BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

EFFECT OF APEX 10 BIOSTIMULANT APPLICATION RATES ON GROWTH RATE AND YIELD OF BUTTERNUT (*CUCURBITA MOSCHATA*)

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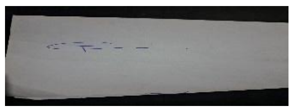
DECLARATION

I, Tendai M. Mubvundu, (B1130652) attest that this research report is entirely my own, independent work, and I have fully acknowledged all of the references and mentioned sources that I used. This report has never been turned in for a test or research.

Student's Signature:  Date: 17/09/2025

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I have supervised the research project for the above mentioned student and I am convinced that the research can be submitted.

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ABSTRACT

The limited understanding of Apex 10's impact on butternut squash necessitates research to determine optimal application rates for enhanced growth and yield, including improved soil fertility and increased crop productivity. The study was conducted to evaluate the effect of different Apex 10 bio stimulant application rates on the growth and yield of butternut squash (*Cucurbita moschata*). The experiment was carried out at Saparanyambuya Irrigation Scheme in Uzumba Maramba Pfungwe using a Randomized Complete Block Design (RCBD) with four treatments (0%, 50%, 75%, and 100% Apex 10 rates) replicated three times. Key growth and yield parameters measured included leaf length, fruit count per plant, and total fruit yield per plot. Analysis of variance (ANOVA) revealed statistically significant differences ($p < 0.05$) among treatments for all measured parameters. Vine length, fruit count, and fruit yield increased progressively with increasing levels of Apex 10. The 100% treatment produced the longest vines (27.33 cm), the highest number of fruits per plant (6.33), and the greatest yield (5.00 kg per plot), while the control (0% Apex 10) consistently recorded the lowest values. The study concludes that the use of Apex 10 biostimulant significantly enhances both vegetative and reproductive growth of butternuts. The 100% application rate is recommended as the optimal dose for achieving maximum yield under local agro-ecological conditions.

DEDICATION

First and foremost, I would like to thank the almighty heavenly father God for guiding me and giving me the strength to conduct this research. However, a number of people have contributed towards the production of this research project. I would particularly like to express my profound gratitude to all people who gave a hand. Special mention goes to the following people:

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LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA…………………………...Analysis of variance

CBD………………………………. Central Business District

FAO……………………………... ...Food and Agriculture Organization

K…………………………………… Potassium

N……………………………………. Nitrogen

P…………………………………… Phosphorus

UMP…………………………………Uzumba Maramba Pfungwe

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CHAPTER 1: INTRODUCTION

1.1 Background of the study

Butternuts play an important role in the global food security(Devaux *et al.*, 2021, Wijesinha-Bettoni and Mouillé, 2019). The butternut yields decreased by 30% than the potential yields of many cultivars in Zimbabwe between 2017 to 2022 seasons (Faostat, 2015) . It is against this background that the study aims to address challenges on the decreased yield in butternut production due to high input requirement and abiotic stress by using a bio stimulant Apex 10. Butternut growth and fruit yield are affected by many biotic and abiotic stresses such as low or high temperatures, drought or heavy rainfall, and the presence of pests and diseases. Climate change may impact biotic stress either positively or negatively, whereas abiotic stresses are likely to be greatly increased (Obidiegwu *et al.,* 2015). The climate change impact simulations for butternut production suggest a decline in global butternut production of between 18% and 32% by 2055 (Raymundo *et al.*, 2018). These ratios indicate the need to improve the butternut yield.

Under climate change conditions, plant growth stimulants have been gaining increasing importance. Bio stimulants contain a wide range of bioactive compounds that have beneficial effects on plant growth and stress adaptation, which allows better use of the cultivar production potential under the environmental conditions of the crop area (Halpern *et al.,* 2015). In recent years, the use of seaweed extracts and humid substances as plant growth stimulants has been increasing (Seyedbagheri, 2010).

Cultivar selection and the application of bio stimulants play an important role in modern butternut cultivation. These factors affect butternut yields and fruit quality, which are parameters of paramount importance in the production of butternut and processing(Pszczolkowski and Sawicka, 2018).

