solution to ensure food security. Vegetable crops are reliable sources of vitamins, minerals and income for both rural and urban dwellers and at the same time plays an important role in human nutrition and health management (Grubben et al., 2014; Keatinge et al., 2010).

Okra (*Abelmoschus esculentus* (L) Moench), a species of the Malvaceae family, is an economically important crop that is mostly cultivated in the tropical and sub-tropical regions of the world. The crop is adapted to wide varieties of soil, but a deep fertile sandy loam with good drainage and a soil pH of about 6.0 to 6.8 is optimum (Eke et al., 2008). An average monthly temperature range of 20 °C to 30 °C is considered optimum for growth, flowering and fruiting (Rice et al., 1987). Okra is a dual crop that is known for its various uses (Mihretu et al., 2014). All parts except the stem are edible and are used to prepare different types of delicacies (Maramag, 2013). The fruits contain mucilage which may be used as an ingredient to modify the food quality in terms of food stability, texture and appearance properties by acting as emulsifiers, thickeners, gelling agents or texture modifiers (Noorlaila et al., 2015).

Decline in soil fertility has been discovered to be as a result of continuous cropping and financial inability of smallholders' farmers to purchase and apply chemical fertilizers to replace soil nutrients that are lost after crop harvest. It is therefore important to provide and maintain adequate management of the soil by preserving the humus and organic matter content thereby increasing the nutrient providing ability of the soil (Defoer, 2002). Adequate soil management with organic manures provides a long-lasting effect and slow release of minerals to the soil which decreases future cost of production and increase future crop output (Alimi et al., 2006) while the accumulation of the use of inorganic fertilizers results in soil structure destruction, environmental pollution by contaminating the soil and water in the environment.

The use of organic-based soil amendments has provided a great opportunity and potentials to release nutrients slowly into the soil for enhanced crop yield and long positive residual effect (Firoz et al., 2009). *G. sepium* has high biomass and research has shown that application of 1 t ha^{-1} provides 21 kg N, 2.5 kg P, 18 kg K, 85 g Zn, 164 g Mn, 365 g Cu, 728 g Fe besides adding considerable quantities of S, Ca, Mg, B, Mo (Srinivasarao et al., 2011), all of which have positive effect on crop yields and helps in improving the soil physical and chemical properties. Alisi et al. (2011) and Tanhan et al. (2011) found that *C. odorata* is a kind of weed that has been used as fallow species in crop rotation, rectifying and correcting contaminated soil, improving soil fertility and possessing pesticidal effect. Studies also confirmed that *C. odorata* contains nitrogen and potassium in high quantity and help plant grow when incorporated to the soil (Jamilah, 2010).

Poultry manure is a type of organic fertilizer that is derived from poultry feces. It can either be wet or dry. Poultry manure is a cheap and good source of plant nutrients that supplies nutrients such as nitrogen, phosphorus, and potassium. It improves the physical characteristics and conditions of the soil and improves the nutrient uptake and crop productivity (Ojeniyi et al., 2013). Poultry manure increases the moisture holding capacity of the soil and improves lateral water movement, thus improving irrigation efficiency and decreasing the general doughtiness of sandy soils (Mohamed Amanullah et al., 2010).

Heavy metals are usually given to livestock and poultry as feed additives to improve growth, meat quality, and also in the control diseases (Li et al., 2007). Record shows that an estimate of more than 20 million hectares of land have been contaminated with heavy metals (Liu et al., 2018) which enters agricultural soils through atmospheric deposition, sewage irrigation, and applications of livestock manures and agricultural chemicals (Peng et al., 2019). These heavy metals can be taken up by crops and accumulate in all edible parts thereby causing health problems for humans and animals through food chain when consumed (Doabi et al., 2018).

Organic manures not only improve the physical, chemical and biological properties of the soil, it also improved yield and quality of agricultural produce (Aboyeji, 2019). Therefore, there is a need to assess the effectiveness of two sources of organic manures (green biomass and poultry manure) and inorganic fertilizer as they affect the growth pattern, yield and quality of okra fruit. It was hypothesized from the objective that each of the amendments present different physical and chemical properties therefore, growth rate, yield and quality of okra will respond differently to sole and integrated application of green biomass, poultry manure and inorganic fertilizers. Studies were therefore conducted to validate this hypothesis; which combinations or sole application of green biomass, poultry manure and inorganic fertilizers will perform best for the cultivation of okra?

Materials and methods

Description of the experimental site

The experiment was conducted during the 2018 and 2019 cropping seasons at the Teaching and Research farm of Landmark University, Omu-Aran, Kwara State (Lat 8° 9′N and Long 5° 61′E) with an altitude of 495 m’ elevation above the sea level in the derived savannah zone of Nigeria. It has an annual rainfall ranging from 600 to 1200 mm and an annual average temperature of 24.9 °C. The months of December and January coincides with the cold and dry harmattan period.

Soil sampling and analysis

Before the commencement of the experiments in 2018 and 2019, surface soil (0–15 cm) samples were randomly collected from 10 different points from each experimental site using soil auger. The soil samples were bulked separately for each year, air-dried and allowed to pass through a 2-mm sieve for routine physical and chemical laboratory analysis as described by Carter (1993).

Treatment and experimental design

The treatments consists of two types of green biomass viz- *G. sepium* leaves (5 and 10 t ha^{-1} Gs), *C. odorata* leaves (5 and 10 t ha^{-1} Co), poultry manure (5 and 10 t ha^{-1} Pm), $ZnSO_4$ (0 and 10 kg Zn ha^{-1}) and NPK fertilizer (200 kg ha^{-1} NPK), they were combined and tested as follows: –5 t ha^{-1} Gs + 5 t ha^{-1} Pm (T_1), 5 t ha^{-1} Co + 5 t ha^{-1} Pm (T_2), 5 t ha^{-1} Co + 5 t ha^{-1} Gs (T_3), 10 t ha^{-1} Gs + 0 kg ha^{-1} Zn (T_4), 10 t ha^{-1} Gs + 10 kg ha^{-1} Zn (T_5), 10 t ha^{-1} Co + 0 kg ha^{-1} Zn (T_6), 10 t ha^{-1} Co + 10 kg ha^{-1} Zn (T_7), 10 t ha^{-1} Pm + 0 kg Zn ha^{-1} (T_8), 10 t ha^{-1} Pm + 10 kg Zn ha^{-1} (T_9), control + 0 kg ha^{-1} Zn (T_{10}), control + 10 kg ha^{-1} Zn (T_{11}) and 200 kg ha^{-1} NPK (T_{12}). Treatments were replicated four times, in a Randomized Complete Block Design (RCBD).

