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An Evaluation of the Effectiveness of Moringa (*Moringa Oleifera*) Leaf Juice Extract as a Foliar Fertilizer and Synthetic Fertilizer on the Growth and Yield of Cabbage (*Brassica Oleracea*) in Namlombwe Camp of Chilanga District in Lusaka

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Abstract

This study evaluates the effectiveness of Moringa (*Moringa oleifera*) leaf juice extract as a foliar fertilizer and synthetic fertilizer on the growth and yield of cabbage (*Brassica oleracea*) in Namalombwe Camp, Chilanga District, Lusaka. The research aims to provide a sustainable and environmentally friendly alternative to conventional synthetic fertilizers. Given the rising costs and environmental concerns associated with synthetic fertilizers, Moringa leaf extract is investigated for its potential to enhance cabbage growth, yield, and quality. The experimental design involves randomized complete block design (RCBD) with cabbage plants treated with different concentrations of Moringa leaf extract, synthetic fertilizers,

and a control group. Key growth parameters such as plant height, leaf count, and head weight are measured throughout the study. Data are analyzed using SPSS version 25.0, with statistical significance determined through one-way ANOVA and Pearson correlations.

The study highlights the importance of sustainable agricultural practices, aiming to reduce the dependence on synthetic fertilizers while ensuring optimal cabbage production. The findings are expected to contribute to the adoption of organic fertilizers and growth promoters in Zambian agriculture, promoting both food security and environmental conservation.

Keywords: Moringa Leaf Extract, Foliar Fertilizer, Cabbage Growth, Synthetic Fertilizers, Sustainable Agriculture, Zambia, Organic Farming, Yield Improvement

Introduction

Background

Cabbage (*Brassica oleracea*) belongs to the Brassicaceae family, one of the largest plant families. It is a well-known cool-season vegetable with shallow roots, cultivated for its large leafy head. The crop was initially grown in Western Europe (FAO (2023)). According to the Food and Agriculture Organization of the United Nations (FAO) in 2021, global cabbage production reached 71.7 million tons, making it one of the world's most cultivated vegetables. Asia accounted for 78.2%, Europe 13%, Africa 5.7%, while the Americas and Oceania contributed 2.9% and 0.2% respectively (Singh (2006)). Cabbage is low in fat but rich in dietary fiber, folate, water, and Vitamin C, giving it a high nutritional density that helps protect against various diseases (Moreb (2020)). Its production varies globally, with China leading at 32,800,000 tons, followed by India with 8,500,000 tons, and Russia at 3,309,315 tons (Moreb (2020)). The precise origin of cabbage is unclear, but it is believed to have originated along the South and Western coasts of Europe or in the Eastern Mediterranean and Asia Minor (Maggioni (2010, 2015)). According to Dixon (2007), Leike (1988), cabbage was first cultivated in the Netherlands in the 14th century and later spread to other European and Mediterranean regions. European colonialists introduced the crop to Africa in the 16th century (Dixon (2007)).

In Kenya, cabbage is among the most popular leafy vegetables, widely consumed in both rural and urban areas (Wambani (2007), Kibata (1997)). It is highly nutritious, consisting of 92% water, 1% proteins, 0.1% lipids, and 5% carbohydrates (Butnariu & Butu (2015)). Additionally, it contains 2% fiber, along with Vitamins A, C, and K, and minerals like calcium, iron,

sodium, zinc, magnesium, phosphorus, and potassium, all crucial for human nutrition and health Singh (2009) [3], Cervantes-Godoy & Dewbre (2010). Cabbage also contains phenolics and glucosinolates, which are known for their anti-carcinogenic properties, effectively reducing cancer risks and preventing other diseases like type 2 diabetes, cardiovascular issues, digestive inflammation, cataracts, and Alzheimer's disease Sarikamis, (2009), Abdull Razis & Noor (2013). Consuming cabbage also ensures sufficient iodine levels, promoting proper brain function, as well as the health of the thyroid gland and nervous system. Beyond its nutritional benefits, cabbage serves as an important income source for Zambian farmers, particularly small scale producers dependent on agriculture for their livelihoods. The rise in cabbage consumption has driven increased production in Zambia. Nutrient supply is crucial for achieving higher yields and better nutrient content Hasan (2018).

