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The impact of organic fertilizer on maize, field beans, and cabbages within the agricultural landscape of Kenya: An assessment of efficacy on sustainable development goals

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The study aimed to address the reduced production in agriculture and offer better opportunities to farmers for a sustainable future through organic farming aligned with the Sustainable Development Goals. Data were collected on the growth performance and yield of three crops (cabbage, field beans, and maize) from six sites: Mau Narok, Mwea, Limuru, Molo, and Njabini, between April and October, 2017. The results of the study were presented in tables and figures, with the figures being pictorial representations. The findings suggest a positive effect of Eco-see 100 on both plant growth and yield for the evaluated crops. Given the consistency of these results across the testing sites, the use of Eco-see 100 as a soil amendment for crop production in Kenya is recommended. This offers a promising solution through organic farming to achieve the Sustainable Development Goals.

Key words: Famine, organic agriculture, food security, Eco-see 100.

INTRODUCTION

Organic agriculture gained momentum in Kenya in the early 1980s with support from non-governmental organizations (NGOs), private companies, and public-funding institutions. Organic agriculture has been suggested to offer various benefits, including hunger reduction, improved food security, climate action, export qualification, and other societal benefits (Amudavi et al., 2014).

Food security and climate adaptability have become prominent areas of research in recent years. According to Islam et al. (2022), food security is achieved when people consistently have physical and economic access to adequate, nutritious, and safe food that can meet their dietary requirements and preferences, enabling them to maintain a functional and healthy life. Despite the crucial role of food security in overall economic stability and the growth of any economy, projections indicate that by 2030, in eastern and southern Africa, a population exceeding 600 million individuals will continue to face the challenge of food insecurity (World Bank, 2023). Moreover,

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agricultural commodity prices are increasing annually due to unexpected global events such as the Covid-19 pandemic, the Ukraine-Russian war, and so on. African countries heavily rely on imports for staple foods such as cassava, maize, palm oil, rice, and wheat. This high net import dependence leads to wider variations in food prices. The IMF estimates that a 1% increase in the consumption share of staple food raises the local price by 1.2% in Africa (IMF, 2022).

Small-scale farmers in Kenya play a central role in the economies of Kenya and other African countries. In Kenya, small-scale farmers contribute to more than 70% of Kenya's total agricultural produce. The agricultural sector accounts for approximately 33% of the gross domestic product (USAID, 2023). Organic agriculture has been considered a key strategy for reducing poverty and food insecurity, which are also central to achieving the Sustainable Development Goals (SDGs) (United Nations Population Prospects, 2008).

Kenya is arguably facing a food insecurity crisis, with an estimated 3.8 million people in rural areas classified as highly to extremely food insecure, and about 4.4 million people projected to experience high levels of acute food insecurity. Overall, 3.1 million people (21% of the analyzed population) are likely to be in crisis, and 1.2 million people (8% of the analyzed population) are in an emergency situation (Bhavnani et al., 2023). The report also highlights that the most affected counties, representing 40% of the total country, are predominantly pastoral livelihoods, such as Isiolo, Turkana, Garissa, Mandera, Marsabit, Samburu, Wajir, and Baringo.

Famine can be attributed to severe drought, lack of fertilizer input, reduced soil fertility, and climate change. However, contemporary agricultural land-use practices have already resulted in significant environmental impacts, including biodiversity loss, accelerated soil erosion and degradation, eutrophication leading to phenomena like algal blooms and oceanic dead zones, adverse effects of pesticides on both humans and wildlife, greenhouse gas (GHG) emissions, and shifts in hydrological cycling regimes (Ponisio et al., 2015). Organic agriculture has the potential to address some of the factors associated with famine, particularly those related to soil fertility, sustainable farming practices, and resilience to climate change.

Organic agriculture can promote self-reliance in terms of food access and production management, leading to sufficient income to survive and access additional food. It fosters a culture of adequate food access and sustainability, as well as participation in protecting the environment to ensure sustainable food production based on soil, water, forest, and climate (Yazdanpanah et al., 2022).

