Journal of Experimental Agriculture International

Volume 45, Issue 7, Page 119-131, 2023; Article no.JEAI.99880
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Effect of Source and Rate of Livestock Manure on Yield, Quality and Net Economic Benefit of Okra (*Abelmoschus esculentus* (L.) Moench.)

Kamunyu Deborah Ncuuri [a*], Gathungu Geofrey Kingori [a] and Muraya Moses Mahugu [a]

[a] Department of Plant Sciences, Chuka University, P.O. Box 109-60400, Chuka, Kenya.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2023/v45i72141

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/99880

Original Research Article

Received: 17/03/2023
Accepted: 18/05/2023
Published: 26/05/2023

ABSTRACT

Okra farmers use inorganic fertilizers which are expensive, they result to water pollution, increases the soil acidity, which affects soil nutrients availability and uptake as well as reducing microbial activity. Organic manure improves soil physical, chemical and biological properties, and are environmental friendly. However, farmers have limited information on the utilization of these organic manure sources on growth yield, quality and net economic benefit of okra. A study was conducted to determine the effects of rate cattle, goat and poultry manure on okra growth, yield, quality and net economic benefit at KALRO-Kandara Centre in Murang'a County between 2018 and 2019. The experiment was laid out in randomized complete block design with three replications for two cultivations. There were 10 treatments, i.e., 0, 3, 6 and 7 tonne ha^{-1} for cattle and goat manure, and 0, 3, 5 and 7 tonnes ha^{-1} poultry manure that were applied before planting okra variety Pusa

**Corresponding author: E-mail: deborahkamunyu@yahoo.com;*

Sawani. Data collected included yield characteristics total fresh pod yield and quality characteristics mainly total soluble solids (TSS). Data collected was subjected to analysis of variance using SAS statistical software version 9.4 and significantly different means were separated using LSD at α = 0.05. The results showed that there was significant effect of treatments ($p < 0.05$) on yield, quality and net economic benefit of okra. Poultry manure at the rate of 5t ha^{-1} recorded highest yield while control had the least. Goat manure at the rate of 6 tonnes ha^{-1} recorded the highest total soluble solids, hence, produced pods of the highest quality of 3.18°Brix and 3.21°Brix for Trial 1 and Trial 2, respectively, whereas the control produced pods of lowest quality of 2.31°Brix and 2.34°Brix for Trial 1 and Trial 2, respectively. Cattle manure at the rate of 6 tonnes ha^{-1} recorded the best net economic benefit of Ksh. 700,267 in Trial 1 and Ksh. 694,320 in Trial 2, while the control gave minimal returns of Ksh. 69,158 in Trial 1 and Ksh. 64,320 in Trial 2. This indicates an increase of net economic benefit of Ksh. 631,109 in Trial 1 and Ksh. 630,000 in Trial 2 for cattle manure compared to the control. The results of this study clearly indicate that in okra production, application of different types of animal organic manure can improve the productivity of the okra. The study recommends application of 5 tonnes ha^{-1} poultry manure, or 6 tonnes ha^{-1} of goat or cattle manure for best growth, yield, quality and net economic benefit of okra.

Keywords: Okra; Poultry; goat and cattle manure; yields; nutritional quality; net benefit.

1. INTRODUCTION

Okra (*Abelmoschus esculentus* L.) is considered as an important vegetable in tropical and sub-tropical regions of the world and as it is valuable for supplement of proteins, vitamins and minerals in diets of people from the developing countries, because they depend on cereal crops, which are lacking them [1]. The fruits are used in making soup, salad and for flavouring when dried and powdered [2] and they contain minerals especially calcium, magnesium, iron and phosphorus, protein, vitamin A and C including riboflavin as well as high mucilage [3]. Despite okra being rich in nutrients and with high economical potential, little attention is being paid to its improvement. Total commercial production of okra has reduced due to use of unimproved cultivars, limited and high cost of fertilizers and irrigation inputs and the limited investments in breeding programs that are aimed at enhancing its yield [4,5].

Most farmers growing okra depend on inorganic fertilizers [6] and among all the various vegetables, okra responds well to the fertilizers and manures [7]. Although inorganic fertilizers play an important role in supplying soil with the various nutrients required by crops, the extent to which farmers can depend on this input is constrained by unavailability of the right type of inorganic fertilizers at the right time, high cost, lack of technical know-how and lack of access to credit [8,9,10]. Inorganic fertilizers are expensive and their use may not be economically justifiable especially for the poor smallholder farmers who mainly practice subsistence farming [11]. Use of inorganic fertilizers can improve crop yields and soil pH, total nutrient content, and nutrient availability, but its use is limited due to scarcity, high cost, nutrient imbalance and soil acidity [12]. Moreover, inorganic fertilizers are usually environmental hazard [8,13]. Thus, to reduce and eliminate the adverse effects of inorganic fertilizers on human health and environment, nowadays a new agricultural practice has been developed called as organic agriculture, sustainable agriculture or ecological agriculture [14].

Extensive use of agrochemicals in the agricultural fields is among the most prominent sources of ground water contamination [15]. It is suggested that the use of chemical fertilizer in okra production has long-term negative effects to the soil biological properties, soil fertility and crop yield and quality [6]. Under intensive agriculture, long term inorganic fertilizer usage is often associated with reduced crop yield, soil acidity and nutrient imbalance [3]. Organic agriculture which avoids or largely excludes the use agrochemicals offers a sustainable alternative farming system to minimize the challenges of chemical farming [15]. The use of organic amendments such as livestock manure is an alternative to these detrimental effects of inorganic fertilizers because of its wide-spread availability, its additional value for soil carbon sequestration, and its capacity for storing and releasing nutrients over a longer time period [11]. Livestock manure are a good alternative to inorganic fertilizers [9,10] because they are locally available renewable resources. Livestock manure are excellent source of organic matter and soil nutrients and the utilization of organic manure in soil fertility management is an integral part of sustainable Okra production [16].

