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Effect of organic and inorganic sources of fertilizer on growth, yield and fruit quality of eggplant *(Solanum Melongena* L)

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ABSTRACT

Declining soil fertility resulting from continuous cultivation of small holder farms and escalating cost of imported fertilizers and the need to conserve and build natural resource capital and biodiversity, has led to renewed interest in the use of local nutrient resources for soil fertility management in Kenya. The study was conducted at Bukura Agricultural college farm during the short (SRS) and long rain seasons (LRS) of the year 2009 and 2010 respectively. The LRS occurs between March and July and SRS from September/October to December with peaks in April and November, respectively. The experiment aimed at evaluating the effect of combination between two levels of the recommended mineral fertilizers(50% and 100% of research recommended rates) with three types of organic manures on growth, fruit yield and quality of egg plant (Solanum melongena L) var. black beauty. The experimental design was split plot design with three replications, where two levels of mineral fertilizers treatments (50% and 100%) were randomized in main plots while three types of organic manures(FYM, Compost and Tithonia) and control treatments were randomized in the subplots. Topsoil (0-20cm depth) were sampled before transplanting seedlings and analyzed for soil physical properties, PH, N, P, K, OC and CEC. Also the organic manures were also analyzed for their chemical properties i.e. PH, N, P, K, OC and CEC. Results showed significant differences in eggplant growth, fruit yield and quality (p<0.05) between the two main treatments (50%RRR and 100%RRR), the three organic manures and their control. Similarly, there was significant difference between and the interactions between the two inorganic fertilizer levels and the organic manures. Increasing NPK from 50% to 100% of the research recommended rates encouraged the vegetative growth of eggplants as expressed as plant height and fresh weight besides increasing the total yield it enhanced the fruit quality. The plants in the organic manure treated plots were characterized with vigorous vegetative growth, which in turn led to increase in total fruit yields as well as improving fruit quality. The farm yard manure was considered the superior source of manure to obtaining the highest value of the parameters under study as compared to compost and Tithonia diversifolia (tithonia). Soil fertilized with 100% recommended NPK combined with organic manures produced the superior growth of plants and the highest amount of total fruit yields. The promising combination was 100% of recommended NPK combined with farm yard manure produced the best response.

Keywords: inorganic fertilizers, organic manures, eggplant growth, yield and quality.

INTRODUCTION

Egg plant (*Solanum melongena* L) is one of the important Asian Vegetables grown in Kenya for export market. As might be expected with crop of such promising potentials, effort to improve its productivity should be emphasized. Among improvement possibilities, the nutritional requirements play a major role. Nitrogen, Phosphorus and Potassium are major essential elements required for physiological mechanisms of plant growth [1]. Nitrogen and phosphorus are usually the most limiting nutrients in many soils in Africa and are often simultaneously deficient (Warren, 1992). Most soils in Sub-Sahara African are used for subsistence farming and are of low and declining fertility [2]. Continuous cropping with low or no fertilizer inputs, nutrient losses through harvest, soil erosion and leaching has led to decline in soil fertility [3, 4].
In the East African region, P deficiency is of common occurrence in the highly populated highlands [2]. Estimates of P limitations in western Kenya range from 80-90% of the farms [5] which often result in low crop yields. To a large extent, this is due to no or little phosphorus inputs. It is necessary to add fertilizer inputs to these soils in order to have good continuous crop yields. Such inputs may be either organic or inorganic in form depending on their availability. Recently, there has been increasing interest in the use of plant residue in agricultural systems in the tropics where low fertilizer inputs are in use [6].

Organic inputs alone will not meet the nutritional needs of crops because they contain a comparatively less quantity of nutrients compared to inorganic fertilizers, the need to integrate the two forms in order to achieve better crop yields. The interaction between organic matter and inorganic fertilizers may lead to either an increase or decrease in nutrients in soil depending on the nutrient and plant material in question [7].