Cabbage requires significant quantities of all nutrients, especially nitrogen, with demands ranging between 130–310 kg/ha Milas & Vincent (2017). However, Zambian cabbage growers face challenges such as nutrient deficiencies in the soil, which lead to poor yield and quality. Although Zambian farmers traditionally use inorganic fertilizers to boost productivity and profits, these fertilizers are often expensive and contribute to health problems and irreversible environmental pollution, making it necessary to explore more sustainable, eco-friendly alternatives Karthiga (2022).

Safe and clean vegetables are essential to human health, and biofertilizers (organic fertilizers) are vital for producing safe leafy vegetables. The use of biofertilizers also helps protect the environment from soil degradation and groundwater contamination. One biofertilizer gaining attention for its potential to improve plant growth and yield is moringa leaf extract, derived from *Moringa oleifera* Zulfiqar (2020), Karthiga (2022). Previous studies have shown that moringa leaf extract can enhance the growth and yield of crops like peppers Matthew (2016), tomatoes Culver (2012), and maize Biswas (2016). Furthermore, continuous use of organic fertilizers like moringa improves soil organic carbon, total nitrogen content, microbial biomass, and the functional diversity of soil microbes, boosting soil productivity Chinnadurai (2014).

Given the importance of cabbage in the diet and livelihoods of the Zambian population, the health and environmental risks posed by the continued use of inorganic fertilizers, and their high costs Snr (2020), it is critical to evaluate the effectiveness of moringa (*Moringa oleifera*) leaf extract as a foliar fertilizer and growth enhancer for cabbage production in Zambia.

Problem Statement

The escalating use of synthetic fertilizers in conventional cabbage farming, driven by the rising global demand for food, presents a significant environmental concern, necessitating a thorough evaluation of alternative agricultural practices Backler (2017). Numerous studies Smith (2018), Gonzalez (2020) have highlighted the detrimental effects of synthetic fertilizer use on ecosystems, including soil contamination, water pollution, and the potential for nutrient imbalances in the soil.

While global research suggests the potential of Moringa leaf extract in reducing fertilizer dependency Hassan (2020), its

applicability to Zambia's unique agricultural landscape remains unclear. Critical questions surround the extent to which Moringa leaf extract can minimize synthetic fertilizer use while maintaining or even improving cabbage growth, yield, and quality. Addressing this knowledge gap is essential, prompting a focused investigation into the effectiveness of Moringa (*Moringa oleifera*) leaf juice extract as a foliar fertilizer and growth enhancer in cabbage production, with the goal of reducing synthetic fertilizer usage.

General Objective

Evaluation of the effectiveness of moringa (*moringa oleifera*) leaf juice extract as a foliar fertilizer and synthetic fertilizer on the growth and yield of cabbage (*brassica oleracea*).

Specific Objectives

1. To evaluate the effectiveness of Moringa leaf juice extract on cabbage plant growth.
2. To evaluate the effectiveness of Moringa leaf juice extract on cabbage plant yield and quality.
3. To compare the effectiveness of Moringa leaf extract and synthetic fertilizer on cabbage plant growth and yield.

Hypothesis

Null Hypothesis (H_0): There is no significant effect of Moringa leaf foliar fertilizer on cabbage growth, yield, and quality.

$$H_0: \mu_{\text{Moringa}} = \mu_{\text{Control}}$$

Alternative Hypothesis (H_a): There is a significant effect of Moringa leaf foliar fertilizer on cabbage growth, yield, and quality.

$$H_a: \mu_{\text{Moringa}} \neq \mu_{\text{Control}}$$

Where:

μ_{Moringa} represents the mean growth, yield, or quality of cabbage plants treated with Moringa leaf extract.

μ_{Control} represents the mean growth, yield, or quality of cabbage plants treated with synthetic fertilizer or no treatment (control group).

