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Efficacy Evaluation of Organic Fertilizers on Growth, Yield and Quality Parameters of French Beans, Maize and Kale in Different Counties of Kenya

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Authors' contributions

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

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ABSTRACT

Sustainable agriculture is an important global issue. Organic fertilizer application improves crop growth by supplying plant nutrients, including micronutrients, as well as improving the physical, chemical, and biological properties of the soil, thereby providing a better environment for root development by improving the soil structure. It has been widely reported that continuous applications of inorganic fertilizers alone resulted in deterioration of soil health in terms of physical, chemical, and biological properties of the soil. Understanding the nutrient variability and release pattern of organic fertilizers is crucial to supply plants with sufficient nutrients to achieve optimum productivity, while also rebuilding soil fertility and ensuring protection of environmental and natural

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resources. This study was conducted to determine the efficacy of Fertiplus on growth, quality and yield in Kale, Maize and French Beans in Kenya. The trial plots were 3 m×3 m arranged in a randomized complete block design and replicated 4 times. The treatments consisted Fertiplus 4-3-3 alone; Fertiplus 4-3-3+100% recommended fertilizer practice; Fertiplus 4-3-3+50% recommended fertilizer practice; Fertiplus 4-3-3+75% recommended fertilizer practice; Reference product (Permeate); recommended fertilizer practice (Conventional) and the absolute control. Application of Fertiplus plus 50% of the recommended fertilizer practice led to the highest number of pods per plant (18) and application with 75% of the recommended fertilizer practice showed a peak harvest of fresh pods with 374.3 g per plant. In an area of 1 m^2, application of Fertiplus and 50% recommended fertilizer practice had 6.7 kilograms of kale with a maximum of 14 mature leave per plant in a span of 20 days. In maize, the Fertiplus and 50% recommended fertilizer treatment showed the highest cob weight per plant (480 g) and an average grain yield of 396.7 g per plant compared to the doubled level (100%) of the recommended fertilizer practice that had 401 g per plant. From the study, it was observed that the highest yield of the three study crops were under the integrated treatments of the organic fertilizer and half the rate of synthetic fertilizer program.

Keywords: Organic fertilizer; soil structure; biological properties; maize; french beans; kale.

1. INTRODUCTION

"French Beans are the immature green pods of *Phaseolus vulgaris*. French beans, also known as snap or green beans and locally in Kenya as *mishiri*, are a major export crop. Interest in French beans farming is fast-growing for fresh consumption and processing (mainly canning and freezing). French beans contain protein, fat, calcium, iron, phosphorus, vitamins A, B, and D and starch. One of the most important cereals in SSA is maize (*Zea mays* L.). It is a staple food for over 600 million people in the region" [1]. It is the most-grown cereal crop in both hectarage and production [2], as well as the second-largest consumer of mineral fertilizers in the country [3]. However, "maize yields across the country remain low compared to the hectarage of land under production, with a decreasing trend over several years. In Kenya, kale (*Brassica oleracea acephala group*), commonly known as *sukuma wiki,* is a popular vegetable in many households. It is a highly rated leafy vegetable and a lgreat food item related to wild cabbage with green or purple leaves that do not form a head with origins in Eastern Mediterranean" [4]. The tender leaves are used for human consumption, and older ones for forage. It is much easier to produce than other vegetables, andthan other vegetables, require fewer chemical inputs and labor, produce large volumes of leaves when sufficiently nourished and can be harvested several times a week. Low production costs translate into lower selling prices in the market, thus making it affordable even to households with less income. Kale production in Kenya is being hindered by declining soil fertility, among other factors.

"Soil is an essential ingredient in farming in Kenya and a key aspect of crop productivity" [5]. "Soil health and fertility are crucial determinants of the suitability to support agriculture" [6]. "Farmers are continually faced with poor soils of low fertility and therefore require supplemental fertilizers during active plant growth of the crop. Even high-yielding crop varieties have to be complemented with appropriate crop nutrition regimes to unlock their yield potential" [7,8]. "Organic Fertilisers applied in the soil have a regular function for the soil minerals. Organic material is important for moisture holding in the soil and prevents erosion. Organic Fertilizer absorbs three times its weight in moisture while the pellet will break down to avail important soil nutrients needed by plants" [5].

