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Impacts of Selected Climate-Smart Agricultural Practices on African Indigenous Vegetables in Kenyan Drylands

[1]*Eric Muthama,* [2]*Rebecca Karanja,* [1]*Namikoye Everlyne Samita and* [2]*Najma Dharani*
[1]*Department of Agricultural Science and Technology, Kenyatta University, Nairobi, Kenya*
[2]*Department of Plant Sciences, Kenyatta University, Nairobi, Kenya*

ABSTRACT

Background and Objective: African indigenous vegetables (AIVs) are important food crops used in combating malnutrition and food insecurity. However, their production is constrained by poor soil fertility caused by soil degradation and poor farming practices. The objective of this study was to evaluate the Impacts of climate-smart agricultural practices on the yield parameters of two AIVs in Kenyan drylands over two growing seasons. **Materials and Methods:** Separate research plots were laid out in randomized complete block design and sowed with cowpeas (*Vigna unguiculata* L.) and black nightshade (*Solanum nigrum* L.) seeds six treatments of organic manure, commercial organic fertilizers, irrigation, mulching, farmer practices and control were used. The ANOVA was conducted on the data and *post hoc* analysis was carried out for significant means using Tukey's Honest Significant Difference (HSD) Test at $p \leq 0.05$. **Results:** The results revealed significant differences in plant height and the primary yield across all climate-smart treatments ($p \leq 0.05$). Plots applied with dry grass mulches had significantly higher yields followed by plots applied with organic manure ($p \leq 0.05$). Control plots had the lowest amounts of yields. The African indigenous vegetables and pulses yield levels were significantly influenced by the climate-smart agricultural products (CSAPs) used. **Conclusion:** The African indigenous vegetable yield levels were significantly influenced by the CSAP products used. Organic manure, mulching and organic fertilizers had significantly higher yields. Control plots had the lowest yields followed by farmer's practices.

KEYWORDS

Soil degradation, food security, malnutrition, ANOVA, organic fertilizers, organic manure, treatments

INTRODUCTION

Generally, there is limited capacity to control the rate of climate change within the 2°C threshold necessitating a need to cope with its effects[1]. Sub-Saharan Africa (SSA) is the most affected by climate change[2].

Climate change has had a significant impact on the cultivation of African indigenous vegetables resulting in insufficient yields and food insecurity[3]. Established that soil degradation is the leading cause of reduced agricultural production among smallholder farmers. Among the soil nutrients, nitrogen is the most

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important and the most deficient mineral element. The use of inorganic fertilizers has been reported to cause an increase in the 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 P and Mo and reduction in soil microbial activities[4]. 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[5]. Notwithstanding the crucial role played by these smart practices, their adoption by small-scale farmers has been of a lower degree, globally[6].

Out of the 45,000 plant species available in SSA, 1000 of them can be eaten as leafy vegetables[7]. According to Muhanji *et al.*[8], there has been active cultivation of African indigenous vegetables 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[9]. These diverse vegetables have the potential to provide nutrition and sustain smallholder farmers' livelihoods. According to Ekesi[10] Kenya has more than 200 species of indigenous vegetables. Indigenous vegetables are naturally dense in nutrients such as vitamins, minerals and micronutrients[11]. African indigenous vegetables have several medicinal values and health benefits such as managing stomach problems, constipation, respiratory diseases and skin ailments[12]. The vegetable is able to provide a wide range of food and main dish accompaniments[13]. According to Yang and Gudrun[14], not much research has been done on the production aspects of AIVs despite their growing popularity and diverse health benefits. 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 known for their medical properties, they include, nicotine, quinine, cocaine and morphine.

African indigenous vegetables are produced mainly on a subsistence basis, they often occupy areas around the house, together with bananas, maize, cassava and sorghum[15]. Most vegetable production is rain-fed[16]. Cowpeas are the most important legume owing to its main economics[17]. Cowpea is an economically and nutritionally important vegetable, which can be harvested for tender and less fibrous leaves[18]. Black nightshade (*Solanum nigrum* L) Is the second most important AIV vegetable in Kenya after cowpeas. The production of highly nutritious vegetables has been severely affected by climate change[19].