Sources of materials

Fresh green biomass of *G. sepium* and *C. odorata* were harvested from a fallow field of Landmark University Teaching and Research farm. Poultry manure was collected from the layers pen of Landmark University farms while NPK and $ZnSO_4$ fertilizers were purchased from a reputable agro-allied store.

Agronomic practices

The land was ploughed and harrowed using tractor drawn disc plough and harrow to loosen and pulverize the soil. Thereafter the field layout was carried out to mark out the appropriate number of treatments per plot. The size of each experimental plot was 2 m × 2 m = 4 m^2 and there were 12 plots per replicate (4 m × 12 m = 48 m^2) which were replicated four times. The size of the whole experimental plot was 48 m × 4 m = 192 m^2.

The variety of okra used for the experiment was the local variety (Omu-Aran local 16–55) that is commonly grown and eaten in the derived savannah ecological zone of Nigeria. Okra seeds were subjected to viability test before sowing. The seeds were sowed on 9th and 18th of June, 2018 and 2019 respectively two weeks after incorporation of the green and poultry manures. The planting spacing was 60 cm by 30 cm inter and intra row respectively. Two seeds were sown per hole and were later thinned to one plant per stand two weeks after sowing.

Fresh and tender biomass of both *G. sepium* and *C. odorata* were picked and chopped into pieces using cutlass. The chopped biomass and poultry manure were weighed according to treatment and incorporated into the soil immediately after land preparation and were allowed to decompose for two weeks before sowing. Inorganic (NPK 20:10:10) and $ZnSO_4$ fertilizers were applied 2 weeks after sowing by side placement 8 cm away from the base of the plant.

However, to control the flea beetle (Podagrica spp), spraying was done at 14 days interval with 30 g Cypermethrin/250 g dimethoate at the rate of 1.5 kg a. i ha^{-1}. Weeds were manually controlled using the local hand-held hoe and rouging. Manual harvesting of fresh and mature okra pods started on the 5th and 18th of August, 2018 and 2019 respectively at 3 day intervals for a period of two weeks. Harvested okra pods were counted and weighed with the aid of automated weighing balance of maximum capacity 2100 g, readable at 0.01 g and a model of OHAUS Corporation, USA based on treatments.

Data collection

Parameters measured and collected during the study were plant growth parameters (plant height, number of leaves, stem girth) at first flowering, crop dry weight at 4, 5, 6 and 7 weeks after sowing, yield and quality parameters (proximate and some heavy metals) at the expiration of the study.

In determining the crop dry weight, the vegetative part of okra was cut at the base of the plant above the ground level at each sampling period, weighed and oven-dried at 70 °C for three days to a constant weight (Hunt, 1982). Crop growth rate (g m^{-2} day^{-1}) and relative growth rate (g g^{-1} day^{-1}) were therefore computed using the data obtained from the crop dry weight per plant at 4–5, 5–6 and 6–7 WAS using the following formulas as suggested by Watson (1956) and Williams (1946) respectively:-

$$\text{Crop growth rate (CGR)} = \frac{(W_2 - W_1)}{(t_2 - t_1)}$$

where W_1 and W_2 = dry weight of the whole plant at time t_1 and t_2 respectively, $t_1 - t_2$ = time interval (days)

$$\text{Relative growth rate (RGR)} = \frac{\log e\, W_2 - \log e\, W_1}{(t_2 - t_1)}$$

where W_1 and W_2 = dry weight of the whole plant at time t_1 and t_2 respectively, t_1 and t_2 = time interval (days) and Log e = natural log.

Laboratory analysis of poultry manure and green biomass

The nutrient composition of powdered poultry manure was determined after ashing in the muffle furnace. Total N was determined by Kjedahl method. For other nutrients, ground samples were subjected to wet digestion using 25–5–5 mL of HNO_3–H_2SO_4–$HClO_4$ acids (AOAC, 2003). The filtrate was used for nutrients determination as done in routine soil analysis. Total P was determined by colorimeter (model 6051 by Jenway), K by flame photometer (model PFP7C by Jenway) and Ca, Mg and micronutrients by atomic absorption spectrophotometer (AAnalyst 800 by PerkinElmer).

Leaf samples of *G. sepium* and *C. odorata* were collected and oven-dried for 24 h at 80 °C and grinded in a Willey mill. These samples were analysed for leaf N, P, K, Ca and Mg as described by Tel et al. (1984). Leaf N was determined by the micro-Kjeldahl digestion method. Ground samples were digested with nitric-perchloric-sulphuric acid mixture for the determination of P, K, Ca and

Mg. Phosphorus was determined colorimetrically using the vanadomolybdate method, K was determined using a flame photometer and Ca and Mg were determined by the EDTA titration method (AOAC, 2003). The percentage of organic carbon in the sample was determined by the Walkley and Black procedure using the dichromate wet oxidation method (Nelson & Sommers, 1996). Sample pH was determined by using a soil–water medium at a ratio of 1:2 using Jenway digital electronic pH meter model 3520 (Ibitoye, 2006).

Laboratory determination of heavy metals in okra fruits

Representative okra fruit samples were taken per plot and per replicate to analyze for the levels of heavy metals contained in the fruit at the crop and soil laboratory of Landmark University, Omu-Aran, Nigeria. Mature fresh okra fruits were collected, oven-dried for 24 h at 80 °C, and ground in a Willey mill. Mineral elements were determined according to the methods as recommended by the Association of Official Analytical Chemists (AOAC, 2003). One gram of each sample was digested using 12 mL of the mix of HNO_3, H_2SO_4, and $HClO_4$ (7:2:1 v/v/v). Contents of Pb, Zn, Cu, Mg and Fe, were determined by an atomic absorption spectrophotometer (AAnalyst 800 by PerkinElmer).