"Maize is a major crop grown and consumed in Kenya, requiring a high fertilizer input. However, the existing inorganic fertilizers in the market are often not affordable, especially to small-scale farmers, which results in decreased maize yields in the country" [9,7]. Despite having the fastest-growing population and the highest soil depletion rates in the world, farmers in Sub-Saharan African (SSA) countries have the lowest global fertilizer use of less than 10 kg/ha [6]. "While there is increased advocacy for the use of inorganic fertilizers, their excessive use is associated with soil, water and air pollution" [10]. Furthermore, "inorganic fertilizers are expensive, and their use may not be economically justifiable, especially for poor smallholder farmers who mainly practice subsistence farming. The use of organic amendments such as processed organic fertilizer is an alternative to these detrimental effects of inorganic fertilizers because of its

widespread availability, its additional value for soil carbon sequestration, and its capacity for storing and releasing nutrients over a more extended time period" [11]. "Processed organic manure can also serve as an alternative to raw cattle manure which is commonly used in SSA countries because it's bulky, expensive to apply, and poses a threat to human health and crops due to a high prevalence of pathogens. On the other hand, manure also emits emissions of carbon–dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ammonia (NH^3), and other volatile substances" [12]. "Such emissions are detrimental to the environment by contributing to global warming, eutrophication, and acidification of ecosystems" [13]. The novelty of the study is to evaluate how different integration methods of organic and inorganic fertilizers can influence the production of maize, French beans and Kales.

2. MATERIALS AND METHODS

2.1 Sites Description

The field experiments were conducted at Mwea in Kirinyaga County, which lies at 0 37' S and longitude 37 20' E with an elevation of 1159 m above sea level. The rainfall pattern of Mwea is bimodal, with a wet season of 3 months occurring from October to January with a dry spell, which in most cases occurs from June to August. The peak rainfall periods are between November and December, while the short dry season is from June through August. The mean daily temperature in Mwea ranges from about 25˚C and 37˚C.

2.2 Experimental Design and Treatments

The trial was laid out in a randomized complete block design (RCBD) and replicated four (4) times at each site. The factors considered were the different products. The treatments in each crop included: Fertiplus 4-3-3 alone 250 kg per hectare); Fertiplus 4-3-3+100% recommended fertilizer practice (100 kg DAP and 100 kg CAN per hectare); Fertiplus 4-3-3+50% recommended fertilizer practice (50 kg DAP and 50 kg CAN per hectare); Fertiplus 4-3-3+75% recommended fertilizer practice (75 kg DAP and 75 kg CAN per hectare); Reference product (Permeate at 2500 kg per hectare); recommended fertilizer practice (100 kg Dap and 100 kg CAN per hectare) and the no application which was the absolute control. The experimental plots measured 3 m long and 3 m wide, with a 0.5 m pathway between plots and a 0.5 m pathway between blocks.

2.3 Cultural Practices, Data Collection and Analysis

The maize variety used was DKC-9089 from Monsanto Seed Company, the kale variety was Collard from Simlaw Seed Company, and the French bean variety used was Serengeti from Syngenta. Data on French beans were collected on the harvested fresh weight of pods, the number of pods per plant and the pod length; in maize, data was collected on the fresh cob weight, the number of cobs per plant, ear height, grain yield per plant and number of grains per cob; and the number of leaves and the leaf weight per plant were recorded on kales. One-way analysis of variance (ANOVA) was used to determine treatment effects on dependent variables at $P \leq 0.05$ probability level using GenStat Version 15.2 statistical package. In the case of significant differences, separation of means was done using Fischer's Protected LSD test at a 95% confidence level.