Theoretical Framework

Sustainable agriculture focuses on developing farming systems that meet the food production needs of the present without compromising the ability of future generations to meet their own needs. This involves maintaining soil health, preserving biodiversity, and minimizing environmental impacts while ensuring economic viability for farmers. In contrast to conventional farming systems that heavily rely on synthetic fertilizers, pesticides, and herbicides, sustainable agriculture seeks to reduce dependency on harmful chemicals and practices. Synthetic fertilizers and pesticides, although effective in enhancing crop yields, are associated with a range of environmental and health concerns, such as soil acidification, contamination of water sources, loss of biodiversity, and human health risks Tilman *et al.* (2002) [11]. These adverse effects have led to increasing global interest in finding alternatives that are not only effective but also environmentally sustainable and economically

accessible.

One promising alternative is the use of organic fertilizers and plant-based inputs, such as Moringa (*Moringa oleifera*) leaf extracts.

Moringa, often referred to as the “miracle tree,” is gaining attention for its potential to enhance agricultural productivity while promoting environmental sustainability. The use of moringa leaf juice extracts in agriculture is particularly notable due to their rich composition of essential nutrients and bioactive compounds that can serve as natural fertilizers and pest deterrents. Studies have shown that moringa leaf extract is not only effective in promoting plant growth but also in improving soil health and reducing the need for chemical inputs, offering a sustainable alternative to conventional fertilizers and pesticides Makkar & Becker (2007). In the context of sustainable agriculture, moringa-based fertilizers are gaining traction as an environmentally friendly solution. These organic alternatives are particularly important in developing countries where smallholder farmers face challenges related to the high cost of synthetic fertilizers and pesticides. Moringa leaf extract’s ability to promote plant growth, enhance soil fertility, and act as a natural pesticide makes it an ideal candidate for promoting both agricultural productivity and environmental sustainability in these regions. As a result, exploring the mechanisms by which moringa leaf extract affects plant growth is essential for advancing sustainable agricultural practices globally.

Plant Growth Promotion with Moringa Leaf Extracts

Moringa oleifera, known for its resilience and rapid growth in diverse environmental conditions, has gained attention as a natural plant growth promoter. The leaves of the moringa trees are packed with essential nutrients, including nitrogen, phosphorus, potassium, calcium, magnesium, and trace minerals, all of which are vital for plant health and growth Moyo (2011). The nutrient density of moringa leaf extracts, combined with their ability to improve plant vitality, make them an attractive alternative to synthetic fertilizers.

Research conducted by Anwar *et al.* Anwar (2015) demonstrated that the application of moringa leaf extracts significantly improved plant height, leaf area, and overall yield in several crops, including cabbage. The positive effects of moringa on plant growth can be attributed to the high levels of essential nutrients present in the leaf extract. Nitrogen, for example, is a critical element for plant growth, as it is an essential building block for amino acids and proteins, which are fundamental for plant development.

Phosphorus is equally important, as it aids in energy transfer and root development, while potassium supports the regulation of water balance, disease resistance, and photosynthesis Moyo (2011). These nutrients, when supplied in the form of moringa leaf extracts, contribute to enhanced growth and improved yields. In addition to these essential macronutrients, moringa leaves also contain various bioactive compounds such as flavonoids, phenolic acids, and antioxidants, which have been shown to have positive effects on plant health. These compounds help improve plant resistance to diseases, pests, and environmental stress, thereby enhancing crop productivity Makkar & Becker (2007). Thus, moringa leaf extracts serve as a multi-functional input that not only enhances plant growth but also promotes overall plant health, reducing the

need for external chemical inputs.

Function of Phytohormones in the Regulation of Plant Growth

A key factor in the growth-promoting properties of moringa leaf extracts is their rich content of plant hormones or phytohormones, which play crucial roles in regulating plant growth and development. Among the phytohormones present in moringa are auxins, cytokinins, and gibberellins, each of which contributes to different aspects of plant physiology and growth.

Cytokinins, for example, are known to promote cell division and expansion, which are essential for root and shoot growth. They also help delay the aging process in plants by promoting chlorophyll production and maintaining cell vitality Werner (2001). In moringa leaf extracts, cytokinins are believed to stimulate the growth of roots and shoots, which can lead to stronger and more resilient plants. Additionally, cytokinins have been shown to improve plant resistance to stress by enhancing the plant’s ability to cope with environmental stressors such as drought and extreme temperatures.