Organic fertilizer besides supplying plant nutrients, also plays an important buffering role in enhancing the cation exchange capacity (CEC), improving soils aggregation, increasing water holding capacity of the soils, stabilizing its humid content, and preventing the leaching of nutrients [17,18]. The application of livestock manure to soils, unlike synthetic fertilizers, also provides organic matter that can enhance infiltration rates, improve water holding capacity, increase cation-exchange capacity [19], and increase soil C [20,21,22]. It also provides food for soil micro-organisms. This increases the activity of microbes which in turn helps to convert unavailable plant nutrient to available form. To maximize the economic value of organic manure, their application should match the nutrient needs of the crops. However, there is limited information on recommended application rates of organic manure in okra production.

Many researchers have tried to assess the importance of organic manures in crop production. Senjobi [23] reported that the use of poultry, sheep/goat manure improved all the evaluated growth variables of the leaf vegetable. Other studies have reported beneficial effects of organic manure on soil properties such as bulk density soil moisture content, water–holding capacity and others soil physical properties [24,25]. Organic matter is an important soil component that has profound influence on the physico-chemical and biological characteristics of soil, and most frequently considered as indicator of soil quality [26]. Other studies, for example, Khandaker [27] reported that some of the organic manure may give high yield and growth performance on okra. Loss of soil fertility is a major problem in crop production in Kenya, limiting okra productivity potential [6]. Okra production can be practiced on small scale farming as well as on large scale farming [4] and majority of farmers growing okra depend on inorganic fertilizers. During the production season, these inorganic fertilizers are in high demand and sellers tend to increase their prices to levels where most of the farmers cannot afford. Okra production should be promoted to diversify on type of crops being grown to enable improve the livelihoods of farming communities.

Organic manure directly improves the physical, biological and chemical conditions of the soil [28], soil organic C, total NPK status and increase the soil microbial growth [29]. In the study area livestock production is a key enterprise and their manures are locally available and where they are used they are environmentally friendly and can stay in the soil for a long period of time facilitating continuous supply of nutrients to crops. These livestock manures can be a potential nutrient source for Okra farmers who cannot afford inorganic fertilizers due to their high cost and in most cases they are unavailable when required, and they have a greater negative impact on soil and water and may pollute the environment. However, farmers have limited information regarding the best type and rate of organic manure application in okra production and they end up mixing all types of organic manures at their disposal at varied rates. This results to sub-optimal rates of application that contribute to poor crop growth and development and hence low okra yields and quality that results to unsustainable production and less economic benefit. There is need for more research on organic manure sources to be done and the information made available to farmers on their efficacy. This study therefore aimed at determining the effectiveness of cattle, goat and poultry manure at different application rates on growth, yield, quality and net economic benefit of okra.

2. MATERIALS AND METHODS

2.1 Study Site

The study was conducted in two cultivations between 2018 and 2019 at Kenya Agriculture and Livestock Research Organisation (KALRO), Kandara Centre in Murang'a County for two cultivations (Trial 1 and 2). The Centre lies within coordinates 0^0 59' South and 37^0 04' East and altitude of approximately 1548 m above sea level (IERRS Reference Meridian, 2017). It is situated approximately 5 Km North of Thika town and 43 Km from Nairobi (High Level) along the Nairobi-Murang'a Road. The average annual temperature is 19.8 °C and the precipitation ranges from 1200 to 1400 mm per annum. The site has well drained Humic Nitisols which are deep, well weathered with moderate high inherent fertility [30]. The rainfall pattern of the area is bimodal falling in two seasons, the long rains lasting from March through June and short rains from October through December, though short rains are more reliable. The region does well in agricultural activities which involves both growing of crops and rearing of domestic animals. The farmers in the area practices crop growing like sunflower cow peas, beans, maize, bananas, cassava, and vegetables. It is a potential okra production region in central Kenya. Livestock rearing include: cattle, goat, sheep and poultry.

2.2 Experimental Design

The experimental design used was Randomized Complete Block Design (RCBD) and was replicated three times. There were 10 treatments, i.e., 3, 5 and 7 tonnes ha^{-1} of poultry, 3, 6 and 7 tonnes ha^{-1} for goat and cattle manure and control treatment (no application of manure). All treatments were applied once during planting. The experiment was carried out in two consecutive cultivations. The blocks measured 35.65 by 1.80 m, while each experimental unit was of size 3.50 by 2.00 m, i.e., 7.00 m^2. Each block consisted of 4 rows at spacing of 50 cm within rows and 50 cm between rows, with each row consisting of 7 plants making a total of 28 plants per plot. The plants in area at the centre of the two inner rows constituted the experimental plot, while the plants in the outer area formed the guard rows.

2.3 Planting Materials, Planting and Crop Maintenance in the Field

Okra Pusa Sawani variety certified seeds was sourced from Simlaw Seeds. The okra seeds were planted at a spacing of 0.5 by 0.5 m giving plant population of 40,000 plants per hectare. Planting hills of about 10 cm deep were dug. Dry Cattle, goat and poultry manure that had naturally decomposed by action of soil organisms and microorganisms was applied in the planting hills according to the rates of application and thoroughly mixed with the soil as per treatment. Two seeds per hill were planted to a depth of 2.5 cm. Routine field management practices carried out after germination include; weeding, thinning, gapping, mulching, irrigation and pest and disease control. First weeding was done two weeks after crop emergence and involved cultivation and uprooting the weeds.