Bio stimulants are increasingly applied in sustainable and environmentally-friendly farming systems to improve nutrient use efficiency, enhance soil fertility, decrease fertilizer rates (mainly N fertilizers), increase agricultural productivity, yields and crop quality, and improve plant tolerance to adverse environmental conditions (Canellas *et al.*, 2015).

In recent years, the use of growth stimulants and soil amendments has gained significant attention as a potential solution to enhance crop productivity and resilience (Calvo *et al.*, 2014).

One such product, Apex 10, a proprietary growth stimulant and soil amendment, has shown promising results in improving plant growth and yield in various sections (Agrochemicals Inc., 2022). Developed by Agrochemicals Inc., Apex 10 is a complex formulation that combines natural plant growth regulators, micronutrients, and soil-conditioning agents. Its unique composition is designed to enhance root development, nutrient uptake, and stress tolerance in plants (Sharma *et al.*, 2014).

The present study aims to investigate the effects of Apex 10 on the development and production of butternut in Uzumba Maramba Pfungwe (UMP), Zimbabwe. butternuts are a significant crop in the region, providing a staple food source and income for smallholder farmers (Muzhinji & Sibanda, 2020). However, butternut yields in the area are often limited by various biotic and abiotic stresses, including nutrient deficiencies, drought, and pest infestations (Mutandwa & Madzinga, 2022).

By evaluating the performance of Apex 10 in butternut cultivation, this research seeks to provide valuable insights into its potential as an eco-friendly and cost-effective solution for enhancing butternut productivity. The study will focus on assessing key parameters such as plant growth, fruit yield, and quality characteristics under field conditions in Uzumba Maramba Pfungwe.

The research will be conducted in collaboration with the Department of Crop Science at Bindura University of Science Education and the Uzumba Maramba Pfungwe Research Station of the Ministry of Agriculture. The study will employ a randomized complete block design with three treatments: control (no amendment), conventional fertilizer, and Apex 10 application. The researchers will closely monitor and record various parameters, including plant height, stem diameter, leaf area index, fruit yield, and quality attributes such as dry matter content and specific gravity.

The findings of this study have the potential to contribute to the development of sustainable agricultural practices in Zimbabwe and beyond. If Apex 10 proves effective in enhancing butternut productivity, it could provide smallholder farmers with an affordable and environmentally friendly solution to improve their crop yields and overall food security. Additionally, the study may shed light on the underlying mechanisms by which Apex 10 influences plant growth and development, paving the way for further research and product refinement.

1.2 Statement of the problem

The global table butternut industry is facing a significant yield and quality gap, with far reaching implications for food security and sustainability. Butternut production is crucial for ensuring food security and meeting the increasing demand for butternut. However, achieving optimal yields and high quality butternuts can be challenging due to various factors such as limited nutrient availability, environmental stress and suboptimal growth conditions. Farmers are constantly seeking effective strategies to enhance butternut development, increases yield and overall crop productivity.

Thus, the issue that this study seeks to solve is the dearth of thorough knowledge and data on the impact of the biostimulant Apex 10 on the cultivation of butternuts. This study aims to close this knowledge gap and offer insights into the possible advantages and viability of utilizing apex 10 bio stimulant in butternut farming by contacting a thorough evaluation. The project intends to help the improvement of butternut yields, quality, and profitability as well as the growth of sustainable practices in butternut agriculture.

1.3 Justification

The research is important for several reasons. Firstly, it aims to address the pressing issue of low butternut yields and poor quality in Zimbabwe, which has a direct impact on food security and the local economy. Secondly, by investigating the effects of Apex 10 growth stimulant and soil amendments, this study can provide valuable insights into sustainable farming practices, potentially reducing the reliance on chemical fertilizers and pesticides. Finally, the research outcomes can contribute to the scientific knowledge base on butternut cultivation, benefiting farmers, researchers, and policymakers.