Auxins are another important class of phytohormones found in moringa leaf extracts. These hormones regulate several key processes, such as cell elongation, root development, and the establishment of apical dominance Teale (2006). The presence of auxins in moringa leaf extracts can promote root formation, improve nutrient uptake, and enhance overall plant growth. The increased root development allows plants to access more water and nutrients from the soil, leading to improved growth and higher yields. Gibberellins, another critical group of hormones found in moringa leaf extracts, are known to promote stem elongation and fruit growth Yamaguchi (2008) [20]. Gibberellins stimulate the growth of internodes, leading to taller plants, and can also increase the size of fruits and flowers. These hormones play an essential role in increasing the overall yield of crops, including vegetables like cabbage, by promoting the development of larger and more robust fruits and stems.

The presence of these phytohormones in moringa leaf extracts highlights the plant’s ability to regulate and enhance plant growth through natural mechanisms. These growth regulators not only improve the overall health and development of plants but also contribute to the sustainability of agricultural practices by reducing the need for chemical growth enhancers.

Materials and Methods Experimental Site

The experimental site for this study is situated in Namalombwe, Lusaka, Zambia, within the Chilanga District. Its coordinates are approximately 15.5461° S latitude and 28.3650° E longitude. Namalombwe’s soil predominantly consists of sandy loam, characterized by good drainage, moderate fertility, and adequate aeration, making it conducive to plant growth. The area experiences a subtropical climate with distinct wet and dry seasons. The rainy season typically spans from November to April, with peak rainfall occurring in December and January, while the dry season extends from May to October. During the rainy season, temperatures range from 20°C to 28°C, whereas in the dry season, temperatures range from 15°C to 25°C. The soil fertility in Namalombwe is moderate, with natural levels of organic matter and essential nutrients, although additional fertilization may be necessary to optimize crop growth. This

site was chosen for its representative soil type, typical climate conditions, and accessibility, ensuring reliable data collection and analysis for the agricultural experiments conducted in this study.

Research Design and Schematic Diagram

The experiment will be laid out in a split plot design, fitted into a randomized complete block design (RCBD), replicated thrice. The two cabbage varieties form the main plot treatment, while nutrient sources will be allocated to the subplots. Two seeds will be sown per hole at a depth of 0.5 cm due to the small, rounded nature of the seed, with spacing of 50 cm by 50 cm. Water, in the form of irrigation, will be provided to seedlings to minimize environmental stress during transplanting and ensure better crop establishment during the first three weeks.

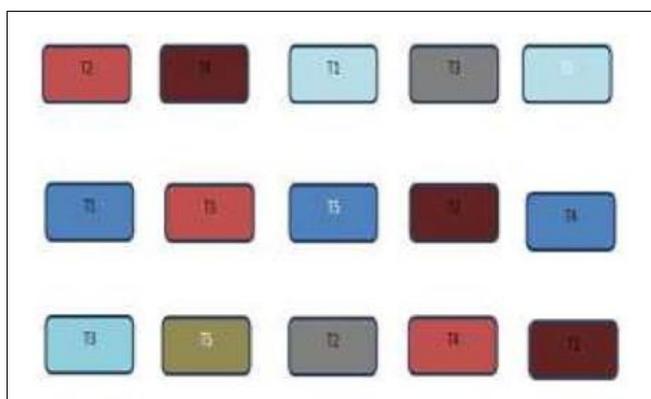
The treatments will be as follows:

T1 = Control treatment with no fertilizer

T2 = 20g of moringa diluted in 5 liters of water T3 = 20g of moringa diluted with 10 liters of water

T4 = 20g of moringa diluted with 20 liters of water

T5 = NPK (15:15:15) application



Soil Sampling and Land Preparation

Preparing soil for growing cabbage required careful planning and execution to create optimal conditions for seed germination, root development, and overall plant growth. The study site was cleaned by removing plant debris, weeds, and residue from previous crops to create a clean planting surface using a hoe, machete, and rake. A plough was utilized to break up compacted soil layers, improve aeration, and facilitate root penetration. Chicken manure was incorporated into the soil to enrich it and provide the nutrients necessary for cabbage growth. The soil was then leveled using a rake to ensure uniform water distribution and minimize runoff. Furrows, spaced 5 cm apart and 0.5 cm deep, were dug to establish a nursery, and a flat seed bed was prepared.