2.4 Data Collection

2.4.1 Soil and organic manure elements analysis

In order to investigate the physical and chemical properties of the soils of the study site, twenty soil samples were taken randomly from the entire experimental site in zigzag pattern before planting. After planting, ten soil samples were taken from each plot for poultry manure at the rate of 5 tonnes ha^{-1}, goat and cattle manure at the rate of 6 tonnes ha^{-1}. The soil samples were taken from 0-30 cm depth of the soil profile using a soil auger. The samples before planting were mixed together in order to get one composite sample weighing 1 Kg. Alike soil samples from specific treatments taken after planting were also mixed together to form a composite sample to determine the effect of source and rate of livestock on soil nutrients.

The composite soil samples were dried and crushed to pass through a 2 mm size sieve for the analysis of pH. For the determination of total nitrogen and organic carbon, the soil sample was passed through 1 mm pore size sieve. The soil was analysed for pH, organic carbon, total N and available P. Soil pH was measured from a suspension 1:2.5 soil-water ratio using an electrodes pH meter [31]. The organic carbon content of the soil was determined by the volumetric method [32]. Total nitrogen was estimated by the Micro-Kjeldahl method with sulphuric acid [33]. Available phosphorous was estimated by the Olsen method [34]. A sample of poultry, goat and cattle manure were tested at National Agricultural Laboratories at KALRO Kabete, to find out the total nitrogen, organic carbon, phosphorous, potassium, calcium, magnesium, copper, iron, zinc, and sodium.

2.4.2 Effects of source and rate of livestock manure on yield okra

The numbers of green pods per plant were counted at every picking day from ten randomly selected and tagged plants in each plot. The total numbers of pods obtained from the selected plants were divided to get the average number of pods per plant. Yield obtained at each harvest from the net plot area was summed up as marketable and unmarketable yield and converted to a hectare basis. This was used to calculate the net economic benefit. The sum of above ground parts of ten selected plants was weighed in grams. The number of plant in the net area of each plot was counted two weeks i.e. fourteen days after sowing and at the time of the last harvest.

2.4.3 Effects of source and rate of livestock manure on quality of okra fruit

2he total Soluble Solids (TSS) content of pods was evaluated using Atago 8469 hand-held refractometer (Atgo Co. LTD., Tokyo, Japan) and was expressed as percentage Brix (% Brix). The samples were collected from each treatment used. The samples then were cleaned and air dried, weighed about 1g for each treatment using electronic balance. The weighed samples were crushed in mortar and pestle and 1 ml of distilled water was added to the refractometer sensor. The readings showed in percentage and the data were recorded.

2.4.4 Effects of source and rate of livestock manure on net economic benefit of okra

Okra productivity was determined by use of total yield, plant height, number of leaves and number of pods per plant while net economic benefits was determined using the cost of manure, amount of manure applied, labour of application and the yield obtained. The productivity and economic analysis for the three animal manure applied in comparison to the control plots. According to Nweke [35], the use of inputs as soil amendments in the form of organic manure has been found useful in improving the productivity of the soil which in turn increase the yield of crops resulting to high profit.

2.5 Data Analysis

The data obtained were subjected to analysis of variance (ANOVA) using the SAS version 9.4 [36]. Significant means were separated using the Least Significant Difference (LSD) test at 5% probability levels.

3. RESULTS AND DISCUSSION

3.1 Soil and Manure Analysis before Planting

Analysis of soil samples indicated that most of the elements were adequate for crop growth (Table 1). Soil pH was slightly acidic, total organic carbon was moderate, nitrogen and phosphorus were deficient and magnesium was high. Chemical properties of the poultry manure used showed a moderate level of phosphorus, potassium, calcium, and carbon while magnesium was low (Table 2). The chemical composition of the organic manure used in this study showed that they contain nutrients that are useful to plant growth and development. The high organic carbon content of the animal manure is an indication of abundant organic matter which plays an important role as reservoir of soil nutrients, buffer the soil reaction, binding the soil particles to form good soil tilth and stimulating the activity of soil organisms [17]. According to Oghaiki [37] manure contains important plant nutrients such as N, phosphorus (P), potassium (K), and other secondary nutrients and trace elements.

Udoh [38] demonstrated an excellent use of animal dung and plant residues to improve soil fertility, fruit nutrient composition, root growth and fruit weight of okra plant. Animal manure provides food for soil micro-organisms. This increases the activity of microbes which in turn helps to convert unavailable plant nutrient to available form [23]. All these enhance and sustain the fertility of soil for good crop production. Since the manure analysis indicated that poultry manure had the highest levels in some of the nutrients elements, the study tried to test the effects of reducing the level of poultry manure with 1 tonne ha^{-1} to the growth, yield, quality and economic benefit of okra.

3.2 Yield of Okra per Hectare

The analysis of variance showed that the treatments had a significant effect on yield per plant over two cultivations. The yield of Okra ranged from 3.08 to 8.64 MT/ha in trial 1 and 3.04 to 8.54 MT/ha in the repeated trial (Table 3). Incorporation of livestock manure increased okra yield per plant. There was a significant effect for all treatments in both Trials. Application of poultry manure at the rate of 5 tonnes ha^{-1} gave the highest yield in both trials with a significant increase in yield by 5.56 and 5.50 MT/ha in trial1 and 2, respectively in comparison to control treatment. Compared to control, incorporation of cattle manure at the rate of 6 tonnes ha^{-1} significantly increased yield per plant by 5.36 and 5.35 MT/ha in both Trials, respectively. Similarly, the yield per plant significantly increased by 4.87 and 4.81 MT/ha in Trial 1 and 2, respectively at incorporation of goat manure at the rate of 6 tonnes ha^{-1} in relation to the control treatment (Table 3).