Crop cultivation in ASALs is heavily dependent on local weather dynamics, climate, land and water for its ability to thrive, agriculture is particularly vulnerable to natural and environmental disasters[20]. 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 ASALs regions, the region has low soil fertility levels, water scarcity and very fragile soils making it a suitable site for this study. The AIVs are highly dependent on good farming practices for good yields[21]. Therefore, the purpose of this study was to determine the effects of selected climate-smart agricultural practices on the yield of two African indigenous vegetables, cowpeas (*Vigna unguiculata*) and black night (*Solanum nigrum* L.) 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. The location of Murang'a County lies between Latitudes 0°34' South and 1°07' South and Longitudes 36°East and 37°27' East. Ithanga Location is located in the eastern part with semi-arid conditions. 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. The study area is characterized by sandy/clay soils with a dense population of an average of 404.5 people per square km. The on-farm experiments were conducted during the long and short rains seasons of October to December, 2021 and long rains of March to May, 2022.

Plant material: The certified cowpea (M-66 variety) and black nightshade (giant leaf variety) plant varieties used in the 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 agro vets 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). Eighteen experimental plots were set up for each of the focal crop crops. Square plots measuring 3 m by 3 m were sowed with 243 seeds for cowpeas and 81 seedlings for the black nightshade. Spacing of 30 cm between plants and 30 cm between rows for uniform crop density across all plots. Thirty grams of organic manure was applied per hole at land preparation. Five grams of inorganic fertilizer (a mixture of NPK 17:17:17 and CAN 26%). In 50% ratio procured from the local agrovets was applied two weeks after crop germination. Mulching using dry grass materials was done two weeks after planting. Surface irrigation was done once every week using plastic watering cans.

Planting and crop management: Three cowpeas-treated 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 the early stages of growth and to ensure seedlings' quality and quantity. Weeding was done by the physical removal of weeds. The weeds were removed 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 as 162 plants per plot.

Fertilizer/manure application: Soil tests were conducted prior to planting and the fertilizers (Organic/inorganic fertilizers) were applied in accordance with the soil test results. The soil tests were conducted at the Kenya soil survey labs located at NARL-KALRO in Kabete.

Pest and disease control: Pest control was done through the 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 fungicide application. Two regimes of fungicide application using Ridomil gold MZ 68 WG were done at 2 weeks and 5 weeks of growth. The broad-spectrum fungicide has two active ingredients i.e., Metalaxyl and Mancozeb.

Data collection: The efficiency of the selected climate-smart agricultural practices was determined by comparing the yields across the treatments. Data was collected on the plant heights at the vegetative stage and the overall primary yield at crop maturity. The weight of the harvested leaves, plant height and primary yield were all recorded and compared across all treatments. Data was collected over a 3 month duration for two consecutive seasons. The recorded data was entered in the Excel spreadsheet, analyzed and compared across the six treatments.

Statistical analysis: Analysis of Variance (ANOVA) was conducted on the quantitative data collected. The Data was analyzed 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 climate-smart practices on the plant height in cowpeas and black nightshade: Cowpeas, (*Vigna unguiculata*). There were significant differences in the heights of the cowpeas plants across the treatments ($p \leq 0.05$). Five treatments were tested in the experiments and results were compared with the control plots that had no treatment products applied to them. Plots treated with commercial organic fertilizers had significantly taller plants (34.2 cm) followed by organic manure (30.17 cm) and irrigation plots (29.00 cm) (Table 1). The plant height ranges from 24.73 to 34.20 cm. The experiments used commercial organic fertilizer rich in N, P and K. Studies done by Shah *et al.*[22] showed a clear correlation between nitrogen application rate and the crop yield which was correlated with the plant's photosynthetic activities. Crop productivity is affected by fertilizer application[23]. Plots installed with the dry grass mulching (24.73 cm) had the lowest plant heights followed by farmer's practices (26.00) and control (28.33). The differences in the plant heights in the two crops can be attributed to the effects of the treatments applied. This study contradicts the works done by McCann *et al.*[24], who revealed that mulching using plastic mulching film materials promotes early growth.

Black nightshade (*Solanum nigrum*): At the vegetative stage, there were significant differences in plant height across all the treatments $p \leq 0.05$). Irrigated plots had the highest plant height at 26.33 cm followed by organic fertilizers (20.00 cm) and organic manure (19.33 cm), respectively (Table 1). According to Cockroft and Olsson[25] crop, yields can be tripled by the use of irrigation water. Farmers' practice plots had the least plant height followed by mulching and control, respectively (Table 1). The plant height ranges from a high of 26.33 cm in irrigated plots to 12.35 cm in the farmer's practices plot. The differences in the plant heights in the two crops can be attributed to the effects of the treatments applied. The results from the mulched plots contradict the works done by Lamont[26], who revealed that mulching using plastic film promotes early growth farmers' practices plots were applied with CAN and NPK inorganic fertilizers as per the soil test results, however, the plant height was the lowest in these plots compared with all the other treatments. The use of inorganic fertilizers has been reported to cause a decrease in the 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 Al toxicity which interferes with the uptake of other elements such as P and Mo and reduction in the soil microbial activities[5]. Black nightshade does well in the pH range of 6.0-6.5. Nightshade crops do very well in fertile soils rich in nitrogen or phosphorus[27]. Good soil fertility improves vigorous vegetative growth and increases leaf production[28].