Proximate analysis of okra fruits

Proximate analysis of okra fruit was carried out at the central laboratory, Landmark University, Nigeria. Fresh fruit samples were oven dried at constant temperature of 70 ^{0}C for 72 h till no moisture was left. Dried fruit samples were grinded per treatment and analyzed for their proximate composition under the Parten D analyzer.

Method of data analysis

Data obtained from the study were subjected to statistical analysis of variance (ANOVA) using GENSTAT discovery (2014). Comparison of the treatment means for significance was carried out using the Duncan multiple range test (DMRT) at 5% probability level.

Results

Initial soil properties

The pre-planting soil analysis is as shown in Table 1. The pH of the soil was strongly acidic, the available phosphorus and nitrogen were relatively low, and the exchangeable K, Ca, Mg and organic matter were low to moderate but not adequate. There was high quantity of sand, with relatively low quantity in silt and clay in the soil, therefore, the textural class sandy loam.

Chemical composition of amendments

Table 2 shows the chemical composition of the organic manures used as amendment for the study. Poultry manure was discovered to have lower C:N ratio than *G. sepium* but higher organic carbon (OC), nitrogen (N), phosphorus (P), magnesium (Mg), copper (Cu) and iron (Fe) content when compared with *G. sepium* and *C. odorata*.

Effect of sole and combined application of organic and inorganic fertilizers on the vegetative parameters of okra

Vegetative parameters of okra were influenced by various types and rates of soil amendments (Table 3). When compared with the control (T_{10}) which gave a statistically lower values for vegetative parameters but similar to the application of the control + 10 kg ha^{-1} Zn (T_{11}), plots treated with 5 t ha^{-1} Gs + 5 t ha^{-1} Pm (T_1) produced higher values for plant height and number of leaves though the values were statistically similar with the application of 5 t ha^{-1} Co + 5 t ha^{-1} Pm (T_2), 10 t ha^{-1} Pm + 0 kg ha^{-1} Zn (T_8), 10 t ha^{-1} Pm + 10 kg ha^{-1} Zn (T_9) and 200 kg ha^{-1} NPK (T_{12}) in both years. In 2018 and 2019, okra plants produced wider girth with the application of 5 t Gs + 5 t ha^{-1} Pm (T_1), 5 t ha^{-1} Co + 5 t ha^{-1} Pm (T_2) and 200 kg ha^{-1} NPK (T_{12}). Other treatments gave varying and statistically similar values for the parameters.

Effect of sole and combined application of organic and inorganic fertilizers on crop dry weight of okra

The response of okra plant to applied amendments were significant on crop dry weight throughout the sampling periods (Table 4). In both years, application of 5 t ha^{-1} Gs + 5 t Pm (T_1), 5 t ha^{-1} Co + 5 t ha^{-1} Pm (T_2), 10 t ha^{-1} Pm + 0 kg ha^{-1} Zn (T_8) and 10 t ha^{-1} Pm + 10 kg ha^{-1} Zn (T_9) increased crop dry weight throughout the sampling periods except at 4 and 5 WAS in 2019. Significantly least values for crop dry weight were observed with the application of Control (T_{10}), Control + 10 kg ha^{-1} Zn (T_{11}).

Table 1 Initials soil physical and chemical characteristics of the experimental sites at 0–15 cm depth

Parameter	Values		Parameter	Values	
	2018	2019		2018	2019
Sand (%)	76.00 ± 0.55	76.22 ± 1.15	Exchangeable bases		
Silt (%)	13.00 ± 0.42	12.58 ± 0.49	K (cmol/kg)	0.12 ± 0.02	0.14 ± 0.02
Clay (%)	11.00 ± 0.63	11.20 ± 0.78	Na (cmol/kg)	0.65 ± 0.02	0.57 ± 0.02
Textural class	Sandy loam	Sandy loam	Ca (cmol/kg)	3.15 ± 0.28	3.16 ± 0.25
pH (H_2O) 1:1	5.32 ± 0.18	5.21 ± 0.20	Mg (cmol/kg)	0.53 ± 0.02	0.58 ± 0.05
Total N (%)	0.15 ± 0.01	0.18 ± 0.01	ECEC (cmol/kg)	4.49 ± 0.10	4.50 ± 0.06
O.M (%)	2.25 ± 0.20	2.28 ± 0.22	Available phosphorus (mg/kg)	9.58 ± 0.46	9.62 ± 0.65
O.C (%)	1.30 ± 0.17	1.34 ± 0.08	Zn (mg/kg)	0.43 ± 0.02	0.37 ± 0.05

Table 2 Chemical composition of amendments used for the experiment

Amendments (ha^{-1})	O.C (%)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (%)	Cu (%)	Fe (%)	C:N
Poultry manure	21.61a	2.88ab	1.30a	1.67b	0.89b	0.54a	4.75a	0.32a	0.62a	7.50b
G. sepium	14.79b	3.56a	0.79b	3.89a	2.41a	0.38a	3.50b	0.17b	0.27b	11.40a
C. odorata	15.60b	1.21b	0.61b	1.03b	2.30a	0.04b	2.84b	0.23b	0.17c	12.90a

Means in a column under any given treatment followed by the same letter(s) do not differ significantly at 0.05 level of probability using Duncan multiple range test (DMRT)

Table 3 Effect of sole and combined application of organic and inorganic fertilizers on the vegetative parameters of okra in 2018 and 2019 cropping seasons