When cattle manure was applied at the rate of 7 tonnes ha^{-1}, it significantly increased yield by 3.08 and 2.76 MT/ha in Trial 1 and 2, respectively compared to the control treatment. Likewise, compared to control, goat manure

Table 1. Chemical properties of soils sampled at the study site before planting (0 - 30 cm depth)

Fertility results	Value	Remarks
Soil pH	6.15	Slight acidic
Total Nitrogen (%)	0.15	Low
Total organic carbon (%)	1.61	Moderate
Phosphorus (ppm)	25	Low
Potassium (% mill equivalent)	1.04	Adequate
Calcium (% mill equivalent)	7.3	Adequate
Magnesium (% mill equivalent)	3.60	High
Manganese (% mill equivalent)	1.13	Adequate
Copper (ppm)	1.65	Adequate
Iron (ppm)	36.7	Adequate
Zinc (ppm)	51.5	Adequate
Sodium (% mill equivalent)	0.18	Adequate

Table 2. Nutrient composition of organic manure used in the study

Manure Source	N %	P (ppm)	K (Me)	Organic C (%)	Mg (Me)	Ca (Me)
Poultry	3.16	1.85	0.72	27.35	1.08	1.35
Goat	2.72	1.02	0.56	21.07	0.49	0.95
Cattle	2.65	0.89	0.43	37.93	0.56	0.84

N = Nitrogen; P = Phosphorus; K = Potassium; C = Carbon; Ca = Calcium; Mg = Magnesium; Me = mill equivalents

Table 3. Yield of okra in metric tonnes per hectare

Treatments		Yield (MT/ha)	
Manure Source	**Manure Rate (tonnes/ha)**	**Trial 1**	**Trial 2**
Control	0	3.08j	3.04j
Poultry	3	5.14g	5.10g
	5	8.64a*	8.54a
	7	5.74f	5.56f
Goat	3	4.56i	4.29i
	6	7.95c	7.85c
	7	5.89e	5.64e
Cattle	3	4.95h	4.60h
	6	8.44b	8.39b
	7	6.16d	5.80d
	CV	1.97	1.97
	LSD	0.0083	0.0051

**Means with the same letter along the column are not significantly different. CV=Coefficient of Variation; LSD=Least Significant Difference.*

at the rate of 7 tonnes ha^{-1} increased yield by 2.81 and 2.60 MT/ha in both Trials, respectively. Significant increase in yield by 2.66 and 2.52, 2.06, 1.87 and 1.56 and 1.42 and 1.25 MT/ha in trial 1 and 2, respectively was recorded upon application of poultry manure at the rate of 7 and 3 tonnes ha^{-1}, cattle manure at the rate of 3 tonnes ha^{-1} and goat manure at the rate of 3 tonnes ha^{-1} compared to control treatment (Table 3).

The okra pod production was significantly higher for all sources and rates of application of animal manures compared to control treatment. These findings are in agreement with those of Abbas [39] who reported that application of organic fertilizers like poultry manure and compost as well as its mixture with full NPK considerably increase the growth and total yield attributes of Okra. In this study poultry manure significantly increased the okra yields. Vikas [40] reported that poultry manure is easily solubilized hence having impact on improved nutrient availability, infiltration rate and water holding capacity of the soil. The results of this study suggest that livestock manure has great potential for okra productivity. The superiority of poultry manure among these three sources could be attributed to more nutrients levels in most elements especially nitrogen. This confirms the findings of Katung [41] and Akanbi [42] who indicated that application of N has been reported to significantly increase growth and fruit yield of okra. Significantly higher flower and fruit production in okra due to high levels of nitrogen has also been reported by Sharma [43] and Akanbi [42]. Sha [44] reported that nitrogen occupies a conspicuous place in plant metabolic system. All vital processes in plants are associated with protein, of which nitrogen is an essential constituent. Consequently, to get more crop production, nitrogen is indispensable and unavoidable.

However, poultry manure at the rate of 5 tonnes ha^{-1} and cattle and goat manure at the rate of 6 tonnes ha^{-1} was more productive in their respective sources of manure. This is an indication that these may be the optimal rates in okra production. Results of this study at sub-optimal rates confirms this. Okra growing on poultry manure performed best in terms of plant height, number of leaves, number of branches as well as pod number. This shows that poultry manure was readily available and in the best form for easy absorption by the plant roots, hence there is a boost in the morphological growth of the plant thus most productive. The fact cattle manure was more productive than goat manure would be because cattle manure had the highest organic carbon hindering leaching of nutrients hence the nutrients are utilized in plant morphological growth resulting to increased production. This is in line with the findings of Asgharipour [17] who recorded that the high organic carbon content of the animal manure is an indication of abundant organic matter which plays an important role as reservoir of soil nutrients, promoting plant growth. This could also be that nutrients in cattle manure are more readily available, easily absorbed and utilized by okra plants.

Although application of 3 tonnes ha^{-1} and 7 tonnes ha^{-1} did better than the untreated control, poor results were observed in terms of crop productivity. The findings of the study suggest that these may be sub-optimal rates. Deviation from the optimum rate results in negative effects to both plant growth and production. The findings are in agreement with Zhang [45] who indicated that too much application of livestock manure leads to accumulation of nutrients in the soil especially P which builds up in the soil causing negative effects on plant growth and productivity.

