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# Impacts of selected Climate Smart Agricultural Practices on African Indigenous Vegetables in Kenyan drylands

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## Abstract

Climate change has had significant impacts on the cultivation of African Indigenous Vegetables (AIVs) resulting in insufficient yields and food insecurity. African indigenous vegetables are important food crops used in combating malnutrition and food insecurity. The AIVs have the potential to provide nutrition and sustain smallholder farmers' livelihoods. However, little is known about the impacts of Climate-Smart Agriculture Practices (CSAPs) on the yield levels in AIVs. This study was therefore conducted to evaluate the impacts of selected CSAPs on the yield levels in cowpeas (*Vigna unguiculata.* L) and black nightshade (*Solanum nigrum*. L) in Kenyan drylands. Six treatments consisting of organic manure, commercial organic fertilizers, irrigation, mulching, inorganic fertilizers and controls were used. Research plots measuring 3m by 3m were set out in a randomized complete block design and sowed with certified cowpeas seeds and well-established black nightshade seedlings. Treatments were applied at land preparation and at 7 days after crop germination. Data was collected on plant height at vegetative stage and the overall primary yield at crop maturity. Analysis of variance (ANOVA) was conducted on the quantitative data collected and analyzed using Genstat software. Post hoc analysis was carried out for significant means using Tukey's Honest Significant Difference (HSD) test at $p \leq 0.05$. The results revealed significant differences in both the plant height and primary yield across all treatments ($p \leq 0.05$). The AIV yield levels were significantly influenced by the CSAPs products used. Plots treated with organic manure, mulching and commercial organic fertilizers had significantly higher yields. Control plots had the least amount of yields.

**Key words**: ANOVA, Climate change, food security, malnutrition and soil degradation.

## Introduction

Generally, there is limited capacity in controlling the rate of climate change within the 2°C threshold necessitating a need to cope with its effects (Rogelj *et al.* 2011) Sub-Saharan Africa (SSA) is the most affected by climate change (Cline, 2007). Climate change has had a significant impact on the cultivation of AIV resulting in insufficient yields and food insecurity (Fox *et al.,* 2004). Soil degradation has also been identified as a leading cause of reduced agricultural production among smallholder farmers (Kimaru, 2003). Among the soil nutrients, nitrogen is the most important and the most deficient mineral element. The use of inorganic fertilizers has been reported to cause an increase in soil pH causing more acidity in the soil. Most crops perform well in pH levels of 6.0-7.0. Low pH levels lead to aluminium toxicity, which interferes with the uptake of other elements such as phosphorus, molybdenum and reduction in soil microbial activities (Kimaru, 2004). It is therefore important to perform soil tests before applying inorganic fertilizers. Good soil fertility improves vigorous vegetative growth and increases leaf production. Climate-smart agricultural practices play a crucial role in enhancing resilience, reducing greenhouse gas emissions, increasing productivity per unit area and mitigating environmental degradation (FAO. 2017). Despite the crucial role played by CSAPs, their adoption by small-scale farmers has been poor globally (Lipper *et al.,* 2014).

Out of the 45, 000 plant species available in SSA, 1000 of them can be eaten as leafy vegetables (Maundu *et al*., 1999). According to Muhanji *et al* (2011), there has been active cultivation of AIVs in SSA for many generations as part of the food systems. African indigenous vegetables form part of Kenyan culture and cuisine. Common indigenous vegetables include; cowpeas, leaf amaranth, black nightshade, jute mallow, *Crotalaria* species, and Cleome species (Abukutsa-Onyango, 2007). These vegetables have the potential to provide nutrition and sustain smallholder farmers' livelihoods**.** According to Ekesi (1999), Kenya has more than 200 species of indigenous vegetables. Indigenous vegetables are naturally rich in nutrients such as vitamins, minerals and micronutrients (Afari-sefa *et al*., 2012). African indigenous vegetables have several medicinal values and health benefits such as managing stomach problems, constipation, respiratory diseases and skin ailments (Kokwaro, 2009). The black nightshade (*Solanum nigrum* L) and cowpeas *(Vigna unguiculata* L*)* vegetables are rich in vitamins, minerals and proteins. These leafy vegetables also contain essential phenols and alkaloids which include; nicotine, quinine, cocaine and morphine, known for their medicinal properties. The vegetables are able to provide a wide range of food and main dish accompaniments (Maundu *et al*., 1999). Despite their growing popularity and diverse health benefits, research on the production aspects of AIVs has not been done (Yang *et al*., 2009).