Henceforth the country will get foreign currency because the butternut can be exported because they will be of high quality. Also the good quality butternuts can be put in open markets and supermarkets where local consumers will be able to access. Enhancing butternut productions: butternuts are vital food crop globally and increasing their productivity and production is crucial for food security. By evaluating the effects of apex 10 bio stimulant there is a possibility to identify a sustainable and effective strategy to enhance butternut development, yield and quality thereby contributing to increased butternut production

Sustainable agriculture: bio stimulants offer a more environmentally friendly and sustainable approach to agriculture production. It has potential to reduce reliance on synthetic fertilizers, pesticides, and growth regulators. This can lead to a more sustainable agriculture system reducing environmental impacts and promoting ecological balance.

Cost effectiveness: the economic feasibility of adopting apex 10 bio stimulant in butternut farming is an important consideration. Can assess the potential benefits and cost effectiveness of using apex 10 bio stimulant will enable farmers to make informed decisions regarding the adoption of bio stimulant considering its potential impact on their yields, quality and profitability.

Scientific evidence: the project will contribute to the existing knowledge base by providing rigorous scientific data on the impact of apex 10 bio stimulant on butternut growth, yield, and quality. The findings will support evidence based decision making for farmers, extension series and policymakers.

Knowledge transfer: the outcomes of this project will disseminated through scientific publications, workshops and extension programs. This knowledge transfer will enable farmers, researchers and stakeholders to benefit from the findings and incorporate the use of apex 10 bio stimulant into their butternut farming practices thereby promoting knowledge exchange and technology adoption in the agriculture sector.

1.4 Objectives of the study

1.4.1 Main objective

To evaluate the effectiveness of Apex 10 Biostimulant application rate on the development and production of butternuts

1.4.2 Specific objectives

1. To determine the effect of Apex 10 biostimulant application rates on the growth rate of butternut in terms of leaf length,
2. To determine the effect of Apex 10 biostimulant application rates on fruit number of butternut.

3. To determine the effect of Apex 10 biostimulant application rates on butternut fruit mass.

1.5 Hypotheses

1. Apex 10 biostimulant application rate has significant effect on the growth rate of butternut in terms of leaf length,
2. Apex 10 biostimulant application rate has significant effect on fruit number of butternut.
3. Apex 10 biostimulant application rate has significant effect on butternut fruit mass.

CHAPTER 2: LITERATURE REVIEW

2.1 Production of butternuts

Butternuts, scientifically known as *Cucurbita moschata.*, is a widely grown crop globally and is considered the fifth most important food crop following maize, wheat, potato and rice (FAO, 2022). Its ability to thrive in various climatic conditions and its significant nutritional value have established it as a fundamental food source for millions of individuals across the world. The production of butternuts plays a vital role in ensuring food security, creating income opportunities, and sustaining the livelihoods of small-scale farmers, particularly in developing nations such as Zimbabwe.

The history of butternut cultivation is extensive, originating in Peru, where indigenous communities domesticated it approximately 8,000 years ago (Spooner *et al.,* 2005). Subsequently, butternuts were introduced to Europe in the 16th century and eventually spread to other regions of the world, establishing themselves as a crop of global significance. In modern times, butternuts are cultivated in numerous countries spanning diverse climatic zones, ranging from tropical to temperate regions.

Butternuts production is significantly affected by a range of biotic and abiotic stresses, such as pests, diseases, nutrient deficiencies, drought, and extreme temperatures (Mutandwa & Madzinga, 2022). These difficulties are especially pronounced in nations like Zimbabwe, where small-scale farmers frequently face limited access to essential agricultural resources, irrigation facilities, and contemporary farming methods.

Butternuts thrive in well-drained soil, with sandy or sandy loam soils being preferable to heavy clay soils for producing high-quality Butternuts. Butternuts flourish in soil with a pH of 6 to 7, which is neutral to slightly acidic. It is crucial to utilize deep tillage to facilitate drainage and eliminate salt accumulation below the root zone when preparing the field.

Planting butternuts in soil with enough moisture is essential for a successful crop. Watering planted butternuts will lower the soil temperature, hinder soil aeration, and encourage weed growth. In warm conditions, it may lead to anaerobic bacteria starting to decompose the seeds. If there hasn't been enough rainfall to moisten the soil to a depth of 30 cm, pre-irrigation is advisable. Sufficient moisture will also make the soil easier to cultivate.