This study aims to determine whether the use of Eco-see 100 as a soil amendment for crop production in Kenya influences crop yield, using height as the plant growth parameter and fresh weight of the edible crop crop produce as the yield parameter.

The study will assess and recommend, or otherwise, the use of Eco-see 100 as a soil amendment for crop production in Kenya.

LITERATURE REVIEW

There is a growing body of literature on food security in developing countries, with most previous studies focusing on objective food security measures at the household level. These measures typically look at consumption (converted into calories) or expenditure data. However, Mallick and Rafi (2010) and others argue that consumption has significant seasonal volatility, and since most of these studies use a single round of surveys, the consumption data may systematically under- or over-report true food security.

Organic agriculture is often perceived as more sustainable than conventional farming. Kabubo-Mariara and Kabara (2018) assert that while organic agriculture is not the sole paradigm for sustainable agriculture and food security, smart combinations of organic and conventional methods could contribute towards sustainable productivity increases in global agriculture.

The current food crisis is a global pandemic evidenced by increasing and unstable food prices, as well as food shortages in various countries, indicating a lack of food security. Scholars from various countries have studied the issue of food security, the challenges involved, and the available avenues for achieving economic stability. In Africa, protests have erupted due to the rising cost of food, which is of great concern to the rural poor as it affects their quality of life and survival. According to FAO, IFAD, UNICEF, WFP and WHO (2022), 193 million people across 53 countries experienced food insecurity in 2022, an increase of 80% from the 108 million who experienced acute food insecurity in 2021.

Various studies that have been conducted in Nigeria by Obayelu et al. (2022) and in Ethiopia by Negash et al. (2009) have established that male household heads have a significant influence on the level of food security in their households. However, other studies, such as one conducted by Masinde (2014), suggest that female household heads are more likely to prioritize spending a significant portion of their income on food, thereby ensuring food security for their households.

In Senegal, Anderson et al. (2021) found that rural households are forced to use coping strategies during droughts to ensure resilience, and food expenditure increases in all categories of households, requiring government intervention to subsidize food prices. Failure to do this results in a food crisis. In the study of Nyangasa et al. (2019) under the Zanzibari households, 65% of households are found to have poor food consumption while 32% are severely food-insecure. Polygamous households and larger households were established to have a higher chance of severe food insecurity. This is catastrophic since the world population is expected to increase by 2.5 billion between 2007 and 2050 which may pose several food security issues (United Nations Population Prospects, 2008).

According to the IGAD Climate Prediction and Applications Centre, the African region is expecting an unprecedented sixth poor season from March to May 2023, especially for the worst-hit countries: Ethiopia, Kenya, and Somalia (Horn of Africa Hunger Crisis Report, 2023). According to Kimwele et al. (2019), there are over 3.5 million people in critical need of food to overcome starvation. Food insecurity remains a public health threat; it is widespread in developing countries, as millions of people continue to suffer from food scarcity and death due to food insecurity. Whereas a varied and balanced diet is essential to reducing the rate of malnutrition, food insecurity jeopardizes dietary intake (Nnakwe and Onyemaobi, 2013).

Scialabba and Hattam (2002) provide organic agriculture as the remedy to food security and a healthy lifestyle wherein organic agriculture encompasses crop, livestock as well and fish farming which is done through a balanced nutritional program of primary organic inputs and addressing environmental factors that reduce stress levels and prevent diseases. A small-scale farmer in Nyandarua stated in a focus group interview conducted (2018) that they were able to survive without any job because they grew vegetables, fruits, fish, and poultry, and had everything they needed in their yard (Von Koerber and Cartsburg, 2020). According to the study, Nyandarua small-scale farmers are content with their simple lifestyle despite not having much money (Von Koerber and Cartsburg, 2020).