African indigenous vegetables are mainly produced on subsistence basis and are mostly planted around the house, together with bananas, maize, cassava and sorghum (Kimiywe e*t al*., 2007). Most vegetable production is rain-fed (Banwat, 2012). Cowpea is the most important legume owing to its main economics (Langyintuo *et al.,* 2003). It is an economically and nutritionally important vegetable, which can be harvested for tender and less fibrous leaves (Odhiambo *et al*., 2021) Black nightshade (*Solanum nigrum.* L) is the second most important AIV vegetable in Kenya after cowpeas.

Agriculture is particularly vulnerable to natural and environmental disasters (FAO. (2018). Crop cultivation in ASALs is heavily dependent on local weather dynamics, climate, land and water to thrive. The ever-alarming levels of weather extremes such as droughts and floods for the last 10 years have negatively affected agricultural production in Kenya, mostly in the ASALs. Murang'a South sub-county is centrally located in the ASAL region. The region has low soil fertility levels, water scarcity and very fragile soils making it a suitable site for this study. African Indigenous Vegetables are highly dependent on good farming practices for good yields (Womdim *et al.,*2012). Therefore, the purpose of this study was to determine the effects of selected CSAPs on the yield of two African indigenous vegetables; cowpeas and black nightshade in Kenyan drylands.

## Materials and methods

### Study site description

The research work was carried out in Ithanga location, Murang'a south sub-county in Murang'a County. Murang'a County lies between latitudes 0° 34´ South and 1 ° 07´ South and longitudes 36° East and 37° 27´ East. Ithanga location is found in the eastern part where semi-arid conditions prevail. The area has two rainfall seasons per year; March to May (long rains) and October to December (short rains). Ithanga has average temperatures ranging from 21-35˚C (Figure 1). The study area is characterized by humic nitisols and a dense population of averagely 404.5 people per square km (Kiboi *et al*., 2018). On-farm experiments were conducted during the short rainy season of October to December 2021 and long rainy season of March to May 2022.