Treatments	2018			2019		
	Plant height (cm)	Number of leaves	Stem girth (cm)	Plant height (cm)	Number of leaves	Stem girth (cm)
5 t ha^{-1} Gs + 5 t ha^{-1} Pm (T_1)	36.32a	25.00a	12.70a	34.87a	24.00a	12.62a
5 t ha^{-1} Co + 5 t ha^{-1} Pm (T_2)	35.66a	24.00a	12.23a	34.61a	23.00a	12.57a
5 t ha^{-1} Co + 5 t ha^{-1} Gs (T_3)	28.89b	18.00b	10.89b	27.84b	18.00b	9.79b
10 t ha^{-1} Gs + 0 kg ha^{-1} Zn (T_4)	28.57b	17.00b	10.43b	28.73b	16.00b	9.67b
10 t ha^{-1} Gs + 10 kg ha^{-1} Zn (T_5)	28.86b	18.00b	10.51b	28.77b	17.00b	9.86b
10 t ha^{-1} Co + 0 kg ha^{-1} Zn (T_6)	27.57b	17.00b	10.75b	27.64b	17.00b	9.58b
10 t ha^{-1} Co + 10 kg ha^{-1} Zn (T_7)	27.32b	18.00b	10.79b	27.83b	17.00b	9.87b
10 t ha^{-1} Pm + 0 kg ha^{-1} Zn (T_8)	35.16a	24.00a	10.45b	32.00a	24.00a	9.51b
10 t ha^{-1} Pm + 10 kg ha^{-1} Zn (T_9)	35.84a	25.00a	10.60b	32.54a	24.00a	9.64b
Control + 0 kg ha^{-1} Zn (T_{10})	15.07c	10.00c	7.40c	13.21c	10.00c	6.69c
Control + 10 kg ha^{-1} Zn (T_{11})	17.24c	11.00c	7.90c	14.54c	12.00c	7.54c
200 kg NPK ha^{-1} (T_{12})	35.84a	24.00a	12.00a	34.57a	23.00a	11.95a

Means in a column under any given treatment followed by the same letter(s) do not differ significantly at 0.05 level of probability using Duncan multiple range test (DMRT)

Gs = *G. sepium*, Co = *C. odorata*, Pm = Poultry manure

Table 4 Effect of sole and combined application of organic and inorganic fertilizers on crop dry weight (g) per plant of okra plant in 2018 and 2019 cropping seasons

Treatments	2018				2019			
	4 WAS	5 WAS	6 WAS	7 WAS	4 WAS	5 WAS	6 WAS	7 WAS
5 t ha^{-1} Gs + 5 t ha^{-1} Pm (T_1)	1.67a	2.47a	4.34a	7.40a	1.44a	2.50a	4.20a	6.92a
5 t ha^{-1} Co + 5 t ha^{-1} Pm (T_2)	1.55a	2.31a	4.10a	7.31a	1.30b	2.19b	3.96ab	5.85ab
5 t ha^{-1} Co + 5 t ha^{-1} Gs (T_3)	1.28b	2.08b	3.56b	5.66b	1.26b	2.02b	3.35b	5.20b
10 t ha^{-1} Gs + 0 kg ha^{-1} Zn (T_4)	1.30b	2.10b	3.36b	5.38b	1.28b	2.04b	3.23b	5.14b
10 t ha^{-1} Gs + 10 kg ha^{-1} Zn (T_5)	1.34b	2.14b	3.68b	5.80b	1.30b	2.09b	3.48b	5.45b
10 t ha^{-1} Co + 0 kg ha^{-1} Zn (T_6)	1.28b	2.08b	3.56b	5.66b	1.26b	2.00b	3.22b	5.32b
10 t ha^{-1} Co + 10 kg ha^{-1} Zn (T_7)	1.30b	2.10b	3.60b	5.68b	1.28b	2.06b	3.35b	5.40b
10 t ha^{-1} Pm + 0 kg ha^{-1} Zn (T_8)	1.68a	2.46a	4.36a	7.43a	1.52a	2.40a	4.17a	6.65a
10 t ha^{-1} Pm + 10 kg ha^{-1} Zn (T_9)	1.70a	2.50a	4.40a	7.50a	1.48a	2.46a	4.19a	6.80a
Control + 0 kg ha^{-1} Zn (T_{10})	0.54c	1.34c	2.08d	3.20d	0.53c	1.21c	2.04c	2.66c
Control + 10 kg ha^{-1} Zn (T_{11})	0.60c	1.40c	2.20d	3.26d	0.55c	1.30c	2.10c	2.73c
200 kg NPK ha^{-1} (T_{12})	1.36b	2.00c	2.90c	4.40c	1.32b	2.25b	2.67bc	3.00bc

Means in a column under any given treatment followed by the same letter(s) do not differ significantly at 0.05 level of probability using Duncan multiple range test (DMRT)

Gs = *G. sepium*, Co = *C. odorata*, Pm = Poultry manure, WAS = Weeks after sowing

Effect of sole and combined application of organic and inorganic fertilizers on crop growth rate (g m^{-2} day^{-1}) and relative growth rate (g g^{-1} day^{-1}) per plant of okra

Figures 1 and 2 show the responses of crop growth rate and relative growth rate to the application of *G. sepium*, *C. odorata*, poultry manure, $ZnSO_4$ and NPK. There was a progressive increase in the crop growth rate in both years and at all sampling periods (Fig. 1a, b). Application of 5 t ha^{-1} Gs + 5 t ha^{-1} Pm (T_1) improved the crop growth rate and was statistically similar with the application of 10 t ha^{-1} Pm + 0 kg ha^{-1} Zn (T_8) and 10 t ha^{-1} Pm + 10 kg ha^{-1} Zn (T_9) while the least value for crop growth rate was observed with the application Control (T_{10}) and Control + 10 kg ha^{-1} Zn (T_{11}). In a similar vein, at all sampling periods and in both years, irrespective of the applied treatments, relative growth rate increased from 5 WAS through 6 WAS while it continuously declined from 6 WAS through 7 WAS (Fig. 2a, b).

Effect of sole and combined application of organic and inorganic fertilizers on yield and yield parameters of okra

Data on yield and yield parameters of okra as influenced by *G. sepium*, *C. odorata*, poultry manure, $ZnSO_4$ and NPK is as shown in Table 5. There was a significant response of okra yield to different types and rates of soil amendments. The two years' study showed that, number of fruits were significantly higher with plots treated with 5 t ha^{-1} Gs + 5 t ha^{-1} Pm (T_1), 5 t ha^{-1} Co + 5 t ha^{-1} Pm (T_2), 10 t ha^{-1} Pm + 0 kg ha^{-1} Zn (T_8), 10 t ha^{-1} Pm + 10 kg ha^{-1} Zn (T_9) and 200 kg ha^{-1} NPK (T_{12}) while fruit weight was only higher and significant with the application 5 t Gs + 5 t Pm (T_1), 5 t ha^{-1} Co + 5 t ha^{-1} Pm (T_2) and 200 kg ha^{-1} NPK (T_{12}). The control (T_{10}) and control + 10 kg ha^{-1} Zn (T_{11}) treatments gave statistically similar and lower yield values when compared with other treatments.