Low use efficiencies of inorganic fertilizers coupled with their rising costs and the need for organically produced foods has directed the attention of farmers towards organic sources. Organic manures may increase soil fertility and thus the crop production potential possibly by changes in soils physical and chemical properties including nutrient bioavailability, soil structure, water holding capacity, cation exchange capacity, soil pH, microbial community & activity etc. [8, 9, 10, 11, & 12]. Soil pH is greatly influenced by addition of organic matter (OM) through different organic amendments and change in pH varies with the nature of OM [9].
Some organic materials can increase crop yields due to improved soil through nutrient release during decomposition and mineralization. They may also improve soil physical properties such as moisture retention, bulk density and aeration [7]. In addition, they generally have greater residual effect on subsequent crops than inorganic nutrient sources due to slow release of their nutrients over time [13]. They can also result in complexion of aluminum and iron with organic compounds from decomposition resulting in greater availability of phosphorus and reduction of aluminum toxicity.

Organic fertilization is also important for providing plant with their nutritional requirements without having an undesirable impact on the environment [14]. Addition of different sources of organic manures increases the plant growth characteristics namely plant height, number of leaves and shoots per plant, fresh and dry weight of shoots of plants [15,16,17]

It has been shown that increase in tomato yield produced by organic-mineral compounds was greater than those produced by mineral fertilizer applied at the same rate [18]. Organic amendments especially when applied in high rates can increase the availability and use efficiency of phosphorus by plants [20].This has been observed to be so for farm yard manure [20]. It has also been demonstrated for green leaf biomass of *Tithonia diversifolia* [21, 22].

Organic materials besides enhancing P availability and even supplying some P, their major benefits are likely to be the provision of other nutrients, especially N. This is because of their high tissue concentration of N compared to other nutrients [23].

MATERIALS AND METHODS

Site description

The experiment was conducted at Bukura Agricultural College in western Kenya (o^o7'N, 34^o30'E) at an altitude of 1,400m with average rainfall of 1,800mm. The rainfall is distributed over two main cropping seasons, the long rainy season, from March to July and the short rainy season from September to December. The soil was an orthic ferralsol with the following properties: pH(H_2O)=5.4; CEC=21.9 cmolkg^{-1},total N(%)= 0.41, P(ppm)= 17, K(cmolkg^{-1})=0.1 and OC(%)=2.12.

Experimental layout and management

The experiment was established in September 2009 and laid out as split plot design with three replications, where two levels of mineral fertilizers treatments (50% and 100%) was randomized in main plots three types of organic manures(FYM, Compost and Tithonia) and control treatments were randomized in the subplots. The seedlings were raised in a seedbed of 1m wide and convenient length. DAP (18%N, 46%P_2O_5) at recommended rate was uniformly applied to the seed bed and lightly mixed with the soil using a rake; seeds were sown in furrows 30cm apart and thinly covered with top soil. The seedlings were ready for transplanting 42 days after sowing i.e. when they were 8-10cm in height.

Farm yard manure and tithonia were applied to the marked plots two weeks before transplanting of the seedlings by evenly spreading them within the appropriate experimental plots and incorporated to a depth of 15cm. During transplanting DAP and compost was applied and CAN applied three weeks later. The normal routine field management practices such as weeding, pest and disease control were carried out as recommended by ministry of agriculture in Kenya.

The main treatments consisted of two levels of inorganic fertilizer derived from the application DAP (18:46:0) and CAN (27%N) applied during transplanting and top dressing respectively. The research recommended rates (RRR) are 220 kg ha^{-1} (10gm/hole) of DAP and 600 kg ha^{-1} (100gm/plant) of CAN applied in three splits. This translates to 640 kg N ha^{-1} and 102 kg P ha^{-1}. Three types of organic manures and control (without addition of organic manures) are sub-treatments. The inorganic fertilizer treatments were applied as follows; 50%RRR (320 Kg N ha^{-1},51 Kg P ha^{-1}) and 100%RRR (640 Kg N ha^{-1}, 102 Kg P ha^{-1}).