Effects of climate-smart agricultural practices on primary yield in african indigenous vegetables (cowpeas)over two growing seasons: Cowpeas (*Vigna unguiculata*), in season one, during the short rains (October to December, 2021) there were significant differences in the amount of primary yields recorded across the various treatments ($p \leq 0.05$). Mulching (3,341.67 g) recorded significantly higher yields followed by irrigated plots (3,048.33 g), organic manure (2,756.67 g), organic fertilizers (2,441.67 g) and farmer's practices (1,600 g). Control (988.33 g) had the least amount of primary yields compared with the other treatments (Table 2). 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[29]. 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 the soils[30].

Table 1: Mean plant height in cm±standard errors in cowpeas and black nightshade at the vegetative stage

	Cowpeas	Black nightshade
Treatment	Mean height (cm)±SE	Mean height (cm)±SE
Control	28.33±1.80[ab]	18.58±2.35[ab]
Farmer practices	26.00±0.68[ab]	12.35±2.05[a]
Irrigation	29.00±1.10[ab]	26.33±1.41[b]
Mulching	24.73±1.99[a]	15.17±2.88[a]
Organic fertilizer	34.20±1.58[b]	20.00±0.73[ab]
Organic manure	30.17±2.55[b]	19.83±2.12[ab]
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, **p-value is less than 0.01 and ***p-value is less than 0.001

Table 2: Mean primary weight in grams±standard errors in cowpeas under different CSAPs over two growing seasons

Cowpeas Treatment	October-December, 2021 short rains seasons Mean weight (g) ±SE	March-May, 2022 long rains season Mean weight(g) ±SE
Control	988.33±0.57[a]	471.67±0.57[a]
Farmer practices	1600±0.75[b]	1080±0.78[b]
Irrigation	3048.33±0.28[e]	1911.67±0.75[c]
Mulching	3341.67±0.29[f]	2195±1.89[cd]
Organic fertilizer	2441.67±0.75[c]	2263.33±0.77[d]
Organic manure	2756.67±0.73[d]	2825±0.39[e]
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 $p \leq 0.05$ and ***p-value is less than 0.001

In season two, there were significant differences in the primary yield recorded across all treatments ($p \leq 0.05$). Organic manure produced significantly higher yields (3,226.67 g) followed by organic fertilizer (2758.33 g) and mulching (2690 g). Control had the least amount of yields at 471.67 grams followed by farmer's practice (1,080 g) and irrigated plots (1,911.67 g) (Table 2). The low yield recorded in the control plots was due to the lack of soil fertility improvement products that were used in the other treated plots. The differences in the primary yield in cowpeas under different treatments can be attributed to the effects of the products applied. Climate-smart agricultural practices/products reduce pest populations, which further improves plant health, which significantly improves yield levels. Further, the study findings indicate that there was no significant difference in the yields recorded in control and farmer's practices plots over the two season periods. This means that despite the differences in rain and weather patterns over the two seasons, failure by farmers to implement climate-smart agriculture practices 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 better rains, which were witnessed in the October to December, 2021 short rain 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. Inadequate supply of primary (N, P and K) nutrients leads to poor yields[31]. Our Findings indicated that the weight of the harvested leaves (Table 2) was positively impacted by grass mulch. The findings agree with the research works by Lorenzo *et al.*[32], on mulching with black polythene, which increased cucumber yields in comparison to plants grown in soil without mulching. According to Jodaugiene *et al.*[33], mulches enhance worm presence and activity which further affects crop quality and quantity.

Effects of climate-smart agricultural practices on primary yield in African indigenous vegetables (black nightshade) over two growing seasons.