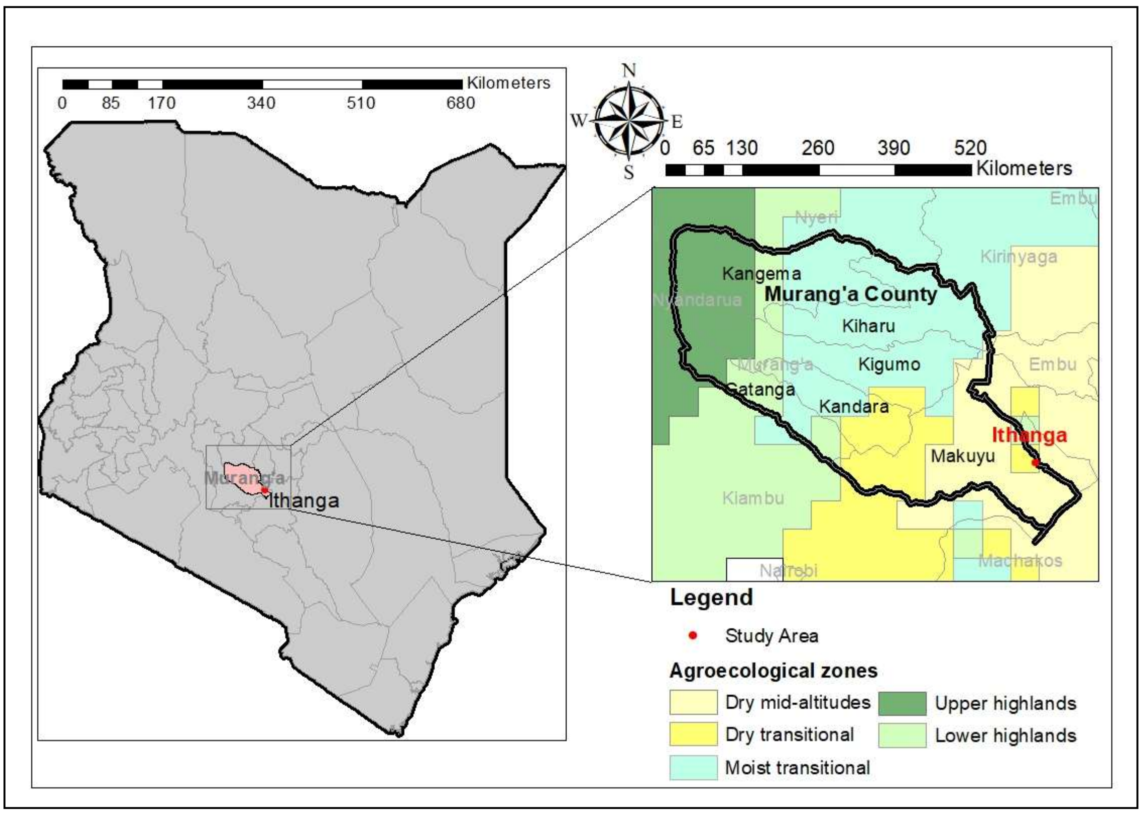


**Figure 1.** Map of Murang'a County showing Ithanga location, the study site.

**Source of vegetable seeds**

The certified cowpea variety M-66 and giant leaf variety of black nightshade used in this study are known to be drought-resistant, high yielding and have robust vegetative growth. Ten grams of the hybrid black nightshade seeds were sourced from the local agrovets and propagated on-site. Two kilograms of cowpeas seeds were sourced from KALRO-Katumani.

**Experimental layout**

The experiments were set out in a randomized complete block design (RCBD) consisting of six treatments replicated three times. The six treatments were; well decomposed organic manure, organic fertilizer (Lisha organic), surface irrigation, mulching (dry grass), farmer practices (CAN and NPK 17.17.17 inorganic fertilizers) and control (no treatments). For each of the focal crops, 18 experimental plots were set up. Square plots measuring 3m by 3m were sowed with 243 seeds for cowpeas and 81 seedlings for black nightshade. They were planted with a spacing of 30cm between plants and 30cm between rows for uniform crop density across all plots. 30g of organic manure was applied per hole at land preparation. Two weeks after crop germination, 5g of inorganic fertilizer (a mixture of NPK 17:17:17 and CAN 26% in 50% ratio) procured from the local agrovets was applied. Mulching using dry grass material was done 2 weeks after planting. Surface irrigation was done once every week using plastic watering cans.

**Planting and crop management**

Three cowpeas seeds were sowed per hole to increase the chances of germination. After thinning and gapping crops, the population was maintained at 162 plants per plot. Yellow and blue stick cards were used for monitoring insect pests. Black nightshade seedlings were first introduced in the nurseries for effective management during early stages of growth and to ensure seedling quality. Weeds were removed physically by handpicking. Two weeding regimes were carried out. Thinning of excess plants was done one week after seed germination. Weak and deformed plants were removed and discarded. Gapping was done to maintain the seed population at 162 plants per plot.

### Fertilizer/manure application

Soil tests were conducted prior to planting and the fertilizers (organic/inorganic fertilizers) applied in accordance with the soil test results. The soil tests were conducted at the Kenya soil survey laboratories located at NARL–KALRO in Kabete.

### Pest and disease control

Pest control was done through application of broad-spectrum biopesticides (pyrethrin with garlic extracts) supplied by Juanco SPS Limited based in Ngong, Kajiado County. Preventive disease control was done by fungicides application. Two regimes of fungicide application using Ridomil gold MZ 68 WG were done at 2 weeks and 5 weeks of growth.

### Data collection and analysis

Efficiency of the selected CSAPs was determined by comparing yields across treatments. Data was collected on plant heights at vegetative stage and the overall primary yield at crop maturity. Weight of harvested leaves, plant height and primary yield were recorded and compared across all treatments. Data was collected over 3 months' duration for two consecutive seasons. Recorded data was entered in Microsoft excel spreadsheet, analyzed and compared across the six treatments. Analysis of variance (ANOVA) was conducted on the quantitative data collected using Genstat software (Genstat-Edition 22). Post hoc analysis was carried out for significant means using Tukey's Honest significant difference (HSD) test at $p \leq 0.05$.