The Organic fertilizer types and their control comprised the sub- treatments; Control (Without addition of organic manures), Tithonia (Ti) , Compost Manure (CM),and Farmyard manure (FYM).

Table (1): Treatment combinations of the inorganic fertilizer and organic manures

Treatment	Treatment combination
T1	50%RRR(Control)
T2	50%RRR + Tithonia
T3	50%RRR + Compost
T4	50%RRR + FYM
T5	100%RRR(Control)
T6	100%RRR + Tithonia
T7	100%RRR + Compost
T8	100%RRR + FYM

FYM=farmyard manure, RRR=Research recommended rates, 50%RRR (320Kg N ha^{-1}, 51Kg P ha^{-}1), 100%RRR (640 Kg N ha^{-1}, 102 Kg P ha^{-1})

Analysis of organic materials and soils

Tithonia was obtained from the hedges bordering the experimental site while the FYM was from Bukura Agricultural College farm. Compost was made at the college farm using crop residues mainly maize stovers. The organic materials were dried and ground to pass through a 0.5 mm sieve. The quality parameters of the OMs i.e. total N, P, K, pH and OC were determined. In both seasons, soil samples (0-0.15 m depth) were collected after site preparation. The soils were air-dried and prepared for chemical analysis using standard procedures.

The soil pH was determined using 1:2.5 soil:water ratioand the available P was determined by olsen method[24] as described by Okhalebo et al[25]. The total nitrogen was determined by kjeldahl oxidation method and total organic carbon by wet combustion oxidation method. Exchangeable bases were determined by extraction of the soil samples with excess 1 M NH_4OAc solution.

Data analysis

Analysis of variance (ANOVA) was done to determine the treatment differences in, growth, yield and fruit quality parameters using Genstat statistical package (3rd edition)[26]. The Duncan Multiple Range Test (DMRT) was used to compare treatment means at $P< 0.05$.

RESULTS AND DISCUSSION

Table (2) Chemical analysis of different organic sources used in this study

Contents	FYM	Compost	Tithonia
N (%)	1.05	0.58	3.1
P(mg/kg)	421.6	114.4	30
K (%)	2.2	0.99	4.1
OC (%)	10.92	4.06	42
PH(1:2.5)	7.33	7.23	6.5

FYM = Farmyard manure. The same farmyard manure and compost were used during short rains of 2009 and long rains of 2010. The manure and compost were stored in a water proof shelter.

Characteristics of organic materials used in the study

Chemical properties of the three organic manures are shown in Table (2). The samples of FYM and compost had PH levels above 7, while tithonia had PH 6.5.The nitrogen levels were also quite high with values above 0.5% .Organic matter levels were medium in compost, high in

FYM and very high in tithonia as seen in high carbon levels. In addition, the phosphorous and potassium levels in all the manures are very high.

Table (3): Comparison of means from different treatments from parameters measured

treatment	Plant Height(cm)		Plant weight(g)		Fruit yield (ton/ha)		Fruit length(cm)		Fruit diameter(cm)	
	2009 SR	2010 LR	2009 SR	2010 LR	2009 SR	2010 LR	2009 SR	2010 LR	2009 SR	2010 LR
T1	40.33g	39g	181g	179g	17.87g	14.74h	7.53g	7.8g	6.07f	6.2g
T2	44.33e	44e	252.33e	250.67e	19.47f	19.58g	8.33f	8.6f	6.47e	6.67f
T3	47d	46.4d	320c	318.93c	22.36e	21.18f	8.83e	8.9e	6.73d	6.87e
T4	58b	57.3b	370.17b	371b	27.91d	25.83d	9.34d	9.6c	6.8d	7.03d
T5	42.93f	42.33f	231.67f	230f	26.99d	23.33e	9.17d	9.47d	7.33c	7.37c
T6	47.67d	47.27d	281.67d	280d	33.72c	27.22c	9.6c	9.83b	7.4c	7.47c
T7	52.33c	51.27c	370b	368.97b	39.37b	36.68b	9.83b	10.03a	7.63b	7.67b
T8	64.5a	62a	407.67a	405a	49.17a	44.17a	10.03a	10.13a	7.83a	7.90a

Means followed by the same letter along the columns are not significantly different using DMRT (P<0.05).