Organic agriculture helps reduce greenhouse gas emissions since it reduces the utilization of fuel-based fertilizers and chemical pesticides leading to a decrease in carbon footprint. According to the Rodale Institute, organic farms use 45% less energy compared to conventional farms (Xu et al., 2022). Organic agriculture also helps soil absorb more carbon.

Organic agriculture aligns with the 17 Sustainable Development Goals (SDGs) and contributes to the sustainable agenda of the planet. Organic agriculture helps to promote biodiversity, with 25% of biodiversity found in the soil (Setboonsarng and Gregorio, 2017). Soils also act as a key reservoir for CO2, containing more carbon than the atmosphere and terrestrial vegetation combined, leading to reduced carbon emissions and mitigating climate issues such as droughts and famines. Setboonsarng and Gregorio (2017) argue that by preventing the use of chemical products in agriculture, organic agriculture also contributes to SDG 6 by reducing the pollution of water systems.

Von Koerber and Cartsburg (2020) connected organically produced food to SDG 1 (no poverty), SDG 2 (zero hunger), SDG 3 (good health and well-being), SDG 6 (clean water and sanitation), SDG 8 (decent work and economic growth), SDG 12 (sustainable consumption and production), SDG 13 (climate action) and SDG 15 (life on land). For us to succeed in the adoption of organic agriculture, and achieving the target of SDGs, it is recommended that foreign solutions along with their business operations get localized to maximize the effect of organic agriculture.

Microorganisms play a crucial role in sustainable farming and the quest for carbon neutrality. They contribute to soil health, nutrient cycling, biological pest control, carbon sequestration, methane reduction, chemical reduction, and sustainable farming via microbial inoculants. Eco-see 100 (Korea's Appropriate Technology; microorganism fertilizer) is a microorganism soil conditioner that is widely used in agriculture to promote sustainable agricultural production and environmental conservation This technology consists of naturally occurring microorganisms that are compatible with one another and can coexist in liquid culture. There are so many species used in agriculture, some of the examples of microorganisms used in Kenya through Eco-see 100 are Lactobacillus acidophilus, Bacillus subtilis, and Saccharomyces cerevisiae. Eco-see 100 was officially registered with the Kenyan and Zimbabwean governments in East Africa and proved its benefits on soil health, plant growth, organic farming, and carbon reduction.

METHODOLOGY

This study collected data on the growth performance and yield of three crops (cabbage, field beans, and maize) at six sites: Mau Narok, Mwea, Limuru, Molo, and Njabini, between April and October 2017. The trials were conducted with eight treatments for each crop at each site, consisting of the following seven treatments: T1: Control; T2: Eco-see 100 (200 L/ha); T3: Eco-see 100 (200 L/ha) + FYM; T4: Eco-see 100 (200 L/ha) + DAP (200 kg/acre), T5: Eco-see 100 (200 L/ha) + DAP (60 kg/acre); T6: Standard rate of DAP alone (200 kg/acre), T7: Reduced rate of DAP (60 kg/acre), and T8: FYM alone. Each block consisted of treatments in plots measuring 3 × 3 m with plant spacing specific to each crop. Data were analyzed for variances using GenStat, and treatments were compared using means ($P \leq 0.05$). Eco-see 100, as a soil amendment, is used with organic manure (compost or farmyard) for soils lacking in organic matter. The manure should be fully decomposed and well incorporated into the soil during the initial application of Eco-see 100.

Generally, 4 to 10 tons of manure per hectare per season is recommended for a good harvest. However, this can vary widely depending on the soil nutrient status, which can be determined at specific sites with the assistance of local experts. Eco-see 100 is used with 20/30/40% conventional fertilizer where organic manure is not initially available. As the soil recovers, conventional fertilizers are gradually eliminated, and instead, crop residues, waste, and cut vegetation are composted. Eco-see 100, as a decomposing agent, helps release nutrients from the compost into the soil, which are then ploughed back into the soil in subsequent seasons. A minimum of 200 L of Eco-see 100 per hectare per growing season is required for a good harvest.