3. RESULTS AND DISCUSSION

3.1 Influence of Treatments on Yield Parameters of Maize, Kale and French Beans

Significant differences were observed between the different treatments of French beans (Table 1). The application of Fertiplus organic fertilizer combined with the normally recommended fertilizer program (RFP) at 50%, 75% and 100% led to the highest fresh pod yield of French beans across the four harvests with an average of over 250g per plant, which was higher by over 25% compared to the sole application of the synthetic fertilizers in the RFP treatment as well as the sole use of the organic fertilizers which yielded even lesser. The pods' quality also increased significantly in terms of the length of pods and number per plant. The integration of the organic and inorganic fertilizers probably worked in tandem to improve the soil's physical, biological and chemical properties of the soil thus leading to higher yields. The use of both organic and inorganic fertilizers by farmers has been reported to increase yield, sustain productivity and improve soil chemical properties [14]. The application of mineral fertilizer in combination with locally available organic fertilizer, is important to maintain soil fertility that achieves a

balance nutrient supply to increase crop yield. It is one of the best practices for plant nutrient management to optimize crop production's social, economic, and environmental benefits.

There were significant differences between treatments on the Kale crop, where integration of organic and inorganic fertilizer led to the highest number of leaves at the different periods of harvesting with a doubling of leaves compared to where organic fertilizers were used alone and three more leaves compared to the inorganic fertilizer (RFP) alone. The average leaf weight did not show significant differences where 50%, 75% and 100% of the inorganic fertilizer program was combined with the organic fertilizer Fertiplus while they were significantly superior to the lone applications and the untreated control. Combined organic/ inorganic fertilization both enhanced carbon storage in soils and reduced emissions from nitrogen fertilizer use while contributing to high crop productivity in the crop. The use of inorganic fertilizers alone has not been helpful under intensive agriculture because it aggravates soil degradation. Maintaining and improving soil quality is crucial if agricultural productivity and environmental quality are to be sustained for future generations [15].

The combined application of organic fertilizer and inorganic fertilizer significantly increased the yield of maize compared to the sole application of the organic fertilizer alone and the synthetic fertilizer program alone. The number of grains per cob almost doubled through the integrated approach compared to the organic fertilizer alone and an increase of over 35% compared to the synthetic fertilizer alone. Prabu and Uthaya [16] concluded that organic manures play a vital role in maintaining soil's physical, chemical and biological conditions and supply of macro and micronutrients to crops besides maintaining humic substances in soil and the wastes are effectively utilized for crop production. Adding organic sources could increase corn yields through increased soil productivity and fertilizer use efficiency. Organic matter plays an important role in nutrient recycling. It has been shown that the addition of organic materials caused an increase in plant dry matter yield and its uptake of the macro and micronutrient elements [17].

Table 1. Pod fresh weight per plant (g) harvest 1-4, pod length (cm) and number of pods per plant of french beans at Mwea

Treatment	Pod weight H-1 (g)	Pod weight H-2 (g)	Pod weight H-3 (g)	Pod weight H-4 (g)	Pod length (cm)	Pods /Plant
RP	144.3c	165.3c	170.0d	170.7d	8.7c	9c
F4-3-3+50% RFP	266.7a	285.0a	288.0a	281.0ab	12.8a	16a
F4-3-3+75% RFP	253.7a	283.7a	293.7a	289.0a	12.7a	17a
F4-3-3+100% RFP	250.3a	277.7a	291.3a	277.1ab	12.3a	17a
F4-3-3 Alone	182.7b	197.7bc	209.0c	210.0c	9.1c	9c
RFP	200.7b	231.3b	252.3b	257.7b	10.5b	13b
Control	95.3d	115.3d	123.7e	109.7e	6.2d	5d
P Value	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**
CV%	**9.7**	**10**	**8.3**	**6.7**	**6.3**	**11.2**
SED	**15.78**	**18.18**	**15.68**	**12.45**	**0.53**	**0.903**

RP-Reference Product; F4-3-3-Fertiplus; RFP-Recommended Fertilizer Practice; H-1-First Harvest; H-2-Second Harvest; H-3-Third Harvest; H-4-Fourth Harvest; SED-Standard error of means. Means followed by different letters in the same column are significantly different at 95% confidence level