Table (4): Comparison of means on effect of inorganic fertilizer levels

Inorganic fert. levels	Plant Height(cm)		Plant weight(g)		Fruit yield (ton/ha)		Fruit length(cm)		Fruit diameter(cm)	
	2009 SR	2010 LR	2009 SR	2010 LR	2009 SR	2010 LR	2009 SR	2010 LR	2009 SR	2010 LR
50%RRR	47.42b	46.68b	280.88b	279.9b	21.90b	20.33b	8.52b	8.73b	6.52b	6.6b
100%RRR	51.89a	50.77a	322.75a	320.99a	37.31a	32.85a	9.66a	9.87a	7.55a	7.6a

Means followed by the same letter along the columns are not significantly different using DMRT (P< 0.05)

Table (5): Comparison of means on effect of different organic fertilizers

Organic fertilizers	Plant Height(cm)		Plant weight(g)		Fruit yield (ton/ha)		Fruit length(cm)		Fruit diameter(cm)	
	2009 SR	2010 LR	2009 SR	2010 LR	2009 SR	2010 LR	2009 SR	2010 LR	2009 SR	2010 LR
Control	41.63d	40.67d	206.33d	204.5d	22.43d	19.04d	8.35d	8.63d	6.7d	6.78d
Tithonia	46c	45.63c	267c	265.33c	26.59c	23.4c	8.97c	9.22c	6.93c	7.07c
Compost	49.67b	48.93b	345b	343.95b	30.86b	28.93b	9.33b	9.47b	7.18b	7.27b
FY M	61.25a	59.65a	388.92a	388a	38.54a	35.0a	9.7a	9.87a	7.32a	7.47a

Means followed by the same letter along the columns are not significantly different using DMRT (P< 0.05)

Plant height and fresh weight

There was a highly significant interaction ($P \leq 0.001$) between the rate of inorganic fertilizers and the organic manures on the plant height and fresh weight values. Table (3), the farm yard manure (FYM) had significantly highest (DMRT, $P<0.05$) plant height of 58 cm and 64.5 cm and fresh weight of 370.67g(T4) and 407.67g(T8) compared to other organic sources of manure and their controls when combined with 50% and 100% RRR rates of inorganic fertilizers respectively in 2009 SR. During 2010LR, a similar trend was observed with plant height of 57.3 cm and 62 cm for FYM compared to 39 cm and 42.33 cm for controls respectively. The plant fresh weight of 405g(T8) and 371g(T4) for FYM compared to 230g(T5) and 179g(T1) for controls respectively. The interaction effect on plant height and fresh weight generally increased from tithonia> compost > farmyard manure in that order.The combination of 50%RRR inorganic fertilizers and the organic manures (T2, T3 and T4) resulted in mean plant heights higher the 100%RRR control treatment (T5). Addition of different sources of organic manures had a significant effect on vegetative growth of eggplants expressed by their height and fresh weight compared to their controls. Organic soils provided more than the nutrients nitrogen and phosphorous. Organic manure normally contains complex compounds and provide not only a variety of nutrients but also add to the most important constituent of the soil, humus. Humus provides excellent substrate for plant growth. The eggplants applied with organic sources of manure especially farm yard manure were exceptionally healthy, taller and heavier plants. This could be attributed to the fact that the nutrients in the organic manure are released gradually through the process of mineralization [27] maintaining optimal soil levels over prolonged periods of time. Some of the organic substances released during the mineralization may act as chelates that help in the absorption of iron and other micro-nutrients [28].