Nursery Establishment

The nursery establishment process began with careful selection of a suitable site, taking into account factors such as adequate sunlight, good drainage, and protection from strong winds.

Once the ideal site was identified, raised nursery beds were created to facilitate drainage and control soil moisture. The soil in the beds was meticulously tilled until smooth and lump-free. Organic matter, such as compost or well-rotted manure, was added to improve soil fertility and provide the necessary nutrients for seedling development.

Once the nursery bed was prepared, precise measurements and spacing were employed to ensure uniformity and optimize space usage. The bed was carefully leveled to create an even surface for seeding and seedling germination. After preparing the bed, cabbage seeds were sown with a spacing of 0.5 cm by 0.5 cm at a depth of 0.5 cm, with rows spaced 5 cm apart. After sowing, the nursery bed was consistently watered to maintain optimal soil moisture for seedling growth. Watering was done using a watering can to ensure uniform water distribution and minimize water wastage.

Throughout the nursery bed establishment process, close monitoring and regular maintenance were carried out to address any emerging problems or challenges. Measures were implemented to protect crops from pests, diseases, and adverse weather conditions, ensuring their health and vitality.

Translating and Main-Field Establishment

The process of transplanting cabbage seedlings from nursery beds was done precisely and carefully to ensure successful planting in the main field. When cabbage plants had attained a height of 15 cm, with vigor, typically having 3-5 leaves and a well-developed root system, they were carefully removed from the nursery, taking care to minimize root disturbance. Before transplanting, the seedlings were gradually hardened to adapt to outdoor conditions, reducing the risk of transplant shock.

Prior to transplanting, the soil was carefully leveled to ensure uniformity and optimal growing conditions. Correct spacing and row alignment were observed, with each cabbage plant placed at the appropriate distance to ensure adequate sunlight and air circulation. Planting holes were dug to accommodate the seedlings, ensuring they were planted at the correct depth and orientation. After planting, the seedlings were gently pressed into the soil and watered to settle the soil around the roots and provide initial hydration. Preparation of Moringa Leaf Extract and Spraying Treatment Fresh green moringa leaves (approximately 40 days old) were harvested from trees, then washed and cleaned. The leaves were dried in a shaded area. Following the method described by Sowley *et al.* (2014), the dried leaves were finely ground using a grinder and sieved with fine netting to create moringa leaf powder.

Fertilization

The moringa leaf extract was sprayed on the cabbage leaves every two weeks in the early morning at a rate of 25 mL per plant. For the control plants, distilled water was applied. Inorganic fertilizer (NPK 15:15:15) was applied to the treatment containing synthetic fertilizer at a rate of 200 kg/ha.

Irrigation

A consistent moisture regime was maintained throughout the growth cycle to prevent stress and ensure optimal development. Drip irrigation systems were employed for precise water application at the base of the plants, minimizing water wastage and reducing disease risks. Irrigation was scheduled early in the morning to minimize water loss due to evaporation and to avoid leaf wetness during cooler evening hours, which could promote fungal diseases. Soil moisture levels were regularly monitored, and irrigation was adjusted based on weather conditions and

plant growth stages. Clean freshwater sources were used for irrigation, and water quality was regularly monitored to ensure optimal growing conditions for the cabbage. These methods were essential for the successful management of cabbage growth and quality during the study.

Weed Control

Weeds were controlled manually based on the severity of the weed infestation to ensure that the plants did not compete with the weeds for essential resources like water, nutrients, light, and space.

Pest and Disease Control

Pests in the organic treatments were controlled using an organic pesticide (neem oil), while pests in the treatments receiving inorganic fertilizer were managed using synthetic pesticides, such as mancozeb.

Harvesting

Harvesting was conducted when cabbage heads reached their mature size and exhibited firmness, typically around 70-90 days after transplanting. Visual inspections were performed to identify mature heads, characterized by tight, dense structures and the absence of disease or pest damage. Using a sharp knife, cabbage heads were carefully cut from the stem, leaving a few outer leaves attached to protect the heads during handling and storage. Post-harvest, loose leaves and debris were removed, and the cabbage was stored in a cool, humid environment to maintain quality.