Effect of sole and combined application of organic and inorganic fertilizers on the proximate and heavy metals composition of okra fruit

Application of *G. sepium*, *C. odorata*, poultry manure, $ZnSO_4$ and NPK significantly influenced the proximate and heavy metals composition of okra fruits (Table 6). Pooled analysis of 2018 and 2019 shows that application of 5 t ha^{-1} Gs + 5 t ha^{-1} Pm (T_1) significantly improved all the parameters measured except the fat content. Fat content significantly increased with the application of 200 kg ha^{-1} NPK (T_{12}) and was statistically similar when Control (T_{10}) and Control + 10 kg ha^{-1} Zn (T_{11}) were applied. The concentrations of heavy metals (Zn, Cu and Fe) in okra fruits are also presented in Table 6. The average concentrations of these heavy metals detected in the samples were below the safe limit as recommended by the Joint FAO/WHO (2010) Expert Committee on food additives though significantly higher in treatments containing poultry manure.

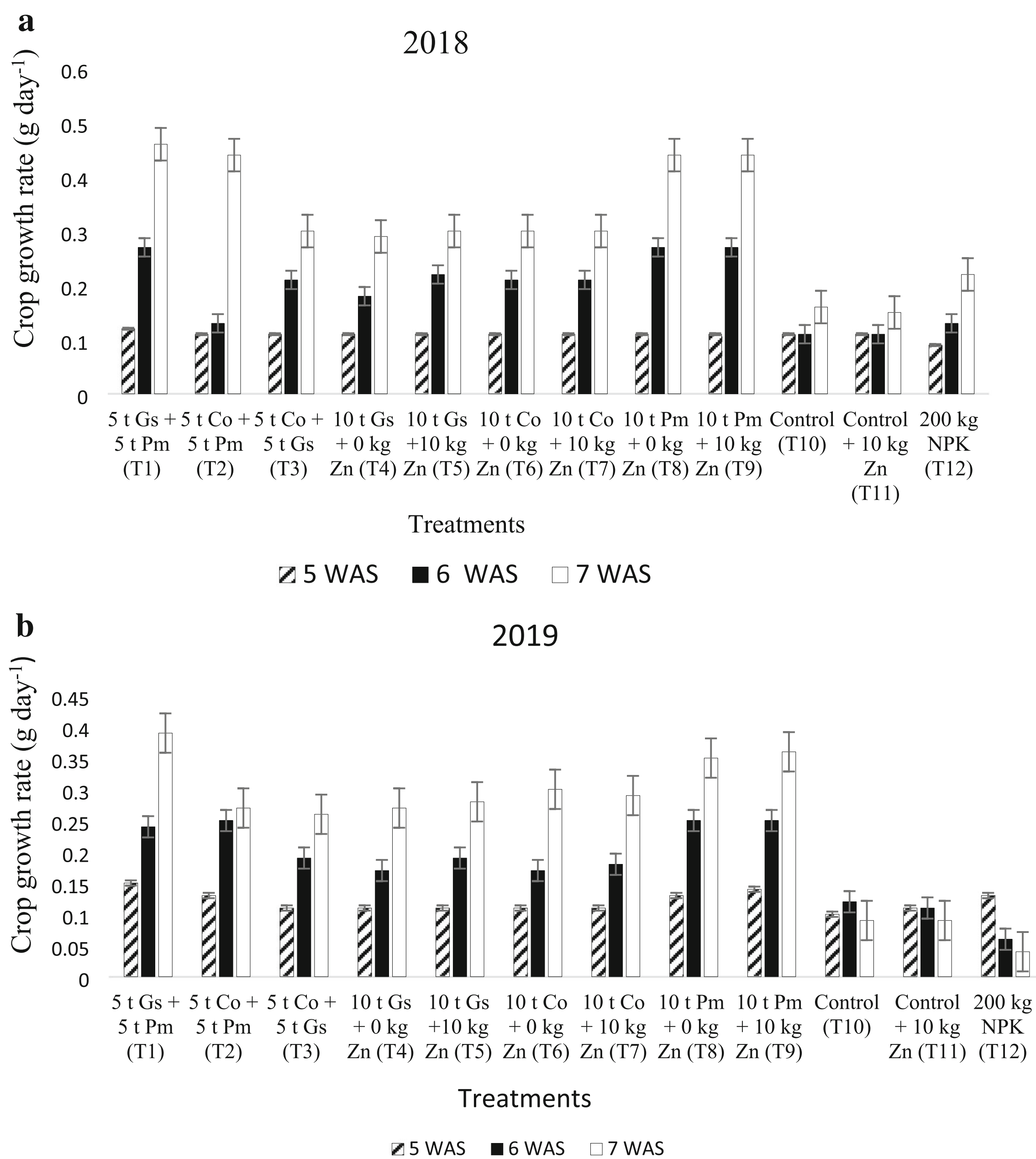

Fig. 1 **a** Effect of sole and combined application of organic and inorganic fertilizers on crop growth rate (g m^{-2} day^{-1}) per plant of okra in 2018 cropping season. Vertical bars show standard errors. **b** Effect of sole and combined application of organic and inorganic fertilizers on crop growth rate (g m^{-2} day^{-1}) per plant of okra in 2019 cropping season. Vertical bars show standard errors. Gs = *G. sepium*, Co = *C. odorata*, Pm = Poultry manure, Number of replicates = 4