3.3 Effects of Source and Rate of Livestock Manure on Okra Fruit Quality

The analysis of variance showed that the treatments had a significant effect on quality per plant. Total soluble solids (TSS) ranged from 2.31 to 3.18 °Brix) in trial 1 and 2.34 to 3.21 (°Brix) in trial 2. Plots applied with goat manure at the rate of 6 tonnes ha^{-1} gave the highest total soluble solids on both trials. Incorporation of cattle manure at the rate of 6 tonnes ha^{-1} increased TSS by 0.73 and 0.76 °Brix) in trial 1 and 2, respectively compared to control treatment. Control treatment produced pods of the least TSS (Table 4).

Organic manure generally improves the soil physical, chemical and biological properties along with conserving the moisture holding capacity of soil and thus resulting in enhanced crop productivity and also maintaining the quality of crop produce [46;47]. This agrees with the findings of Maaz [48] who recorded that growing of crops through organic manure contained non-toxic chemicals, produce have good taste and maintained better health. According to Schoenau [19], Bogaard [49], and Oghaiki [37] manure contains important plant nutrients such as N, phosphorus (P), potassium (K), and other secondary nutrients and trace elements, with farmers all over the world having discovered its benefits and associated it with increased crop production as well as improving the crop quality. The lowest level of TSS was found in absolute control devoid of the livestock manure. It was observed that TSS could highly be increased with the application of livestock manure along with recommended rates of these livestock manure. Goat and cattle manure at the rate of 6 tonnes ha^{-1} produced significantly high total soluble solids, which was statistically significant ($p < 0.05$). This is an indication that nutrient elements in the two types of animal manure improve the quality of okra fruits. The findings of this study suggest that the gradual release of nutrients in goat and cattle manure as opposed to poultry manure may be of great contribution to the high total soluble solids and hence the best quality.

Low total soluble solids recorded by the three sources of manure at the rate of 3 tonnes ha^{-1} could be as a result of very low nutrients available at that rate. The low amount of nutrients absorbed most of them were used in growth stage such that during the production stage most of the nutrients were deficient leading to the production of pods of low quality. Consequently, the low levels of total soluble solids recorded by the three livestock manure sources 3 tonnes ha^{-1} could be due to release of too much nutrients which may have led to interference with absorption and physiological processes of the plant therefore lowering the quality of the Okra fruits produced.

3.4 Effects of Source and Rate of Livestock Manure on Economic Benefit of Okra

The analysis of variance showed that the treatments had a significant effect on gross income per plant. Gross income per trial for different treatment were computed (Table 5). The income ranged from Ksh. 369,060 to Ksh. 1,037,224 in trial 1 and Ksh. 364,320 to Ksh. 1,025,280 in trial 2. Incorporation of livestock manure significantly increased gross income. Poultry manure at the rate of 5 tonnes ha^{-1} gave the highest gross income in both trials resulting to significant increase by Ksh. 668,164 and Ksh. 660,960, respectively compared to control treatment. Similarly, application of cattle manure at the rate of 6 tonnes ha^{-1} significantly increased gross income by Ksh. 643,207 and Ksh. 642,000 in both Trials, respectively compared to control. Control experiment recorded the least gross income.

Total cost in the production of okra ranged from Ksh. 300,000 to Ksh. 340,000 (Table 6). Incorporation of poultry manure at the three rates tested significantly increased total cost compared to other treatments. Application of poultry manure at the rate of 7 tonnes ha^{-1} recorded the highest total cost. However, total cost for application of cattle and goat manure at the same rates (7 tonnes ha^{-1}, 5 tonnes ha^{-1} and 3 tonnes ha^{-1}) did not differ. The least cost of production was observed in plots without application of any manure (control plots). The analysis of variance showed that the treatments had a significant effect on net profit. The net economic benefit was arrived at by deducting total cost of production from gross income for each treatment. Net profit ranged from Ksh. 69,158 to Ksh. 700,267 in trial1 and Ksh. 64,320 to Ksh. 694,320 in the repeated trial. Cattle manure at the rate of 6 tonnes ha^{-1} gave the highest net profit. Control treatments recorded the least net profit in both trials (Table 7).

Table 4. Total soluble solids of okra fruit under different treatments

Treatments		Total soluble solids (°Brix)	
Manure source	**Manure rate (tonnes/ha)**	**Trial 1**	**Trial 2**
Control	0	2.31g	2.34e
Poultry	3	2.36g	2.41e
	5	2.72c*	3.02b
	7	2.51f	2.53d
Goat	3	2.58de	2.60cd
	6	3.18a	3.21a
	7	2.62d	2.69c
Cattle	3	2.52ef	2.54d
	6	3.04b	3.10b
	7	2.60d	2.67c
		2.27	2.27
		0.0653	0.1006

**Means with the same letter along the column are not significantly different. CV=Coefficient of Variation; LSD=Least Significant Difference.*

Table 5. Okra productivity in Ksh/ha under different treatments in two trials

Treatments		Gross income (Ksh./ha)	
Manure source	**Manure rate (tonnes/ha)**	**Trial 1**	**Trial 2**
Control	0	369060j	364320j
Poultry	3	617120g	611520g
	5	1037224a*	1025280a
	7	888960f	666840f
Goat	3	569543i	515280i
	6	953920c	941760c
	7	703227e	676720e
Cattle	3	594443h	551920h
	6	1012267b	1006320b
	7	738907d	696080d
	CV	1.97	1.97
	LSD	7788.50	742.64