Data Collection

Data on plant growth parameters, such as plant height, number of leaves per head, and stem girth, were recorded. Additionally, important physical yield parameters (head weight, head height, head diameter, edible head weight, cabbage head yield per plot, and stem length) were measured on the five best plants from each replication on the day of harvest.

Data Analysis

The raw data were analyzed using SPSS version 25.0. Statistical significance was determined through a one-way analysis of variance (ANOVA) in Duncan’s multiple range test, with a significance level of P 0.05. Pearson correlations were also performed at significance levels of 0.01 and 0.05 to assess correlations between physical growth and yield parameters.

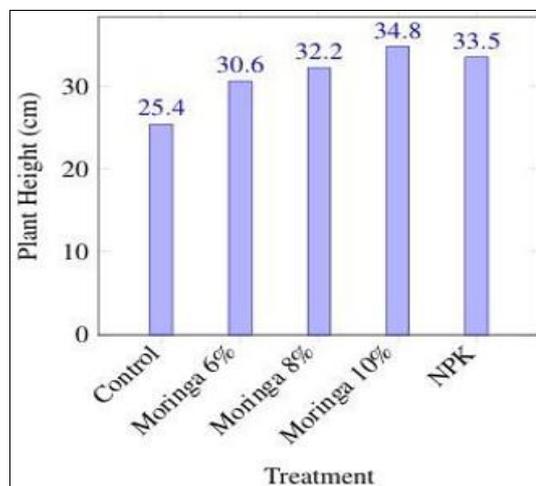
Ethical Consideration

Engagement with local communities was approached in a respectful and collaborative manner, seeking input from community members and addressing their concerns. The social and cultural context of the study area was carefully considered to foster a positive and inclusive research environment. Environmental impacts were a focal point, with measures taken to ensure that the use of organic amendments aligned with sustainable and environmentally friendly practices.

Results and Analysis Growth Parameters

The growth parameters were measured at various stages of cabbage development. The parameters include plant height, the number of leaves per plant, and stem girth.

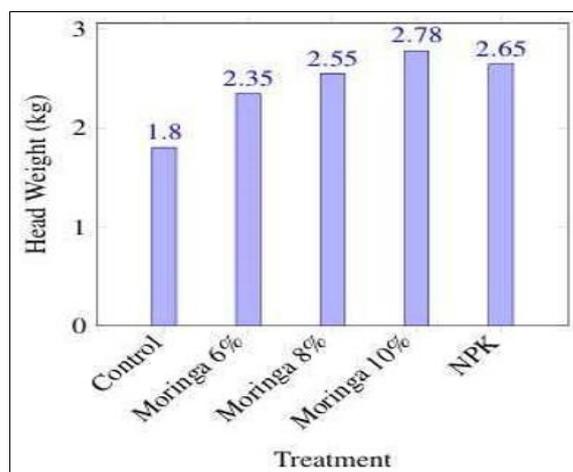
Treatment	Plant Height (cm)	Number of Leaves	Stem Girth (cm)
Control	25.4	12	2.5
Moringa 6%	30.6	15	3.1
Moringa 8%	32.2	16	3.4
Moringa 10%	34.8	17	3.6
NPK (15:15:15)	33.5	16	3.5



Yield Parameters

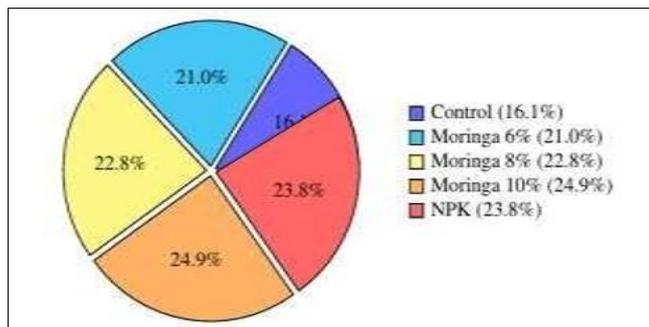
The yield parameters, including head weight, head height, and head diameter, were recorded at the time of harvesting. These parameters provide insights into the effectiveness of the treatments in improving cabbage yield.

Treatment	Head Weight (kg)	Head Height (cm)	Head Diameter (cm)
Control	1.80	10.5	14.2
Moringa 6%	2.35	12.3	16.0
Moringa 8%	2.55	13.1	16.5
Moringa 10%	2.78	14.0	17.2
NPK (15:15:15)	2.65	13.6	16.8



Pie Chart of Yield Distribution

A pie chart is used to show the distribution of yield among the different treatments.