Discussion

Incorporation of *T. diversifolia*, *C. odorata* and poultry manure either as sole or combined improved all the plant growth parameters (plant height, number of leaves and stem girth) measured during the experiments and the effect was comparable with the effect of application of inorganic fertilizer. Higher mineralization occurs where *G. sepium* and poultry manure were combined, compared to their individual application, indicating a synergistic relationship (Adekiya, 2018). Increase in vegetative parameters as a result of application of *G sepium*, *C. odorata* and poultry manure can be adduced to increased soil organic matter which enhanced microbial activities leading to increased soil nutrients availability. Adekiya et al., (2020a, 2020b) found that application of green manure, animal manure and many agricultural waste improved chemical and biological properties of the soil. Increased vegetative growth in plots

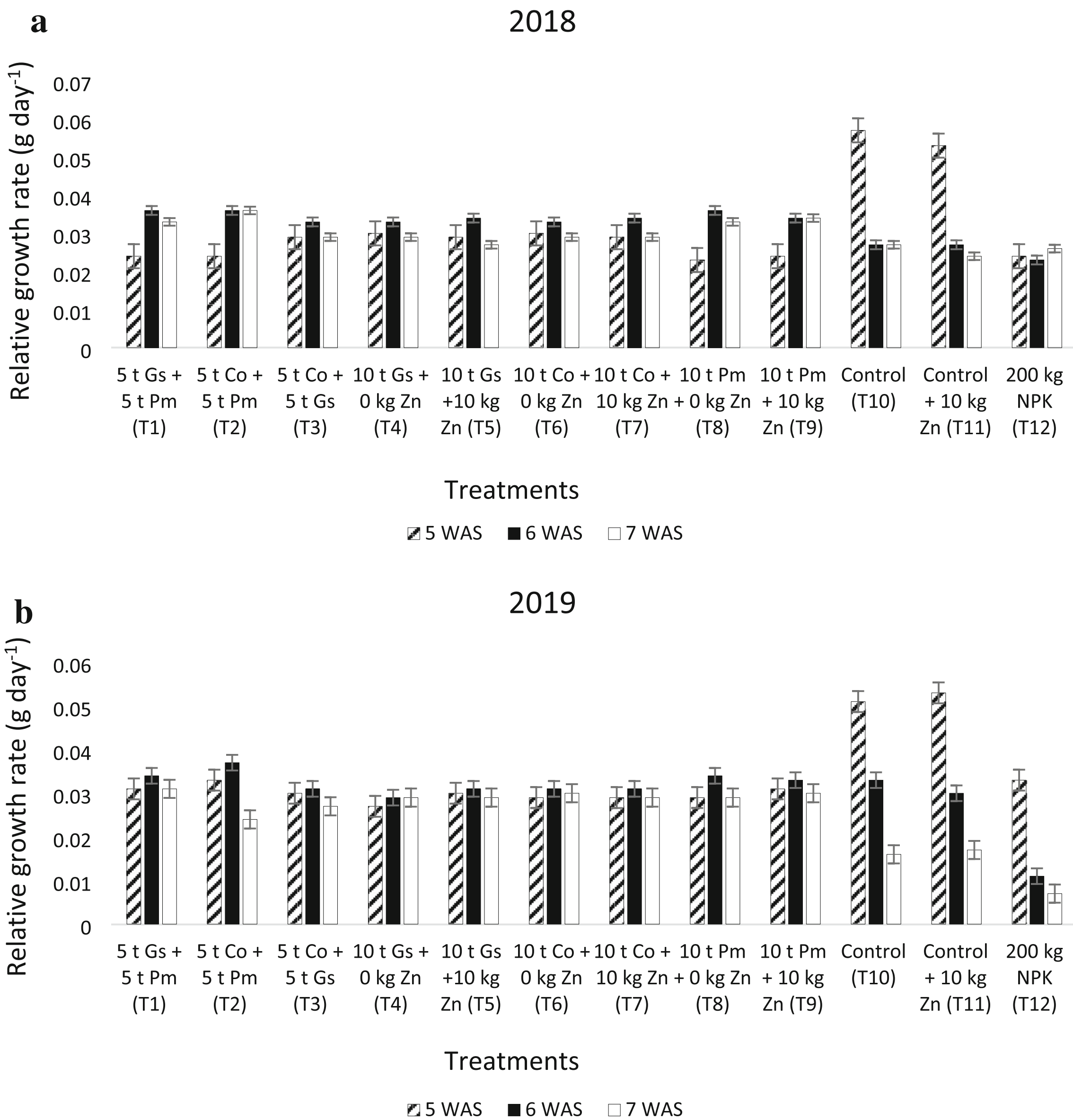

Fig. 2 **a** Effect of sole and combined application of organic and inorganic fertilizers on relative growth rate (g g^{-1} day^{-1}) per plant of okra in 2018 cropping season. Vertical bars show standard errors. **b** Effect of sole and combined application of organic and inorganic fertilizers on relative growth rate (g g^{-1} day^{-1}) per plant of okra in 2019 cropping season. Vertical bars show standard errors. Gs = *G. sepium*, Co = *C. odorata*, Pm = Poultry manure, Number of replicates = 4

treated with poultry manure could be ascribed to presence of adequate quantity of Mg in poultry manure which assisted in facilitating the rate of photosynthesis. Ntia et al. (2017) found that application of poultry manure significantly influenced the vegetative and fruit yield parameters which they attributed to the essential nutrients contained in poultry manure which contributed to the high photosynthetic activities of the crop and eventually promote vegetative growth and reproductive traits of okra.