**Means with the same letter along the column are not significantly different. CV=Coefficient of Variation; LSD=Least Significant Difference.*

Table 6. Total cost of production

Manure Source	Manure Rate (tonne/ha)	Cost/tonne (KSh)	Amount	Other costs	Total expenses/ha
Control	0	0	0	300,000	306,000
Poultry	3	6,000	18,000	300,000	326,000
	5	6,000	30,000	310,000	340,000
	7	6,000	42,000	312,000	354,000
Goat	3	2,000	6,000	300,000	306,000
	6	2,000	12,000	308,000	312,000
	7	2,000	14,000	300,000	314,000
Cattle	3	2,000	6,000	300,000	306,000
	6	2,000	12,000	300,000	312,000
	7	2,000	14,000	300,000	314,000

Table 7. Net profit of Okra production under different treatment in two trials

Treatments		Net profit	
Manure source	**Manure rate (tonne/ha)**	**Trial 1**	**Trial 2**
Control	0	69158h	64320j
Poultry	3	291120f	285520g
	5	696724a*	685280b
	7	334960e	312840f
Goat manure	3	263543g	209280i
	6	641920b	629760c
	7	389227d	362720e
Cattle manure	3	288443f	245920h
	6	700267a	694320a
	7	424907c	382080d
	CV	1.97	1.97
	LSD	7841.40	742.64

**Means with the same letter along the column are not significantly different. CV=Coefficient of Variation; LSD=Least Significant Difference*

Different sources and rates of animal manure application gave significantly higher net profit compared to control treatments. This is despite low cost of production accruing form control treatment, in terms of labour and input costs. This could be explained by the fact that control treatment recorded the least number of leaves, branches, pods and the shortest plant height per plant resulted to the lowest production. When a few okra pods produced were converted into monetary form actually the net profit was not only the lowest but was also very minimal. This study suggest that the resultant net profit may be not worthwhile bearing in mind that the crop took three months to attain the little profit. Although poultry manure differed significantly with other livestock manure sources applied and the control treatment in terms of number of leaves and branches, plant height and okra yield, it had poor it had poor net economic benefit. This could be attributed to the high cost of poultry manure to other animal manure tested despite the selling price of okra pods being the same. This resulted to reduction in net profit. The low net profit could also be as a result of plots where poultry manure was applied being much acidic after the harvest. This means that for most of crop plants to do better in such fields liming should be done. Again this increases the cost of production and hence reducing the net profit.

Net economic benefit from plots treated with cattle and goat manure at the rate of 6 tonnes ha^{-1} gave highest returns. This finding suggest that this could be due to relatively low manure prices which led to great reduction in costs which in turn resulted to high returns. This could also be due to soil pH being at the suitable range for most of other crops therefore foregoing the cost which could be incurred in poultry manure and hence maximising on the profit. Nevertheless, poultry manure at this rate of application recorded the highest net economic benefit. The findings suggest that the reason for poultry manure gave more profit than goat manure at the same rate could only be due higher productivity since all the other cost incurred by the two types of manure were constant. The findings of this experiment suggest that cattle manure has the best returns than the goat manure. Low productivity recorded by 7 tonnes ha^{-1} could be as a result of highest cost of manure despite the fact that yield was low resulting to low net profit. Similar low net profit was observed on manure at 3 tonnes ha^{-1}. This study suggests that even though manure cost at this rate was relatively low, yield was also very low and hence there could be no break even. However, higher net benefit was observed irrespective of the organic manure source. The findings of this study agree with Akter [50] who reported that organic manure appeared to be more remunerative in augmenting the yield and economic return in Okra production [51].

4. CONCLUSION

Findings showed that application of livestock manure can enhance Okra yield, quality, and net benefit. There was significant effect of incorporation of poultry, goat and cattle manure on yield and the general productivity of okra. Optimum rates remained at 5 tonnes ha^{-1} poultry manure and 6 tonnes ha^{-1} goat and cattle manure. Poultry manure at the rate of 5 tonnes ha^{-1} was most productive. Application of poultry, goat and cattle manure had significant response on quality of okra pods. Pods with highest Total Soluble Solids were produced by goat manure at the rate of 6 tonnes ha^{-1}. There was significant response of incorporation of poultry, goat and Cattle manure on Net Economic Benefit in Okra enterprise. At optimum rates, cattle manure at the rate of 6 tonnes ha^{-1} recorded highest Net Economic Benefit. The study recommends incorporation of poultry manure at the rate of 5 tonnes ha^{-1}, goat and cattle manure at the rate of 6 tonnes ha^{-1} to enhance the yield of Okra. Goat manure should be applied at the rate of 6 tonnes ha^{-1} to enhance production of high quality and cattle manure at the rate of 6 tonnes ha^{-1} for maximum net economic benefit in Okra.

DISCLAIMER

This paper is an extended version of a Thesis document of the same author.

The Thesis document is available in this link: http://repository.chuka.ac.ke/handle/chuka/7860

ACKNOWELEDGEMENTS

The authors are grateful to Centre Director Kenya Agricultural and Livestock Research Organization, Kandara Centre for allocating land which enabled to set up the experimental plots for purpose of data collection.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Kota AKR, Kerketta A, Topno SE, Bahadur V, Tripathi P. Effect of organic fertilizers on growth yield and quality of Okra (*Abelmoschus esculentus* L.) Kashi Lalima. 2022.