## Results and discussion

### Effects of CSAPs on plant height in cowpeas and black nightshade

There were significant differences in heights of cowpeas plants across the treatments ($p \leq 0.05$). Five treatments were tested in the experiments and results were compared with control plots that had no treatment products applied to them. The plant heights ranged from 24.73cm to 34.20cm. Plants in plots treated with commercial organic fertilizers and organic manure had significantly taller plants (34.2±1.58cm and 30.17±2.55cm respectively) compared to plants that had been mulched with dry grass materials (24.73±1.99cm). However, plants in plots treated with organic fertilizer and manure did not differ significantly with plants exposed to farmer practices, irrigation and controls. (table 1). The experiments used commercial organic fertilizer rich in N, P and K. Studies done by Shah *et al.* (2001) showed a clear correlation between nitrogen application and growth parameters such as height, leaf size and crop biomass which was correlated with the plant's photosynthetic activities. Plots treated with dry grass mulching had the shortest plants followed by farmer's practices (26.00±0.68cm) and controls (28.33±1.80cm). There was no significant difference in height of plants that were mulched, under farmer practices, irrigated and controls. This study contradicts the work done by Kuru *et al*. (2020) who revealed that mulching using dry grass materials significantly increased the plant height in maize and beans in experiments carried out in Wairaka, Jinja, Uganda.

At vegetative stage, there were significant differences in black nightshade plant height across all the treatments ($p \leq 0.05$). Irrigated plots had the highest plant height at 26.33±1.41cm followed by organic fertilizers (20.00±0.73cm) and organic manure (19.33±2.12cm) respectively. Farmers' practices plots had the least plant height followed by mulching and controls respectively (table 1). The three treatments did not have significant effect on black nightshade height. The plant heights ranged from a high of 26.33±1.41cm in irrigated plots to 12.35±2.05cm in farmer's practices plot. There was no significant difference in plant heights among organic manure, organic fertilizer, mulching, farmer practices and control plots. In addition, there was no significant difference in plant height among organic manure, organic fertilizer, irrigated and control plots. Plants in plots under irrigation however showed significantly higher heights compared to plants under mulching and farmer practices. The results agree with Saleh *et al*. (2018) who found out that irrigation water increased the vegetative growth such as plant height and the number of leaves in two bean cultivars.

Differences in plant heights in the two crops can be attributed to effects of treatments applied. Farmers' practices plots were applied with CAN and NPK inorganic fertilizers. The use of inorganic fertilizers has been reported to cause a decrease in the soil pH causing more acidity in soil and this may have negatively affected the plant height. Most crops perform well in pH levels of 6.0-7.0. Low pH levels lead to Al toxicity, which interferes with the uptake of other elements such as P, Mo, and reduction in the soil microbial activities (FAO, 2017). Black nightshade does well in the pH range of 6.0-6.5. Good soil fertility improves vigorous vegetative growth and increases leaf production (Zhao *et al.,* 2009).

**Table 1.** Mean plant height in cowpeas and black nightshade at vegetative stage.

| **Treatment** | **Cowpeas**<br>**Mean height (cm)±SE** | **Black nightshade**<br>**Mean height (cm)±SE** |
|---|---|---|
| Control | 28.33±1.80ab | 18.58±2.35ab |
| Farmer practices | 26.00±0.68ab | 12.35±2.05a |
| Irrigation | 29.00±1.10ab | 26.33±1.41b |
| Mulching | 24.73±1.99a | 15.17±2.88a |
| Organic Fertilizer | 34.20±1.58b | 20.00±0.73ab |
| Organic Manure | 30.17±2.55b | 19.83±2.12ab |
| ***p* Value** | **0.00608 **** | **4.875e-05 ***** |

Means followed by the same letters within a column are not significantly different according to the LSD test at $p$=0.05

**Effects of CSAPs on primary yield in cowpeas over two growing seasons**

During the short rains (October to December 2021), there were significant differences in the amount of primary yield recorded across the various treatments ($p \leq 0.05$). Mulching (3341.67±0.29g) recorded significantly higher yields followed by irrigated plots (3048.33±0.28g), organic manure (2756.67±0.73g), organic fertilizers (2441.67±0.75g) and farmer's practices (1600±0.75g). Control plots (988.33±0.57g) had the least amount of primary yields compared with the other treatments (table 2). Mulching with dry grass material provided a prolonged moist environment, smothered all weeds and ensured continued supply of nutrients through the decaying biomass. This explains the relatively higher yields recorded in the mulching plots. Gradual organic matter mineralization releases essential nutrients into the soil, which are made available for plant absorption and growth. The findings from this research corroborate results by Niang *et al*. (1996) who noted that adding fresh *Tithornia* biomass increased maize yield. Similar results were also obtained by Buyushan *et al*. (2002) who used polythene mulch and dried sorghum straws which considerably improved the crop height, dry matter weight and the quantity of leaves in maize.