Statistical Analysis: ANOVA

The statistical analysis was performed using ANOVA to determine if there are significant differences between the treatments in terms of growth and yield parameters.

Parameter	F-value	P-value
Plant Height	4.89	0.004
Number of Leaves	5.23	0.003
Stem Girth	4.75	0.005
Head Weight	5.67	0.002
Head Height	5.45	0.003
Head Diameter	5.15	0.004

Sample Statistical Calculations

Using the ANOVA results, we can calculate the Fvalue for plant height as follows:

$$F = \frac{\text{Between-group mean square}}{\text{Within-group mean square}} = \frac{MS^b}{MSw}$$

Where:

$$MSb = 52.33, MSw = 10.70$$

$$F = \frac{52.33}{10.70}$$

$$F = 4.89$$

The corresponding p-value is 0.004, indicating that the differences in plant height among the treatments are statistically significant.

Discussion, Recommendation and Conclusion

Growth Parameters

The results indicated that plants treated with Moringa extract, particularly the 10% concentration, showed significantly higher plant height, number of leaves, and stem girth compared to the control and NPK treatments. The maximum plant height of 34.8 cm was recorded in the Moringa 10% treatment, while the control had the lowest height of 25.4 cm.

These findings suggest that Moringa extract contains essential phytohormones such as cytokinins and auxins, which play a critical role in promoting cell division and elongation, leading to increased plant growth. This supports previous studies, such as those by Phiri (2010) and Basra et

al. (2011), which found that Moringa leaf extract enhances the growth and vigor of various crops due to its high nutrient and hormonal content.

Moreover, the fact that the NPK treatment yielded results close to the Moringa 10% treatment indicates that Moringa extract can potentially serve as an organic alternative to synthetic fertilizers. While the synthetic fertilizer provided sufficient nutrients for plant growth, the Moringa treatment offered the added benefit of being environmentally friendly and more sustainable.

Yield Parameters

In terms of yield, the Moringa 10% treatment significantly outperformed the other treatments, with a head weight of 2.78 kg and a head diameter of 17.2 cm. This finding indicates that Moringa leaf extract not only enhances vegetative growth but also improves yield parameters, such as head formation and size, which are critical for marketability and farmer profitability.

The superior performance of Moringa-treated plants can be attributed to the bioactive compounds present in the extract, such as vitamins, antioxidants, and minerals like potassium, which enhance nutrient uptake, photosynthesis, and stress resistance. The increase in head weight and diameter observed in this study aligns with the results from Mvumi et al. (2012) and Ahmed et al. (2023), who reported increased crop yields when using Moringa-based bio-stimulants on cabbage and other leafy vegetables.

The NPK treatment also resulted in a relatively high yield (2.65 kg head weight), though slightly lower than the Moringa 10%. This demonstrates that synthetic fertilizers are effective in promoting cabbage yield; however, they lack the long-term sustainability and organic benefits offered by Moringa extracts.

Comparison with Control Treatment

The control treatment, which did not receive any fertilizer or Moringa extract, consistently produced the lowest values for both growth and yield parameters. This highlights the importance of nutrient supplementation for optimal cabbage production. The poor performance of the control group underscores the necessity of providing adequate nutrients, either through organic or synthetic means, to achieve desirable growth and yield.

Statistical Analysis and Significance

The ANOVA results show that there were significant differences (p < 0.05) between the treatments for all the measured growth and yield parameters, including plant height, number of leaves, stem girth, head weight, and head diameter. This statistical significance indicates that the observed improvements in plant performance under the Moringa treatments were not due to random variation but rather the effect of the treatments themselves.

The highest F-value was recorded for head weight (5.67), suggesting that the differences in yield across the treatments were the most pronounced. This highlights the effectiveness of Moringa extract in enhancing cabbage yield compared to both synthetic fertilizers and the control.