The process of land preparation typically begins with ploughing to ensure adequate depth for supporting ridging and promoting good fruit formation in plants. This is followed by disking to achieve a fine tilth. Using a rotavator ensures that all soil clods are broken up. A ripper is then used to create lines 90cm apart, after which fertiliser is applied manually and covered by the rotavator set to a shallow depth.

During the flowering stage, it's important to closely monitor irrigation as the plants require increased water for fruit formation. Inadequate water supply can significantly impact the number of fruits produced. Two weeks prior to harvesting, the above-ground green matter is trimmed to facilitate the hardening of the butternuts.

2.2 Importance of butternuts production

Butternuts play a vital role in a balanced diet because they offer a rich source of carbohydrates, vitamins, and minerals. The presence of vitamin C, vitamin B6, potassium, and dietary fibre in butternuts contributes significantly to human health and well-being (Burlingame *et al.,* 2009). Furthermore, their relatively low glycemic index makes them a suitable option for individuals managing diabetes or seeking to regulate their blood sugar levels (Fernandes *et al.*, 2005).

Butternut farming plays a crucial role in ensuring food security and providing income for small-scale farmers in Zimbabwe (Muzhinji & Sibanda, 2020). Butternuts are both a primary food source and a means of generating revenue, as any excess harvest is marketed locally or sold to larger purchasers. Due to its short growth period and high productivity, this crop is an appealing choice for small-scale farmers aiming to optimize their land use and income generation.

2.3 Origins and nature of Apex 10 Biostimulant

Agrochemicals Inc. has developed Apex 10, a proprietary biostimulant and soil amendment, which is a sophisticated blend of natural plant growth regulators, micronutrients, and soil-conditioning agents (Agrochemicals Inc., 2022). The primary objective of this product is to boost root development, nutrient absorption, and stress resistance in plants, resulting in enhanced growth, yield, and overall quality.

Biostimulants have garnered more interest in recent years for their ability to improve plant growth and productivity in an environmentally sustainable way, making them a relatively new type of agricultural inputs (Calvo *et al.,* 2014). Derived from natural sources like plant extracts, seaweed, beneficial microorganisms, and different organic compounds (Yakhin *et al.,* 2017), biostimulants stand apart from traditional fertilizers and pesticides.

Agrochemicals Inc. closely guards the specific formulation of Apex 10 as it is proprietary. However, the product brochure (Agrochemicals Inc., 2022) states that it comprises a combination of natural plant growth regulators. These compounds play a role in regulating different aspects of plant growth and development, including cell division, elongation, and differentiation (Calvo *et al.*, 2014). Moreover, Apex 10 contains essential micronutrients like iron, zinc, and boron, which are necessary for plant metabolism and enzyme activities. The formulation also includes soil-conditioning agents that are intended to enhance soil structure, water-holding capacity, and nutrient availability (Agrochemicals Inc., 2022).

2.4 Effects of bio stimulants

Numerous research studies have highlighted the potential of biostimulants in enhancing butternut production by boosting plant growth, yield, and quality parameters. For example, a study conducted by (Sharma et al. 2020) demonstrated that the use of a biostimulant derived from increased fruit yield, higher dry matter content, and improved nutrient uptake in butternuts cultivated under field conditions in India. The biostimulant was observed to stimulate the growth of roots, enhance photosynthetic efficiency, and elevate the activity of antioxidant enzymes, leading to enhanced stress tolerance and overall plant performance.

In a study by Calvo *et al.* in 2014, it was found that utilizing biostimulants created from plant extracts and helpful microorganisms improved the growth, yield, and stress resistance of various crops, such as butternuts. They emphasized that biostimulants can adjust plant hormonal balance, nutrient absorption, and physiological functions, resulting in enhanced crop productivity and quality.

In a separate research conducted by El-Sawy and colleagues in 2021, the impact of a biostimulant obtained from brown seaweed on the growth and yield of butternuts under various irrigation practices was examined. It was observed that the application of the biostimulant led to an increase in fruit yield, enhanced water use efficiency, and elevated antioxidant activity in butternuts plants, particularly in conditions of water scarcity. These results indicate that biostimulants may have a pivotal role in alleviating the adverse effects of environmental stresses, such as drought, on butternut farming.