The crop growth rate simply indicates the change in dry weight over a period of time. Study revealed that crop dry weight and crop growth rate increased progressively with plant age and across all treatments and this represents a good determinant to okra yield and its attributes. Treatments containing poultry manure –5 t ha^{-1} Gs + 5 t ha^{-1} Pm (T_1), 5 t ha^{-1} Co + 5 t ha^{-1} Pm (T_2), 10 t ha^{-1} Pm + 0 kg ha^{-1} Zn (T_8) and 10 t ha^{-1} Pm + 10 kg ha^{-1} Zn (T_9) increased crop dry weight and crop growth rate. The positive influence of the treatments to increased crop dry weight and crop growth rate implied that the treatments supplied the nutrients needed by okra in required quantity for metabolic activities. Eifediyi et al. (2010) reported that the most vital factor that determines growth of plants and it's dry matter accumulation is the mode of nutrients

Table 5 Effect of sole and combined effect of the application of organic and inorganic fertilizers yield parameters of okra in in 2018 and 2019 cropping seasons

Treatments	2018			2019		
	Number of fruits/Plot	Number of fruit per hectare	Fruit weight/ hectare (kg)	Number of fruits/Plot	Number of fruit per hectare	Fruit weight/ hectare (kg)
5 t ha^{-1} Gs + 5 t ha^{-1} Pm (T_1)	47.67a	119,175a	1196.13a	46.54a	116,350a	1118.72a
5 t ha^{-1} Co + 5 t ha^{-1} Pm (T_2)	46.00a	115,500a	1160.55a	46.00a	115,000a	1107.75a
5 t ha^{-1} Co + 5 t ha^{-1} Gs (T_3)	41.67b	104,175b	1110.05b	41.25b	103,125b	1038.88b
10 t ha^{-1} Gs + 0 kg ha^{-1} Zn (T_4)	40.00b	100,000b	994.68c	40.10b	100,250b	983.33c
10 t ha^{-1} Gs + 10 kg ha^{-1} Zn (T_5)	41.00b	102,500b	1062.33b	40.75b	101,875b	1033.21b
10 t ha^{-1} Co + 0 kg ha^{-1} Zn (T_6)	39.67b	99,175b	996.23c	39.15b	97,875b	978.74c
10 t ha^{-1} Co + 10 kg ha^{-1} Zn (T_7)	38.33b	95,825b	1065.05b	39.62b	99,050b	1044.55b
10 t ha^{-1} Pm + 0 kg ha^{-1} Zn (T_8)	46.66a	116,650a	999.70c	45.15a	112,875a	991.63c
10 t ha^{-1} Pm + 10 kg ha^{-1} Zn (T_9)	47.33a	118,325a	1069.13b	45.85a	114,625a	1060.42b
Control + 0 kg ha^{-1} Zn (T_{10})	25.00c	62,500c	310.38d	23.00d	57,500d	304.55e
Control + 10 kg ha^{-1} Zn (T_{11})	27.00c	67,500c	324.41d	26.00c	65,000c	355.30d
200 kg NPK ha^{-1} (T_{12})	46.67a	116,175a	1159.99a	45.85a	115,285a	1117.45a

Means in a column under any given treatment followed by the same letter(s) do not differ significantly at 0.05 level of probability using Duncan multiple range test (DMRT)

Gs = *G. sepium*, Co = *C. odorata*, Pm = Poultry manure

release by the applied organic amendments. Increased crop dry weight and crop growth rate with sole or integrated application of poultry manure with *G. sepium* or *C. odorata* could also be attributed to the increased production of assimilates during the growth stages (Akande et al., 2010).

Relative Growth Rate (RGR) expresses the total plant dry weight increase in a time interval in relation to the initial weight (Williams, 1946). Results showed that relative growth rate increased during the period of constant rate of dry matter accumulation (4–5 WAS and 5–6 WAS) and start declining at 7 WAS. The decline in the relative growth rate as the crop ages could be attributed to reduction in the rate of dry matter accumulation which was associated to the functional and visual leaf senescence. Leaf senescence is a major event in a plant's life history as it vividly displays the end of the growing season, that is, the end of the photosynthetic activity, which affects water, carbon and nutrient cycling in many ecosystems (Panchen et al., 2015). Leaf senescence is directly related to chlorophyll levels and the conversion of chloroplasts into gerontoplasts (Sobieszczuk-Nowicka et al., 2018).

Okra had better relative growth rate with sole poultry manure and poultry manure augmented with green biomass than other treatments. Increased relative growth rate with the application of sole poultry manure and poultry manure augmented with green biomass could be attributed to the presence of high value of Mg in the poultry manure as indicated in the laboratory analysis which leads to higher photosynthetic performance of okra when compared with other amendments (Mashavira et al., 2015). Mg is part of chlorophyll molecule located in the thylakoid membrane of the leaves that are essential for increased photosynthesis.

Increase in fruit yield of okra as a result of application of various levels of *G. sepium*, *C. odorata* and poultry manure could be attributed to some major mineral elements needed for plant growth and development that are present in the amendments. Increase in these parameters could also be as a result of taller plants and more number of leaves produced making the plants to trap more sunlight for the

Table 6 Effect of sole and combined application of organic and inorganic fertilizers on proximate and heavy metals composition of okra fruit (pooled analysis of 2018 and 2019 cropping seasons)

Treatments	Ash	%			mg		
		Crude protein	Carbohydrate	Crude fat	Zn	Cu	Fe
5 t ha^{-1} Gs + 5 t ha^{-1} Pm (T_1)	7.23a	23.90a	32.69a	6.00c	6.22a	0.55a	0.074a
5 t ha^{-1} Co + 5 t ha^{-1} Pm (T_2)	6.65b	23.00a	31.22a	6.35c	6.01a	0.55a	0.073a
5 t ha^{-1} Co + 5 t ha^{-1} Gs (T_3)	5.23c	21.44b	25.36b	8.96b	3.01.c	0.36c	0.045b
10 t ha^{-1} Gs + 0 kg ha^{-1} Zn (T_4)	5.28c	21.38b	25.78b	8.82b	3.11c	0.38c	0.044b
10 t ha^{-1} Gs + 10 kg ha^{-1} Zn (T_5)	5.45c	21.38b	26.00b	8.82b	4.58b	0.33c	0.042b
10 t ha^{-1} Co + 0 kg ha^{-1} Zn (T_6)	5.22c	21.82b	25.66b	8.94b	3.15c	0.39c	0.043b
10 t ha^{-1} Co + 10 kg ha^{-1} Zn (T_7)	5.36c	21.31b	26.15b	8.72b	4.55b	0.33c	0.041b
10 t ha^{-1} Pm + 0 kg ha^{-1} Zn (T_8)	7.28a	23.19a	30.74a	6.86c	3.12c	0.58b	0.076a
10 t ha^{-1} Pm + 10 kg ha^{-1} Zn (T_9)	7.55a	23.63a	31.10a	6.94c	6.35a	0.58b	0.076a
Control + 0 kg ha^{-1} Zn (T_{10})	4.85d	18.63c	20.14c	9.24a	1.90d	0.30c	0.043b
Control + 10 kg ha^{-1} Zn (T_{11})	4.90d	18.13c	19.98c	9.22a	4.21b	0.33c	0.042b
200 kg NPK (T_{12})	6.80b	24.10a	25.23b	10.81a	2.10d	0.32c	0.043b
FAO/WHO Limit	NA	NA	NA	NA	9.94	1.00	0.3