Farmer's practices plots were applied with CAN and NPK inorganic fertilizers in a ratio of 1:1. Use of fertilizers increases the soil's natural fertility (El-Aziz, 2007). Fertilizers are designed to directly meet plant needs by altering aspects of the soil's structure and pH. The quantity and quality of plant growth are greatly improved when the right fertilizers are applied to soils (Liu, 2010). Low yields recorded in control plots was due to lack of soil fertility improvement products that were used in the other treated plots. According to Cockroft *et al*. (2000) crop yields can be tripled by the use of irrigation water. Well-irrigated crops have increased photosynthetic rates and are able to also withstand attack by some insect pests leading to higher yields as recorded in this study. These results agree with those obtained by Fageria (2006). Dry soils caused by reduced rainfall or lack of soil cover such as mulching leads to low productivity. During dry weather, lack of sufficient moisture makes it difficult for the plants to take up essential nutrients from the soil for better crop performance. Irrigated plants tend to be less stressed and have better chances of reaching physiological maturity (Stewart, 1990). Optimal nitrogen presence in the soil due to application of inorganic fertilizers and organic manure led to increased photosynthetic activity and thus yields (Nduwimana *et al*., 2020).

During the long rains (March to May 2022), there were significant differences in primary yield recorded across all treatments ($p \leq 0.05$). Plots treated with organic manure produced significantly higher yields (2825± 0.39g) followed by organic fertilizer (2263.33± 0.77g) and mulching (2195±1.89g). Controls had the least amount of yields at 471.67± 0.57g followed by farmer's practice (1080±0.78g) and irrigated plots (1911.67±0.75g) (table 2). Low yields recorded in control plots was due to lack of soil fertility improvement products and moisture that were increased in the other treatment plots. The differences in primary yield in cowpeas under different treatments can be attributed to effects of the products applied. Climate-smart agricultural practices/products reduce pest populations, improve plant health and thus yield levels. Further, the study findings indicate that there was significant difference in the yields recorded in control and farmer's practices plots over the two seasons. An inadequate supply of primary (N, P, and K) nutrients leads to poor yields (Burney *et al.,* 2012). This means that despite the differences in rain and weather patterns over the two seasons, failure by farmers to implement CSAPs will continuously result in poor yields. Mulching, irrigation, organic manure and organic fertilizer recorded significantly different yields over the two seasons with season one having comparatively higher yields. This could be explained by the heavier and extended rains, which were witnessed in the October to December 2021 short rainy season. The rains diluted the nutrients supplied by mulching materials, organic manure and organic fertilizer and made them readily available for the plant's uptake. The weight of harvested cowpea leaves was positively impacted by grass mulch (table 2). These findings agree with Jodaugienė *et al*.(2010) and Lorenzo *et al.* (2011) who recorded increased crop yields attributable to mulching.

**Table 2.** Mean primary weight in cowpeas under different CSAPs over two growing seasons

| **Cowpeas** | **Short rainy seasons (Oct-Dec 2021)** | **Long rainy season (March-May 2022)** |
|---|---|---|
| **Treatment** | **Mean weight (g) ±SE** | **Mean weight(g) ±SE** |
| Control | 988.33±0.57a | 471.67±0.57a |
| Farmer Practices | 1600±0.75b | 1080±0.78b |
| Irrigation | 3048.33±0.28e | 1911.67±0.75c |
| Mulching | 3341.67±0.29f | 2195±1.89cd |
| Organic Fertilizer | 2441.67±0.75c | 2263.33±0.77d |
| Organic Manure | 2756.67±0.73d | 2825±0.39e |
| ***p*-value** | **1.609e-05 ***** | **1.609e-05 ***** |

Means followed by the same letters within a column are not significantly different according to the LSD test at $p \leq 0.05$.