This study aimed to determine the pronounced effects on each

Table 1. Effect of Eco-see 100 on plant height at flowering and yield of field beans (var GLP2 KK8).

Treatment	Mean plant height at flowering (cm)	Mean yield (kg/ha)
Control	26.70[a]	729a
EC100 (200 L/ha)	31.31[ab]	1027[ab]
FYM	35.50[abc]	1085[ab]
DAP 60 kg/acre	37.15[bc]	855[a]
EC100 (200 L/ha)+DAP 60	39.68[bc]	1105[ab]
EC100 (200 L/ha)+ FYM	40.73[c]	1335[b]
EC100 (200 L/ha)+ DAP200	42.17[c]	946[ab]
DAP200 kg/ha	42.49[c]	934[ab]
Mean	37	1002
LSD (p≤ 0.05)	5.53	259.2
CV (%)	23.2	23.1

*FYM: Farm Yarm Manure, DAP: Chemical Fertilizer Brand in Kenya; *Means in the same column followed by the same letter are not significantly different at P≤0.05.
Source: Eco-see Industries Limited Technical Report (2017).

crop when the product is used in combination with farmyard manure (organic fertilizer). The results of this study were presented in the form of tables and figures, with the figures being pictorial representations.

FINDINGS

The Korean-based company ECO-SEE AFRICA, which has a subsidiary in Kenya, has successfully tested its microorganism solution, known as Eco-see 100, on local crops (Von Koerber and Cartsburg, 2020). The efficacy of this solution was evaluated on maize, field beans, and cabbages in Kenya. Trials were conducted at six different sites to determine the effectiveness of Eco-see 100 on the growth performance and yield of these three crops: Mau Narok, Mwea, Limuru, Molo, and Njabini. The introduction of a Korean bio soil fermenter yielded Eco-see 100, a plant growth booster and bio soil amendment consisting of three main bacteria: *Lactobacillus acidophilus*, Bacillus subtilis, and *Saccharomyces cerevisiae* (Von Koerber and Cartsburg, 2020). The trial results suggest a positive effect of Eco-see 100 on both plant growth and yield, with a 10 to 20% increase in crop yield. The results also indicate the potential for sustainable farming and recycling organic waste.

According to Higa and Wididana (1991), Eco-see 100 enhances overall plant growth and improves soil physical properties by increasing the population of beneficial microorganisms in the soil and on the plants. This increase in beneficial microorganisms leads to several benefits, including increased breakdown of organic matter, which releases nutrients for plant uptake; improved soil aeration and water retention capacity by incorporating organic matter into the soil; increased solubility and mineralization of salts for plant uptake; and the release of useful amino acids, hormones, and enzymes that promote plant growth, as well as the suppression of pathogenic microorganisms in the soil and on the plants.

Eco-see 100 and plant height and yield of field beans

Statistically (P<0.001) significant effects were detected from the use of Eco-see 100 as a soil drench on field beans. Table 1 shows differences in the mean height of field bean plants at the flowering stage after treatment with Eco-see 100. These results suggest that Eco-see 100+FYM led to an increase in plant height (40.73 cm) in Field beans at the flowering stage as contrasted with control plots (26.70 cm). However, the largest mean height (42.49 cm) was achieved in treatments with DAP applied at the rate of 200 kg/acre.

Yield assessment of field beans

Yield assessment of Field beans revealed statistically significant (P<0.001) effects of Eco-see 100 on mean dry weight (Table 1). Application of the test product (Eco-see 100) at the rate of 100 L/acre in combination with FYM produced the highest mean yield of bean yield (1335 kg/ha) compared with control plots in which a mean weight of 729 kg was achieved. The yield achieved from the use of Eco-see 100+FYM was also significantly higher than what was achieved from the application of DAP alone at 60 or 200 kg/acre (Figure 1).