The potential impact of Apex 10 biostimulant on butternut production has not been thoroughly researched, although its distinct composition and the established advantages of biostimulants overall indicate that it may improve butternut growth, yield, and quality. Additional studies are necessary to assess the effectiveness of Apex 10 in various environmental and farming conditions, especially in areas like Uzumba Maramba Pfungwe, Zimbabwe, where butternut cultivation encounters diverse obstacles.

The categorization of bio stimulants, as suggested by (Basak, 2008), may depend on the mode of action and the source of the active ingredient. Meanwhile, (Bulgari *et al*, 2015) proposed that the classification of bio stimulants should be based on their impact on plants or the physiological responses of plants, rather than their composition. Additionally, (Yakhin *et al*, 2017) highlighted the importance of the ultimate effect on plant productivity, indicating that any definition of bio stimulants should prioritize their agricultural functions, whether related to their components or their modes of action.

2.5 Effects of bio stimulants on butternuts

The market offers various biostimulants, each designed for specific purposes. Biostimulant products aim to improve the plant's ability to withstand abiotic stresses like harsh temperatures and drought. They consist of bioactive elements that assist the plant in managing the impact of stress.

Biostimulants simulate the activity of hormones, enhancing the plant's response to hormones and amplifying their impact. The components of the product can also influence various plant functions, potentially leading to enhanced plant growth and increased yield (such as improved photosynthetic efficiency, enhanced nutrient absorption, and reduction of abiotic stress effects through the mentioned mechanisms). Biostimulants lead to an increase in both the quantity and weight of fruits.

2.6 Resistance/tolerance to climate change

Bio stimulants have the ability to improve plants' resistance to abiotic stress, like drought or extreme temperatures. As a result, the application of bio stimulants can aid in lessening the adverse effects of climate change and severe weather conditions. This is particularly crucial for farmers as they are required to adjust their methods to cope with evolving and demanding climatic circumstances.

The increased occurrence and severity of droughts, heat waves, and other extreme weather events pose a significant threat to agricultural production globally. Studies have demonstrated that biostimulants can boost plant tolerance and resilience to the non-living environmental pressures linked to climate change (Yakhin *et al.,* 2017). These substances have the potential to enhance water use efficiency, elevate photosynthetic efficiency, and trigger antioxidant mechanisms, thereby empowering plants to better endure unfavourable environmental conditions.

Numerous research studies have illustrated the capacity of biostimulants to alleviate the adverse impacts of drought stress on a variety of crops, including butternuts. For instance, El-Sawy *et al*. (2021) discovered that administering a biostimulant derived from seaweed enhanced the efficiency of water usage and boosted the production of fruits in butternuts cultivated in conditions of water scarcity. Similarly, according to (Sharma *et al*. 2020), a biostimulant sourced from seaweed enhanced the resistance to drought and the yield of butternuts by regulating physiological and biochemical processes, such as the effectiveness of photosynthesis and the activities of antioxidant enzymes.

Numerous research studies have illustrated the capacity of biostimulants to alleviate the adverse impacts of drought stress on a variety of crops, including butternut. For instance, (El-Sawy *et al*. 2021) discovered that administering a biostimulant derived from seaweed enhanced the efficiency of water usage and boosted the production of fruits in butternuts cultivated in conditions of water scarcity. Similarly, according to (Sharma *et al.* 2020), a bio stimulant sourced from seaweed enhanced the resistance to drought and the yield of butternut by regulating physiological and biochemical processes, such as the effectiveness of photosynthesis and the activities of antioxidant enzymes.

Bio stimulants have the potential to assist plants in managing heat stress, which is a common outcome of climate change. (Yakhin *et al.*2017) conducted research that illustrated how bio stimulants obtained from humic substances and plant extracts can boost the heat tolerance of different crops, such as butternuts, by stimulating the production of heat shock proteins and other protective mechanisms.