2. Olaniyi JO, Akanbi WB, Olaniran OA, Ilupeju OT. Effect of organic, inorganic and organo-minerals on growth, fruit yield and nutritional composition of okra (*Abelmoscus esculentus*). Journal of Animal and Plant Sciences. 2010;9(1): 1135-1140.
3. Abd El-Kader AA, Shaaban SM. Abd El-Fattah MS. Effect of irrigation levels and organic compost on okra plants (*Abelmoschus esculentus* L.) Grown in Sandy Calcareous Soil. Agric. Bio. J. N. Am. 2010;1(3):225–231.
4. FAO. The State of Food Security and Nutrition in the World 2017. Building Resilience for Peace and Food Security. Rome: FAO; 2017.
5. Sreeparna C, Sanjeev K. Okra Breeding: Recent Approaches and Constraints. Department of Genetics and Plant Breeding, School of Agriculture, Lovely Professional University, Phagwara-144 411 (Punjab), India; 2019.
6. Mohammad MK, Fadhilah NM, Tahir D, Mohammad HS, Nashriya, M. 2017.Effect of Different Rates of Inorganic Fertilizer on Physiology, Growth and Yield of Okra (*Abelmoschus esculentus*) cultivated on BRIS Soil of Terengganu, Malaysia. Australian Journal of Crop Science AJCS. 2017;11(07):880-887.
7. Yadav R, Harendra Deb P, Kishor S, Maurya D. Studies the effect of organic, inorganic and bio-fertilizers on the growth and yield of okra cv. Arka Anamika. Biological Forum – An International Journal .2023;15(2):207-212.
8. Weltzein, HC. The Use of Composted Materials for Leaf Disease Suppression in Field Crops; 1990.
9. Ojeniyi, SO. Effect of goat manure on soil nutrients and okra yield in a rainforest area of Nigeria. Appl. Tropical Agri. Onweremadu, E.U; 2000;5:20-23.
10. Amhakhin SO, Isaac IB. Effects of Organic Manure on the Growth Parameters and Yield of Okra in Anyigba, Kogi State, North Central, Nigeria. Journal of Agricultural Science and Egineering. 2016;2(4):24-30.
11. Joseph J, Keneth C, Allan JK, Jacob I. Comparative performance of organic fertilizers in maize (*Zea mays* L.) Growth, yield, and economic results. Department of Agricultural and Biosystems Engineering, College of Agricultural and Environmental Sciences, Makerere University, Kampala P.O. Box 7062, Uganda; 2020.
12. Akande MO, Oluwatoyinbo FI, Makinde EA, Adepoju AS. Adepoj IS. Response of okra to organic and inorganic fertilization. Nature and Science. 2010;8(11):261-266. (ISSN: 1545-0740).
13. Jaja ET, Ibeawuch II Effects of organic and inorganic manure mixture rates on soil productivity of okra. International Journal of Agriculture and Rural Development; 2015.
14. Chandini Randeep K, Ravendra K, Om P. The Impact of Chemical Fertilizers on our Environment and Ecosystem. In book: Research Trends in Environmental Sciences, Edition: 2nd, Chapter: 5. 2019;69-86.
15. Varun D. Organic farming for sustainable environment: Review of existed policies and suggestions for improvement. International Journal of Research and Review. Research Degree Scholar, School of Earth & Environmental Sciences, Waste Management Laboratory, Central University of Himachal Pradesh, Dharamshala, India; 2020.
16. Ntia JD. Shiyam JO. Offiong ED. Effects of organic manure on soil nutrient and okra yield. Asian Journal of Soil Science and Plant Nutrition; 2017.
17. Asgharipour MR. Effects of vermicompost produced from municipal solid waste on the growth and yield of bobgol (*Plantago ovate* forsk) and *Cuminum cyminum*. Journal of Medicinal Plant Research. 2012; 6(9):612–1618
18. Dudal R. Deckers J. Soil organic matter in relation to soil productivity; 1993.
19. Schoenau JJ. Benefits of Long-term Application of Manure. Adv. Pork Prod. 2006;17,153.
20. Kim SK, Tiessen K, Beeche A, Mukankurunziza J. Kamatari A. Cattle manure management in rwanda—a case of girinka cow beneficiaries in the district of Ngoma. Rwanda J. 2011;24:39–48.
21. Gattinger A, Muller A, Haeni M, Skinner C, Fliessbach A. Buchmann N. Enhanced top soil carbon stocks under organic farming. proc. Natl. Acad. Sci. U.S.A. 2012;109: 18226–18231.
DOI: 10.1073/pnas.1209429109
22. Maillard E, Angers D, Animal Manure Application and Soil Organic Carbon Stocks: A meta-analysis. Glob. Chang. Biol. 2014;20;666–679.
DOI: 10.1111/gcb.12438
23. Senjobi BA, Peluola AC, Senjobi CT, Lawal IO, Salam BT. Performance of