Means in a column under any given treatment followed by the same letter(s) do not differ significantly at 0.05 level of probability using Duncan multiple range test (DMRT)

Gs = *G. sepium*, Co = *C. odorata*, Pm = Poultry manure, NA = Not applicable

process of photosynthesis and transporting enough assimilates to the flower buds and consequently higher number of fruits (Aboyeji et al., 2019). Better physical condition of the soil which increases soil organic matter and availability of both macro- and micro-nutrients also contributed to crop yield (Atakora et al., 2014). Increased yield could also be attributed to the effect of high percentage of phosphorus element contained in poultry manure which enhanced good root development and promoted absorption of more nutrients and subsequently higher yield. Mkhonza et al. (2020) in their study, found that poultry manure contains high amount of phosphorous which are more readily to plants than other organic sources. The presence of quality N and P in the organic materials could also lead to increased yield. Adekiya et al., (2020a, 2020b) found that combining the use of organic N and P will enhance yield of okra.

There was a yield reduction though not significant with the application of NPK fertilizer. This could be ascribed to nutrient leaching, volatilization and possible soil erosion. It could also be attributed to the inability of NPK fertilizer to aggregate soil particles as a result low organic matter content of the soil. Aboyeji et al. (2019) reported that organically produced vegetables performed better than those produced with chemical fertilizer while Masarirambi et al. (2010) found that chemical fertilizers do not possess good characteristics of aggregating the soil particles.

Performance and quality of agricultural produce are determined by the type, quantity and quality of amendments used. Crop production with the use of organic amendments determines growth and chemical composition of many plants (Abdou et al., 2011). Proximate analysis is the laboratory estimation of food components such as protein, crude fiber, carbohydrate, ash and moisture content (Ekwumemgbo et al., 2014). Poultry manure alone or in combination with green biomass increased the crude protein and carbohydrate with reduced crude fat content Gopalan et al. (2007).

Heavy metals are elements with metallic properties and an atomic number > 20. Some of these metals are micronutrients necessary for plant growth and have nutritional benefits. Consumption of food crops deficient in micronutrients could result in the deficiency of such micronutrients in humans (Manzeke et al., 2019). Zn, Cu and Fe are some of the micronutrients (heavy metals) that are important for nourishment though in minute quantity. Results of the chemical composition of the amendments used for the experiment showed that poultry manure contained higher values for Zn, Cu and Fe. There were relatively higher values for Zn, Cu and Fe with all the treatments containing poultry manure and Zn although the values were below the safe limits as recommended by the Joint FAO/WHO Expert Committee on food additives to ensure the safety of the consumers (Joint FAO/WHO 2010). It has been widely reported that heavy metal contamination of agricultural soil caused by animal manure application (Azeez et al., 2009). Concentrations of heavy metals in food have been shown to be closely related to heavy metals' concentrations in soil (Hough et al., 2012).

Green manures from different tree species have different rates of decomposition and nutrient release. Cellulose, lignin, tannins, some macro and micro elements are the major constituents of leaves. The use of *T. diversifolia* and *C. odorata* had been widely reported for improving soil fertility in crop production (Sanyaolu & Adepoju, 2018) while research work on the use of *G. sepium* as green manure is still scanty. *G. sepium* performed better than *C. odorata* in this present study. The better performance of *G. sepium* could be due its low C: N ratio and high nitrogen content as indicated in the table of chemical composition of the amendments used for the experiment which facilitated the rate of mineralization and nutrient release. The difference in the C:N ratio of *G. sepium* and *C. odorata* suggests variability in green biomass decomposition and nutrient release. USDA (2011) opined that C:N ratio greater than 24:1 will result in a temporary nitrogen deficit (immobilization), and those with a C:N ratio less than 24:1 will result in a temporary nitrogen surplus (mineralization). Both *G. sepium and C. odorata* have a C:N ratio of less than 24:1. The better performance of *G. sepium* could also be attributed to the higher percentage of P, K, Ca and Zn contents in the leaves.

Crop residues contain about 40–50% of carbon in dry weight, but their nitrogen content varies significantly, which translates into differences in the C:N ratio (Grzyb et al., 2020). The influence of organic residues on soil properties depends upon the amount, type, size, chemical and physical characteristics of the added organic materials (Zhang et al., 2015). Gliricidia tree leaves had a great benefit due to its early decomposition and faster release of C and N, which ultimately activate the process of immobilization and mineralization of nutrients, and thus increases the availability of nutrients in the soil (Keya et al., 2020).

Conclusion

Sole poultry manure was found to be more efficient in improving yield and quality of okra compared to sole green manure. Application of 5 t ha^{-1} Co + 5 t ha^{-1} Pm (T_2), 10 t ha^{-1} Pm + 0 kg ha^{-1} Zn (T_8) and 10 t ha^{-1} Pm + 10 kg ha^{-1} Zn (T_9) increased plant growth parameters, number of fruits and quality of okra fruits similar to application of NPK except fruit weight per hectare while 5 t ha^{-1} Gs + 5 t ha^{-1} Pm (T_1) improved all the parameters including fruit weight. Inclusion of Zn in the soil fertility programme may not be necessary as the effect was not significant on the parameters measured. Hence, for improved growth, yield and good quality of okra fruits, combined application of *G. sepium* and poultry manure at 5 t ha^{-1} Gs + 5 t ha^{-1} Pm is recommended.

Declarations

Conflict of interest Authors declare that there are no conflicts of interest associated with this study.

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