Table 2. Number of leaves per plant and the fresh weight of leaves per 1 m^2 at Mwea

Treatment	Leaf no. (20 DAT)	Leaf no. (40 DAT)	Leaf no. (60 DAT)	Leaf weight (20 DAT)	Leaf weight (40 DAT)	Leaf weight (60 DAT)
RP	3c	5.c	6c	0.57cd	2.16c	3.39c
F4-3-3+50% RFP	5a	8b	10a	1.50a	4.03a	6.06a
F4-3-3+75% RFP	5a	10a	9a	1.37a	3.83a	5.57a
F4-3-3+100% RFP	5a	10a	9a	1.45a	3.99a	6.10a
F4-3-3 Alone	4b	5c	6c	0.77c	2.43bc	3.75bc
RFP	4b	8b	8b	1.07b	3.06b	4.19b
Control	2d	4.c	4d	0.44d	1.42d	2.17d
P Value	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**
CV%	**5.9**	**12.6**	**7**	**9.6**	**13.1**	**8.8**
SED	**0.2086**	**0.71**	**0.431**	**0.0793**	**0.3201**	**0.3221**

RP-Reference Product; F4-3-3-Fertiplus; RFP-Recommended Fertilizer Practice; DAT-Days after Transplanting; SED-Standard error of means. Means followed by different letters in the same column are significantly different at 95% confidence level

Table 3. Yield parameters of maize crop as influenced by test treatments at Mwea

Treatment	Fresh cob weight/plant (g)	Cobs/plant	Ear height (cm)	Grain yield (g) plant	Grains/cob
RP	298.3c	1b	20.0b	226.3c	281c
F4-3-3+50% RFP	480.0a	2a	25.7a	396.7ab	424a
F4-3-3+75% RFP	469.7a	2a	26.3a	398.3a	431a
F4-3-3+100% RFP	470.3a	2a	25.7a	401.0a	434a
F4-3-3 Alone	300.0c	1b	19.7b	241.0c	297bc
RFP	417.0b	2a	2077b	352.3b	346b
Control	289.7c	1b	12.6c	222.7c	217d
P value	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**
CV%	**7.4**	**6**	**3.6**	**7.9**	**8**
SED	**20.04**	**0.069**	**0.638**	**20.6**	**22.76**

RP-Reference Product (Permeate); F4-3-3-Fertiplus; RFP-Recommended Fertilizer Practice; DAT-Days after Transplanting; SED-Standard error of means. Means followed by different letters in the same column are significantly different at 95% confidence level

Intensive agriculture has negatively affected the soil environment over the past decades (e.g. loss of soil organic matter, soil erosion and water pollution). Management methods that decrease requirements for agricultural chemicals are needed in order to avoid adverse environmental impacts. It has been observed that combined application of organic and inorganic fertilizers increased the growth and yield of maize more than when any of the fertilizers was used alone [18]. Tolessa and Friesen [19] reported that maize growth and yield were significantly increased by farmyard manure (FYM) application enriched with chemical fertilizers. The role of organic fertilizers (compost) is to improve soil organic matter, nitrogen content and phosphorus concentration. Furthermore, decreasing soil pH, results in increasing solubility of nutrients and nutrient availability to the plants, hence enhancing plant growth and development as well as gradually increasing crop yield.

4. CONCLUSION

A positive and consistent trend was observed in the growth and yield parameters of French beans, kale and maize in Kirinyaga. Applying Fertiplus plus 50%, 75% and 100% of recommended fertilizer practice led to the most significant growth rate and highest yield of French beans, kale and maize. On kale, Fertiplus plus 50% of recommended rates of fertilizer practices had the highest positive influence on yield components as well as in maize, with a marginal increase observed when the recommended fertilizer practice rate was doubled or increased by half. Because of environmental and health concerns, the use of organic fertilizers should be on the rise given the positive results from this study where the application of Fertiplus and reduction of synthetic fertilizers by 50% is recommended, and thus more adoption in the use of organic fertilizers is expected.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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