This indicates that the addition of microorganisms to the soil effectively improved soil fertility by enhancing nutrient absorption. It also suggests the potential reduction in chemical usage in the soil, leading to the active application of organic waste. Additionally, beans possess a unique ability to capture nitrogen from the air. They can fix atmospheric nitrogen in specialized root

Figure 1. Dry bean yield per plant: Eco-see 100+Farm Yard Manual (Left); Control plot (Right).
Source: Eco-see Industries Limited Technical Report (2017).

Table 2. Effect of Eco-see 100 on plant height at tussling and fresh weight at harvesting of maize (var H614).

Treatment	Mean plant height (cm)	Fresh weight (Kg) per plot
CONTROL	203.1[a]	32.00[a]
EC 100 (200 L/ha)	269.7[b]	48.81[ab]
DAP 60kg/acre	261.9[ab]	59.24[ab]
DAP 200kg/acre	267.6b	44.95[ab]
EC 100 (200 L/ha)+DAP 60	261.1[ab]	52.57[ab]
EC 1000 (200L/ha)+ DAP200	244.0[ab]	49.48[ab]
EC 100(200L/ha)+ FYM	262.2[ab]	61.62[b]
FYM	276.7b	60.15[b]
Mean	255.8	51.1
LSD ($P \leq 0.05$)	33.19	14.07
CV %	7.4	15.7

Means in the same column followed by the same letter are not significantly different at P≤0.05.
Source: Eco-see Industries Limited Technical Report (2017).

nodules, known as rhizobia. This aids in nitrogen utilization by plants, contributing to improved resource recycling. A reduced requirement for additional nitrogen fertilizers helps decrease overall fertilizer usage and promotes a more efficient utilization of resources.

Eco-see 100 and maize crop performance

To evaluate the effect of Eco-see 100 on maize crop performance, the yield (fresh weight) of fresh cob tubers was assessed. Greater effects on the cob were observed in plots treated with Eco-see 100 in combination with farmyard manure (FYM) at planting compared to the untreated control plots. Eco-see 100 applied during planting at a rate of 200 L/ha, together with 60 kg/acre of diammonium phosphate (DAP), produced a mean cob yield of 61.62 kg. This yield did not differ significantly ($P < 0.05$) from the value (44.95 kg) achieved when DAP was applied alone at 200 kg/acre. This is shown in Table 2.

The combination of Eco-see 100 + FYM resulted in the highest harvest, indicating that organic waste can be more efficient than chemicals in production. This approach helps farmers utilize more agricultural by-products, thereby enhancing soil fertility as the soil composition becomes richer in natural nutrients, especially micronutrients that are absorbed by the soil and plants. Overall, the use of organic waste contributes to the overall health and productivity of maize crops by improving soil fertility, structure, and microbial activity while reducing the environmental impact associated with conventional farming practices.

Eco-see 100 and fresh head weight

For the third crop, cabbage, on which Eco-see 100 was evaluated, two parameters were assessed: head weight

Table 3. Effect of Eco-see 100 on fresh head weight (g) of cabbage (var Victoria).

Treatment	Head diameter	Head weight (kg)	Yield per plot (kg)	Yield (t/ha)
Control	15.57[ab]	2.425[a]	60.62[a]	67.4[a]
EC100 (200 L/ha)	14.91[a]	2.466[a]	61.66[a]	68.5[a]
DAP200 kg/acre	18.09[abc]	3.771[ab]	94.29[ab]	104.8[ab]
EC100 (200 L/ha)+ DAP200 kg/acre	18.29[abc]	4.113[ab]	102.83[ab]	114.3[ab]
DAP60 kg/acre	18.77[bc]	3.458[ab]	86.45[ab]	96.1[ab]
EC100 (200 L/ha)+ DAP 60 kg/acre	18.92[bc]	4.180[ab]	104.49[ab]	116.1[ab]
FYM	19.00[bc]	3.946[ab]	98.65[ab]	109.6[ab]
EC100 (200 L/ha)+ FYM	19.56[c]	4.544[b]	113.59[b]	126.2[b]
Mean	17.9	3.6	90.3	100.4
LSD ($P \leq 0.05$)	2.28	1.21	30.1	33.5
CV %	13.5	35.2	35.2	35.2

Means in the same column followed by the same letter are not significantly different at P≤0.05.
Source: Eco-see Industries Limited Technical Report (2017).