Cochorusolitoriusas Influenced by Soil Type and Organic Manure Amendments in Yewa North Local Government Area, Ogun State. African Journal of Biotechnology. 2010;9(33):5309-531.
24. Fawole OB, Ajayi TJ, Aduloju MO. Olaniyan JO. 2010. The use of *Parkia* husk and melon wastes as soil amendment. Journal of Agric. Research and Development, University of Ilorin. In Press.
25. Adeleye EO, Ayeni LS. Ojeniji SO. Effect of poultry manure on soil physico-chemical properties, leaf nutrient contents and yield of yam (*Dioscorea rotundata*) on Alfisol in Southwestern Nigeria. Journal of American Science. 2010;6(10):871-878.
26. Maria H, Abdalla AS. Potentiality of Organic Manures in Supporting Sustainable Agriculture in Sudan. Environment and International Journal (ENRIJ); 2018.
27. Khandaker MM, Jusoh N, Al NH, Ralm A, Ismail SZ. The effect of different types of organic fertilizers on growth and yield of *Abelmoschus esculentus* L. Moench (okra). Bulg. J. Agric. Sci. 2017;23(1): 119–125.
28. Singh SK. Productivity of Indian gooseberry trees as function of vermicompost and mustard cake application. 6th International Conference on Advancements in Engineering & Technology (ICAET-2018) Sangrur. 2018;484-492.
29. Singh SK, Singh SK. Singh S. Vegetable crops as most efficient and economical intercrops: A brief review. Plant Archives. 2018;18(1):923-929.
30. Jaetzold R. Schimidt H. Farm management handbook of kenya. Vol. II natural conditions and farm management information part b central Kenya. Ministry of Agriculture. Nairobi, Kenya. 1983;389-413.
31. Motsara MR. Roy RN. Guide to laboratory establishment for plant nutrient analysis. FAO Fertilizer and Plant Nutrition Bulletin. 2008;19:17-219.
32. Walkley AJ, Black IA. Estimation of soil organic carbon by the chronic acid titration method. Soil Science. 1934;37:29-38.
33. Jackson ML. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi. 1962;498.
34. Olsen SR, Sommer LE. Phosphorus. In: Page AL, Ed., Methods of soil analysis Part 2 Chemical and Microbiological Properties. American Society of Agronomy, Soil Science Society of America, Madison. 1982;403-430.
35. Nweke IA, Ijearu SI. Igili DN. Effect of different sources of animal manure on the growth and yield of okra (*Abelmoschus Esculentus* L. Moench) In Ustoxic Dystropept at Enugu South Eastern, Nigeria; 2017.
36. SAS Institute. SAS/OR 9.3 User's Guide: Mathematical Programming Examples. SAS institute; 2012.
37. Oghaiki AN, David EP, Jesse OO, Fridtjof DB, Theun V. Manure management practices and policies in Sub-Saharan Africa: Implications on Manure Quality as a Fertilizer; 2019.
38. Udoh DJ, Ndon BA. Asuquo PE Ndaeyo NU. Crop production Techniques for the Tropics, Concept Publication Lagos, Nigeria. 2005;446.
39. Abbas Z, Mubashir M, Riaz U, Javid Z, Ashraf M, Qamar MJ, Mehdi SM. Combined impacts of compost, poultry manure and NPK fertilizers on yield of okra plant (*Abelmoschus esculentus* L.). Pakistan Journal of Agricultural Research. 2019;32(3).
40. Vikas V, Sharma JP, Dhotra B, Sharma A, Verma D. Application of organic manures and their influence on okra growth parameters. Journal of Pharmacognosy and Phytochemistry. 2020;9(1):999-1005.
41. Katung MD, Olanrewaju JD, Gupta US. Kureh I. Fruit and seed yields of okra as influenced by farm yard manure and nitrogen fertilizer. In: Proc. 14th HORTSON Conf; Ago-Iwoye; 1996.
42. Akanbi W, Togn AO, Adediran JA. Ilupeju EAO. Growth, dry matter and fruit yields components of okra under organic and inorganic sources of nutrients. Department of Agronomy, Ladoke Akintola University of Technology, Ogbomoso, Nigeria; 2010.
43. Sharma AR. Mittra BN. Effect of different rates of application of organic and nitrogen fertilizers in a rice-based cropping system. Journal of Agricultural Science (Cambridge). 1991;117:313-318.
44. Sha JL, Niaz AW, Abdul H, Ghulam M. and Khalid HT. Role of Nitrogen for Plant Growth and Development; 2016.
45. Zhang H, Schroder JL., Fuhrman JK., Basta NT, Storm DE, Payton ME. Path analysis and multiple regression of phosphorus sorption capacity. Soil SciSoc Am J. 2005;69:96–106.

46. Eghball B, Ginting D, Charles AS, James SS. Christopher JB. Manure as carbon source for soil improvement and crop production site specific application. Proceeding Great Plant Soil Fertility Conference. 2002;22-28.
47. Tensingh NB, Lega SP, Priya C. Effect of organic fertilizers on the growth and biochemical characteristics of okra (*Abelmoschus esculentus* (L.) Moench) International Journal of Science and Research (IJSR). 2017
48. Maaz K, Fazal U, Bibi Z, Muhammad NK, Amir Z, Kabir A. Inayat URA. Effects of poultry manure levels on growth and yield of cucumber cultivars. Department of Horticulture, Faculty of Crop Production Sciences, the University of Agriculture, Peshawar, Pakistan; 2018.
49. Bogaard A, Frasera R, Heatonb THE, Wallacec M., Vaiglovaa P, Charlesa M. crop manuring and intensive land management by Europe's first farmers. Proc. Natl. Acad. Sci. U.S.A. 2013;110: 12589–12594.
Doi: 10.1073/pnas.1305918110
Briggs DJ, Courtney FM. Agriculture and Environment. New York: Longman. 1989; 1:26-37.
50. Akter M, Shil NC, Ahmad S. Effects of tillage and nutrient management on yield of okra (*Abelmoschus esculentus* (L.) Moench). Thai Journal of Agricultural Science. 2020;53(2):97-108.
51. Adhikari A. Piya A. Effect of different sources of nutrient on growth and yield of okra (*Abelmoschus esculentus* L. Monech) Nepal Polytechnic Institute, Bharatpur 44200, Nepal. International Journal of Environmental & Agriculture Research (IJOEAR); 2020.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/99880