Black nightshade (*Solanum nigrum*), in season one, there were significant differences in the primary yield recorded among all the treatments ($p \leq 0.05$) (Table 3). Season one experiments were conducted during the short rainfall season in October to December, 2021 while season two experiments were conducted during the March to May, 2022 long rainfall season. There was a significant difference between the yield levels across the two seasons and across the treatments used. Season two *** had significantly higher primary yields ($p \leq 0.0001969$) compared to season one ($p \leq 7.014e{-}05$***). In season one, irrigated plots recorded the highest yields (1,825 g) followed by organic fertilizer (1,683.33 g) and mulching (1,528.33 g), respectively. Control (791.67 g) had the lowest amounts of yields followed by farmer's practices (1026.60 g) and organic manure (1,453.33 g) (Table 3). According to Burney and Naylor[31], 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. However, the heavy rains witnessed in the short rainfall 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 the highly nutritious topsoil and plant nutrient depletion.

Table 3: Mean primary weight in grams±standard errors in black nightshade under different CSAPs over two growing seasons

Black nightshade	October-December, 2021 short rains seasons	March-May, 2022 long rains season
Treatment	Mean weight (g)±SE	Mean weight (g) ±SE
Control	791.67±1.22^{a}	1373.33±0.77^{a}
Farmer practices	1026.6t±2.02^{a}	1875±1.11^{b}
Irrigation	1825±1.79^{c}	2306.67±2.12^{c}
Mulching	1528.33±1.71^{b}	2690±2.10^{d}
Organic fertilizer	1683.33±4.34^{bc}	2758.33±3.19^{d}
Organic manure	1453.33±1.34^{b}	3226.67±3.54^{de}
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 $p \leq 0.05$ and ***p-value is less than 0.001

In season two during the long rains season (March to May, 2022), plots applied with organic manure had significantly higher yields (3,226.67 g) followed by plots applied with the commercial organic fertilizer (2,758.33 g), mulching (2,690 g), farmers' practices (1,875 g), irrigation (2,306.67 g) and control (1,373.33 g). The moderate and evenly distributed rainfall in season two effectively diluted all the applied products and made them available for the plant's uptake. The control plots that had no products applied in them recorded the least amount of yields followed by farmer's practices plots that had been applied with inorganic fertilizers (Table 3). Plots applied with organic manure had significantly higher yields compared with all the other treatments. Soil organic carbon found in organic manure is the main component of the soil organic matter[34]. Soil organic matter affects plant growth since it is a source of energy and triggers nutrient availability through the mineralization process. Soil organic matter improves the soil's water-holding capacity[35].

Season two had significantly higher yields compared to season one across all treatments. There were massive rains witnessed in season one in the study sites (October to December, 2021) this created dumped soils and probably caused nutrient leaching. Black nightshade belongs to the *Solanaceae* family, crops in this family require well-drained soils for proper nutrient uptake and growth. The dump soils also lower the soil temperature, which reduces the plant's metabolic rates leading to poor growth and low yield. Season 2 had modest rainfall, which provided well-drained soils and high temperatures, which resulted in better crop performance. Plants manufacture their own food through the process of photosynthesis, which depends on available nutrients prevailing temperatures and carbon dioxide concentrations in the atmosphere. The highest yield in crops relies on the plant's maximum photosynthetic productivity[36]. The use of organic manure resulted in higher yields compared with all the other treatments. Soils applied with organic manure have robust microbial activity[37], which further improves the crop yield.

The study further recommends that farmers should use sustainable farming practices that preserve soil fertility and structure and increase AIVs crop yield. Evaluation of the effectiveness of the climate-smart agricultural practices should be carried out in the context of yield improvements among smallholder farmers in Murang'a South.

CONCLUSION

Yield levels in the two indigenous vegetables were significantly influenced by the CSA products used. Organic manure, mulching and commercial organic fertilizers had higher yields across all crops and growing seasons. Control plots had the lowest yields. Based on these findings, an analysis of the crop's economics suggests that farmers can achieve excellent yield results with the adoption of climate-smart agricultural practices. More research is needed on the long-term effects of CSA practices on soil structure and fertility.

SIGNIFICANCE STATEMENT

Kenyans have seen an increase in diet-related ailments such as diabetes and obesity. African indigenous vegetables are micronutrient-dense and could prove a powerful weapon in the fight against obesity, disease and poverty alleviation. Daily consumption of AIVs and pulses in their recommended portions prevents serious diseases and safeguards food insecurity. This study investigated the effects of climate-smart agriculture practices on the production of AIVs in Kenya's dryland. The results showed that the adoption of climate-smart practices such as mulching; organic manure, irrigation and the use of organic fertilizers can significantly increase the quantity of the yields and build on farmer's resilience and adaptation to climate change.

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