(kg) and head diameter (cm). Consistent with the observations for the two previous crops (field beans and maize); similar trends in crop performance were observed. The results of the assessment are presented in Table 3.

The effect of Eco-see 100 on cabbage yield was significantly higher (P < 0.001) in the various treatments involving the test product in combination compared to the control. The highest mean yield (126.2 t/ha) was recorded in plots treated with Eco-see 100 in combination with farmyard manure (FYM). However, there was no statistically significant difference (P < 0.05) between this yield and that achieved with diammonium phosphate (DAP) at either 60 or 200 kg/acre. These findings are shown in Table 3.

Eco-see 100 and cabbage head diameter

The treatment effects were also reflected in the cabbage head diameter, where larger values were recorded in produce from plots treated with 200 or 60 kg/acre of DAP together with 200 L/ha of Eco-see 100. This contrast is revealed by the control plots, which had a low mean value for head diameter (15.57 cm). This suggests a higher possibility of replacing chemical products with organic resources. The incorporation of organic waste reduces reliance on synthetic fertilizers, aligning with sustainable agricultural practices and promoting a more environmentally friendly and cost-effective approach to cabbage cultivation. Figure 2 shows the circumference of cabbage harvested from a plot treated with Eco-see 100 + FYM. The value for circumference was then used to compute the diameter.

Conclusions

Organic agriculture offers environmental and societal benefits in addition to agricultural advantages. By aligning with the Sustainable Development Goals, it targets hunger reduction to sustain the livelihoods of low-income households and addresses climate action to combat climate change. Furthermore, organic agriculture enhances environmental and human health and contributes to the achievement of the SDGs.

Findings from this study indicate that plant growth indicators responded positively to the application of Eco-see 100 as a pre-plant soil drench. The most pronounced effects on each crop were achieved when the product was used in combination with farmyard manure (organic fertilizer). While there was a consistent positive effect of Eco-see 100 on plant growth and yield for each crop at each site, the specific levels of response of yield parameters to Eco-see 100 varied depending on the crop.

The soil also showed improvement in moisture content. The combination of Eco-see 100 + farmyard manure exhibited higher moisture content at 10.9 g/100 g of soil, and the pH value remained at 7, proving to be the optimal condition for plant growth. Eco-see 100 (Korea's Appropriate Technology; microorganism fertilizer) played a crucial role in the decomposition of organic matter. As organic materials, such as plant residues or animal waste, decompose, microorganisms break down complex organic compounds into simpler forms, releasing carbon dioxide (CO_2) as part of the natural decomposition process. This contributes to the carbon cycle without introducing additional carbon into the atmosphere.

RECOMMENDATIONS

Numerous campaigns have promoted organic agriculture initiatives, and now a new approach is needed to encourage local farmers to adopt these practices more readily. To achieve this, it's essential to introduce new solutions from outside Kenya and help local farmers gain confidence in and adapt to new farming methods and

Figure 2. Taking the circumference of cabbage harvested from a plot treated with Eco-see 100FYM. The value for circumference was afterward used to compute the diameter.
Source: Eco-see Industries Limited Technical Report (2017).

solutions, such as those demonstrated by ECO-SEE AFRICA using a Korean solution.

The results of this study suggest a positive effect of Eco-see 100 on both plant growth and yield for the evaluated crops. Given the consistent results across the testing sites, the use of Eco-see 100 as a soil amendment for crop production in Kenya is recommended. This will not only improve food productivity and soil and human health but also contribute to developing solutions to address climate issues through biodiversity and natural resource recycling. Furthermore, by harnessing the activities of microorganisms, it is possible to develop sustainable practices that contribute to carbon neutrality and mitigate the impact of human activities on the global carbon balance.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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