Amidst the ongoing impact of climate change on agricultural production, the utilization of bio stimulants like Apex 10 could be pivotal in bolstering crop resilience and ensuring long-term food security. By enhancing plant tolerance to abiotic stresses, bio stimulants can aid in alleviating the adverse effects of climate change on crop yields and contribute to the advancement of sustainable and climate-resilient agricultural practices.

2.7 Potential economic and environmental benefits of using bio stimulant in agriculture

Pesticides and fertilizers play a crucial role in agricultural production to meet the needs of a growing global population. However, the increasing use of chemicals poses a significant risk to the health of humans, animals, plants, and the environment due to their harmful effects. Bio stimulants offer a chance to reduce the chemical impact on agriculture by virtue of their multiple beneficial properties, contributing to greater sustainability and resilience in farming.

The expansion of urban areas and the impact of climate change are leading to a decrease in the amount of arable land available for agriculture worldwide, posing a threat to the global food supply, which needs to be doubled by 2050 (Calicioglu *et al.,* 2019; Valoppi *et al.,* 2021). In response to the growing demand for food, farmers have been excessively utilizing synthetic fertilizers and pesticides since the green revolution. However, research shows that only 10 to 20% of the applied nutrients are actually absorbed by plants from the soil, and an even smaller proportion (0.1%) of pesticides effectively target the intended organisms (Damalas and Koutroubas, 2016; Del Buono, 2021).

Bio stimulants differ from chemical fertilizers because they trigger cellular and adaptive responses, regardless of whether mineral elements are present in the formulations (Baltazar *et al.,* 2021). Hence, these substances can be utilized as an addition to fertilizers and plant protection products, potentially strengthening the plant's immune system and boosting tolerance to abiotic challenges, thereby offering an economically feasible approach to sustaining higher yields while minimizing ecological impact (Nephali *et al.*, 2020; Del Buono et al., 2023). Over the past decade, microbiome research has revolutionized our understanding of the complexity and makeup of microbial communities.

Bio stimulants, which consist of a diverse range of organic substances and microorganisms in different formulations, are gaining popularity as a valuable aid in agriculture. These new compounds have the potential to boost plant resistance to stress, improve the efficiency of nutrient utilization, enhance the solubility of nutrients in the soil or rhizosphere, and enhance qualitative characteristics. It has been noted that bio stimulants have the ability to increase agricultural yields in the presence of both abiotic and biotic stress

In agriculture, the application of bio stimulants has the potential to provide both economic and environmental advantages, contributing to sustainable and efficient farming practices. Bio stimulants have demonstrated the ability to increase crop yields, resulting in higher profits for farmers (Calvo *et al.*, 2014). By improving plant growth, nutrient absorption, and tolerance to stress, bio stimulants can enhance crop productivity, even in challenging environmental conditions. This can result in increased earnings and better living standards for small-scale farmers who heavily rely on their crop yields for their sustenance and income.

Moreover, the use of bio stimulants has the potential to decrease the necessity for synthetic fertilizers and pesticides, thus cutting down the expenses for farmers (Yakhin *et al.*, 2017). Traditional agrochemicals can be costly and may need frequent applications, creating a significant financial strain on smallholder farmers with limited resources. By stimulating plant growth and enhancing resilience with bio stimulants, farmers may potentially lessen their dependence on these traditional inputs, leading to reduced costs and increased profitability.

2.8 Effectiveness of bio stimulants

The effectiveness of bio stimulants depends on several factors, including the right choice of products, their dosage, concentration, and application methods, as well as the plant species and cultivars, and environmental conditions. However, farmers are generally hesitant to embrace suggestions for adopting alternative crop management methods, especially on small-scale farms or in developing nations.

The primary reason for the reluctance to use bio stimulants or innovative crop protection strategies is the lack of guaranteed success. Farmers' scepticism about these alternative methods is also based on the belief that they are less effective compared to traditional chemicals.

2.9 Biostimulants and Abiotic, Water, and Temperature Stresses in Plants

Plant growth and productivity can be significantly impacted by abiotic stresses such as water deficit, temperature extremes, and other environmental factors. It has been discovered that biostimulants can help alleviate the adverse effects of these stresses by regulating various physiological and biochemical processes in plants.