Organic fertilizers improve soil water holding capacity as well as the CEC and nutrients are released slowly to crop plants. Organic inputs have a number of effects on nutrients availability. They add new organic matter to the soil and contribute to the maintenance of physical fertility, and result in better soil moisture status. Two main functions of organic manures in soils are the supply of nutrients and increase in the organic matter content of soils. During the decomposition and mineralization process, part of the residue-carbon ends up in more recalcitrant form, which contribute to the organic matter pool. The significance of organic based fertilizers as suppliers of nutrients to plant growth is determined by the rate of nutrient release; the higher the rate of nutrient release the less the soil organic matter. The slow or gradual release of nutrients by organic fertilizers is called the additive effect of organic fertilizers. This is in contrast to inorganic fertilizers that release nutrients rapidly and may fit the plant demand during the crop growth. Due to improved soil properties it enables the roots to grow deeper ensuring strong stems and taller plants. The organic materials have relatively higher PH compared with the soils, hence should have raised the PH increasing the availability of most nutrients.

The results of the chemical analysis in table (2) also indicate that FYM has relatively higher level of both nitrogen and phosphorous than the other organic manures, hence could have contributed to its superiority.

Organic materials could have reduced the P-sorption capacity of the soil and increase P availability by (i) forming complex (or chelate) with ions of Fe and Al in soil solution, preventing the precipitation of phosphate, and also reducing Al and Fe toxicity, (ii) compete with P for sorption sites, and/or (iii) solubilize P from insoluble Ca, Fe, and Al phosphates. This observation concurs with findings made by Iyamuremye and Dick [19] which concluded that organic materials can reduce the P-sorption capacity of the soil, enhance P availability, improve P recovery or result in better utilization by plants. Organic materials add Carbon into the soil provides substrate for microbial growth, and subsequent microbial activity. The turnover resulting from the decomposition of organic materials improves the nutrient cycling and availability to the plants especially, N and P which improved root development and subsequently vegetative growth. Similar observation was made by Smith et al, [29] who found that addition of organic residues can increase microbial pool sizes and activity, C and N mineralization rates, and enzyme activities, all these affect nutrient cycling.

Fruit yield and its quality

A highly significant interaction ($P \leq 0.001$) between the inorganic fertilizers and the organic manures were realized with positive effects on the fresh fruit yield in both seasons. Treatments; T1 and T5 are controls of 50%RRR and 100%RRR main plot respectively. During the 2009SR season the treatment 100%RRR + FYM (T8) had fruit mean yield of 49.17 ton ha^{-1} compared to 26.99 ton ha^{-1} of its control. Treatments T4 and T5 did not have a significantly different (DMRT,$P<0.05$) mean fresh fruit yield during 2009SR season, however, during the 2010LR season T4 recorded significantly higher (DMRT, $P<0.05$) than T5(Table 4).The data generally indicates that 2009 SR season had higher mean fruit yield compared the 2010 LR season in all the treatments.

A highly significant interaction ($P< 0.001$) between inorganic fertilizer rates and organic manures had effect on the fruit length and diameter. During the 2009SR season the treatment T8 maintained a significantly larger (DMRT, $P<0.05$) fruit mean diameter than other treatments as shown in table 4. No significant difference was observed between treatments T3 and T4, which recorded fruit mean length of 6.73 cm and 6.8 cm respectively. Similarly treatment T5 and T6 had no significant difference (DMRT, $P<0.05$) by recording 7.33 cm and 7.4 cm respectively. During 2010LR, all treatments had significant difference (DMRT, $P<0.05$) in their mean fruit diameter. No significant difference was observed between treatments T4 and T5 which recorded fruit mean length of 9.34 cm and 9.17 cm respectively. During 2010LR, treatment T8 and T7 recorded 10.13 cm and 10.03 cm respectively and had no significant difference (DMRT, $P<0.05$). However, both displayed a significantly larger fruit mean length than other treatments during the season.