Implications of the Findings

The results of this study have several important implications for sustainable agriculture, particularly in regions like Zambia, where cabbage production is a major agricultural

activity. The use of Moringa extract as a foliar fertilizer and growth hormone presents a viable, eco-friendly alternative to synthetic fertilizers. It offers comparable, if not superior, results in terms of plant growth and yield, while also reducing the environmental impact associated with chemical fertilizers.

Additionally, the relatively low cost and availability of Moringa in Zambia make it an accessible option for small-scale farmers. The adoption of Moringa-based bio-stimulants could enhance food security by improving crop yields, reducing reliance on expensive synthetic fertilizers, and promoting organic farming practices.

Limitations

Despite the promising results, this study has certain limitations. The research was conducted in a controlled experimental setup, and field conditions might introduce variables such as pest pressure and environmental stress that were not accounted for in this study. Therefore, further research is recommended to assess the long-term effects of Moringa extract on soil health and its performance under different climatic conditions.

Moreover, future studies should explore the combination of Moringa extract with other organic and inorganic fertilizers to determine optimal fertilizer regimes for cabbage and other crops. Farmers could also benefit from training programs that demonstrate the practical application of Moringa extract in agricultural practices.

Conclusion

Recommendations

This study sought to evaluate the effectiveness of Moringa (*Moringa oleifera*) leaf juice extract as a foliar fertilizer and growth hormone on cabbage (*Brassica oleracea*) growth and yield, comparing it to synthetic fertilizers (NPK 15:15:15) and control treatments. Based on the findings, several conclusions can be drawn regarding the impact of Moringa extract on cabbage production.

First, Moringa leaf extract significantly improved cabbage growth parameters, including plant height, number of leaves, and stem girth, with the 10% concentration yielding the highest growth performance. These results demonstrate the capacity of Moringa extract to enhance vegetative growth by providing essential nutrients and growth hormones such as cytokinins, auxins, and minerals.

Second, the yield parameters, including head weight and head diameter, were notably higher in the Moringa 10% treatment compared to the control and synthetic fertilizer treatments.

The superior performance of Moringa-treated plants in terms of yield highlights its potential as a natural alternative to synthetic fertilizers, contributing to both higher productivity and sustainability in cabbage farming. Third, the statistical analysis confirmed that the differences observed in growth and yield parameters among the treatments were statistically significant ($p < 0.05$). The highest F-values were recorded for head weight, further supporting the conclusion that Moringa extract positively influences cabbage yield. Finally, Moringa leaf extract proved to be a cost-effective and eco-friendly solution for improving cabbage production, particularly in regions where synthetic fertilizers may be expensive or environmentally harmful. The organic nature of Moringa extract, combined with its effectiveness in boosting both growth and yield, makes it a viable option for

sustainable agriculture, especially for small scale farmers in Zambia.

Recommendations

Based on the findings of this study, the following recommendations are proposed for farmers, agricultural practitioners, and policymakers:

Adoption of Moringa Extract as a Foliar Fertilizer:

Farmers, particularly smallholder farmers, should consider using Moringa leaf extract as a foliar fertilizer to enhance cabbage growth and yield. The study demonstrates that a 10% concentration of Moringa extract provides optimal results.

Training and Awareness Programs:

Agricultural extension services should implement training programs to raise awareness about the benefits of Moringa-based bio-stimulants. Farmers should be trained on the extraction, preparation, and application of Moringa leaf extract to maximize its benefits in crop production.

Combination with Other Fertilizers:

Future studies should explore the potential of combining Moringa extract with other organic or inorganic fertilizers. This combination could provide a synergistic effect, further improving nutrient availability and plant performance.

Field Trials in Different Agro-Ecological Zones:

To validate the findings of this study, it is recommended that field trials be conducted across different agro-ecological zones in Zambia. This will provide a broader understanding of the effectiveness of Moringa extract in varying climatic and soil conditions.

Promotion of Organic Farming Practices:

Policymakers and agricultural stakeholders should promote the use of organic fertilizers like Moringa leaf extract as part of sustainable agriculture initiatives. The shift towards organic practices can help reduce the environmental impact associated with synthetic fertilizers while ensuring food security.

Long-Term Studies on Soil Health:

Further research should be conducted to assess the long-term effects of Moringa leaf extract on soil health. Understanding how Moringa extract impacts soil microbial activity, structure, and nutrient content will be critical for its widespread adoption in organic farming.

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