### Effects of CSAPs on primary yield in black nightshade over two growing seasons

During the short rains (October to December 2021), there were significant differences in the primary yield recorded among all the treatments ($p \leq 0.05$) (table 3). There was a significant difference between the yield levels across the two seasons and across treatments. During the long rainy season, significantly higher primary yields were recorded ($p \leq 0.05$) compared to short rainy season ($p \leq 0.05$). During short rainy season, irrigated plots recorded the highest yields (1825±1.79g) followed by organic fertilizer (1683.33±4.34g) and mulching (1528.33±1.71g) respectively. However, there was no significant difference between yields from plots where mulching was done and where organic manure was applied. Controls (791.67±1.22g) had the least amounts of yields followed by farmer's practices (1026.6±2.02g) and organic manure (1453.33±1.34g) (table 3).

According to Burney *et al*. (2012), irrigation makes it easier to use other productivity-boosting inputs and intensifies smallholder-farming methods. Irrigation water dilutes available nutrients and makes them available for plant uptake thus irrigated fields produced the highest yields. However, the heavy and extended rains witnessed in the short rainy season from October to December 2021 negatively affected the yields by causing nutrient leaching and erosion of nutrients through surface runoff. Surface runoff leads to soil erosion of highly nutritious top soil and plant nutrient depletion. Leaching removes nutrients from surface soils (top soil) and moves them to deeper layers making them inaccessible to the plants. The downward movement of the nutrients further denies plants essential minerals meant for their proper growth. This leads to stunted plants and thus poor yields.

During the long rainy season (March–May 2022), plots treated with organic manure had significantly higher yields (3226.67±3.54g) followed by plots treated with commercial organic fertilizer (2758.33±3.19g), mulching (2690±2.1g), irrigation (2306.67±2.12g), farmers' practices (1875±1.11g) and controls (1373.33±0.77g) respectively (table 3). The moderate and evenly distributed rainfall experienced during this season effectively diluted all the applied products and made them available for the plant's uptake. Control plots recorded the least amount of yields followed by farmer's practices plots that had been treated with inorganic fertilizers (table 3), though the difference was significant. Plots treated with organic manure had significantly higher yields compared to all the other treatments. Soil organic carbon found in organic manure is the main component of soil organic matter (Yemefack *et al*.,2006). Soil organic matter affects plant growth since it is a source of energy and triggers nutrient availability through mineralization process (Yemefack *et al*., 2006). Soils applied with organic manure have robust microbial activity (Jabeen *et al*., 2018) which further improved the crop yield. Further, Ahmad *et al*. (2022) discovered that soils' water holding capacity is highly improved by the soil organic matter and this probably explains why plots applied with organic manure recorded higher yields in the second season.

Significantly, higher yields were recorded during the long rainy season compared to short rainy season across all treatments. There were heavier rains witnessed during short rainy season in the study sites. This created damp soils and probably caused nutrient leaching. Black nightshade requires well-drained soils for proper nutrient uptake and growth. The damp soils lowered the soil temperature and reduced the plant's metabolic rates leading to poor growth and low yield. The long rainy season had modest rainfall, which provided well-drained soils which resulted in better crop performance. The highest yield in crops relies on the plant's maximum photosynthetic productivity (Singh and Singh, 2007).

**Table 3.** Mean primary weight in black nightshade under different CSAPs over two growing seasons.

| **Black nightshade** | **Short rainy season (Oct-Dec 2021)** | **Long rainy season (March -May 2022)** |
|---|---|---|
| **Treatment** | **Mean weight (g)±SE** | **Mean weight (g) ±SE** |
| Control | 791.67±1.22a | 1373.33±0.77a |
| Farmer Practices | 1026.6t±2.02a | 1875±1.11b |
| Irrigation | 1825±1.79c | 2306.67±2.12c |
| Mulching | 1528.33±1.71b | 2690±2.10d |
| Organic Fertilizer | 1683.33±4.34bc | 2758.33±3.19d |
| Organic Manure | 1453.33±1.34b | 3226.67±3.54de |
| ***p*-value** | **7.014e-05 ***** | **0.0001969***** |

Means followed by the same letters within a column are not significantly different according to the LSD test at $p \leq 0.05$.

## Conclusion and recommendations

Yield levels in the two indigenous vegetables were significantly influenced by the CSAPs used. Plots treated with organic manure, mulching and commercial organic fertilizers produced higher yields across all crops and growing seasons. Control plots had the least yields. These findings suggest that farmers can achieve excellent yield results with the adoption of CSAPs. More research is needed on the long-term effects of CSAPs on soil structure and fertility. The study further recommends that farmers should use sustainable farming practices that preserve soil fertility and structure and increase AIVs crop yield.

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