In general, all organic fertilizers were sufficient to encourage the capability of plants to produce high total yield and enhanced the fruit characters as compared to plants treated with inorganic fertilizers alone. The results also indicate that of the three organic manures, FYM was the most the most superior compared to compost and tithonia. The superiority of FYM is due to its high rate of N and P, organic matter (OC) and pH as shown in table (3), this in turn led to increased vegetative growth and consequently favoured carbohydrate build up which resulted in in more plant growth characters and yield components of eggplant. Chindo and Khan (1986) reported that addition of suitable organic manure in the soil improves the soil structure and hence, encourage the plant good root and lead to higher yields. This could be attributed to the fact that the nutrients in the organic manure are released gradually through the process of mineralization [27] maintaining optimal soil levels over prolonged periods of time. Some of the organic substances released during the mineralization may act as chelates that help in the absorption of iron and other micro-nutrients [28].

The most favorable treatment combination was 100% RRR + FYM compared with the other treatments. The superiority of the treatment may be due to increased uptake of N and P which resulted in increased plant weight due to increased number of leaves and branches. The improved plant growth led to better carbohydrate build up which increased the plant fruit yield and their quality components. In this concern, [30] reported similar results and explained that addition of suitable organic manure in the soil improves the soil physical and chemical properties which encourages better root development, increased nutrient uptake and water holding capacity which leads higher fruit yield and better fruit quality.

The higher yields from organic materials plus inorganic fertilizer treatments than sole inorganic fertilizer treatment is an indication that integrated use or organic and inorganic nutrient sources of N is advantageous over the use or inorganic fertilizer alone. Earlier studies demonstrated that use of organics could enhance efficiency of chemical fertilizer [31]. Other researchers have observed higher eggplant yields through application of high quality organic inputs in combination with inorganic fertilizer as compared to sole application of inorganic fertilizers [32]. Integration of inorganic and organic nutrient inputs could therefore be considered as a better option in increasing fertilizer use efficiency and providing a more balanced supply of nutrients. Vanlauwe *et al*., [33] reported that combination of organic and inorganic nutrient sources result into synergy and improved conservation and synchronization of nutrient release and crop demand, leading to increased fertilizer efficiency and higher yields.

CONCLUSION

The above studies show that both mineral fertilizers and organic manures have their own roles to play in soil fertility management but none can solely supply all the nutrients and other conditions of growth for producing eggplant. Increased growth and yield parameters in this study may be associated with the supply of essential nutrients by continuous mineralization of organic manures, enhanced inherent nutrient supplying capacity of the soil and its favorable effect on soil physical and biological properties. As per the objectives of the study set out in section 1.3, the following conclusions can be drawn:

1. Increasing the inorganic fertilizers from 50% to 100% research recommended rates leads to direct increased growth and yield and fruit quality parameters of eggplant.
2. All the organic manures used significantly enhance growth, yield and fruit quality of eggplant. Though tithonia yielded the lowest eggplant yields among the organic resources tested in this study, the observed increase in eggplant yield with application of tithonia compared with the control demonstrate that it makes a significant contribution to crop production.
3. Results indicate treatments gave significantly ($P < 0.05$) higher yields than the recommended rate of inorganic fertilizer, indication that organic materials improved nutrient use efficiency from inorganic fertilizer. The results revealed that among the different combinations of inorganic and organic manure treatments, eggplant responded well to the application of 100% RRR + FYM. The growth characters and yield attributes as well as the fruit quality of eggplant were most significantly enhanced by the application of 100% RRR + FYM and their use should be promoted. Overall conclusion is that organic sources i.e. FYM, compost and *Tithonia* applied in combination with inorganic fertiliser could be used as nutrient sources and can meet nutrient requirement for eggplant in the following order FYM> compost > tithonia.

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