Drought, also known as water stress, is a major abiotic stress that affects crop yields. Plant tolerance to drought can be improved by biostimulants through the enhancement of water uptake and use efficiency.

Temperature stress, which includes high and low temperatures, can harm plant growth and development. It has been discovered that biostimulants improve plant tolerance to temperature extremes by triggering the production of stress-protective compounds, such as heat shock proteins, and adjusting physiological processes.

The ways in which biostimulants alleviate abiotic stress in plants include enhancing nutrient uptake, regulating plant hormones, triggering antioxidant systems, facilitating osmotic adjustment, and adjusting gene expression. These processes assist plants in dealing with environmental stresses and sustaining growth and productivity under difficult condition and drought tolerance in crops, such as maize and butternuts.

2.10Active Ingredients of Apex 10 Biostimulant

Natures Wonder has developed a unique bio stimulant formulation known as Apex 10, which is not publicly disclosed. Although the specific composition is kept confidential, the active ingredients of the product are outlined in the marketing material.

Apex 10 is enriched with vital micronutrients such as iron, zinc, and boron, which participate in diverse metabolic processes and enzyme functions within plants. Specifically, iron is essential for both photosynthesis and respiration, while zinc contributes to protein synthesis and carbohydrate metabolism. Moreover, soil-enhancing components in Apex 10 aim to boost soil quality, moisture retention, and nutrient accessibility. Such components could consist of humic substances and other natural compounds that improve soil fertility and encourage plant development.

The collective impact of these active elements is anticipated to collectively improve plant growth, nutrient absorption, and resilience to stress. Nevertheless, the effectiveness of Apex 10 might differ based on variables like crop variety, surroundings, and farming techniques.

Table 1: **Composition of Apex 10**

COMPOSITION	INDUCIVE COUPLED PLASMA-mass
Nitrogen	0.7000 wt.%
Phosphorus	0.1123wt.%
Potassium	0.1101 wt.%
Iron	0.0716 wt.%
Calcium	0.420 wt.%

CHAPTER 3: MATERIALS AND METHODS

3.1 Research site

The research study was conducted in region IV at Saparanyambuya Irrigation Scheme located in Uzumba Maramba Pfungwe, situated 70km from the central business district (CBD) of Murehwa. According to the Ministry of Agriculture, natural region IV receives an average of 400mm to 650 mm of rainfall per year. It is prone to seasonal drought and severe dry spells during rainy seasons. The area is dominated by sandy loam soils.

3.2 Experimental design

Research design is defined by (Tuckman 1972) as a specification for testing of a hypothesis under a given set of conditions. The design of a research can be defined as a strategic plan outlining the approach, method, and effective strategies to be used in addressing the problem. The research employed the quantitative research method, which focuses on measuring variables and testing hypotheses using numerical data, particularly through pre- and post-treatment experiments.

The research utilized a completely random block design. There were four treatments, each replicated three times, resulting in a total of 12 plots in the field. This replication approach was employed to ensure the experiment's reliability and to accommodate any potential variability. A scientific calculator was utilized to randomly assign treatments to plots: a control group with 0% Apex 10 growth stimulant applied, a 50% treatment with 240 ml of Apex 10 per Knapsack, a 75% treatment with 360 ml of Apex 10 per Knapsack, and a 100% treatment with 480 ml of Apex 10 per Knapsack.

3.3 Plot preparation and planting

Before planting, the areas were carefully prepared by hand. The dimensions of each plot measured 10m by 10m. A garden hoe was used to dig the soil to a depth of approximately 75cm. To achieve a fine tilth without excessive clods, a garden rake was used for harrowing. The soil was plowed and leveled to create an ideal seedbed. Planting furrows were then made at consistent intervals within each plot. Each plot was then planted with certified butternut seed of the squash variety. The seeds were planted at a depth of 5cm, with a spacing of 90cm between rows and 30cm between plants within a row. The plots were subsequently irrigated to field capacity using drip irrigation.

Once a row is finished, a knapsack sprayer is utilized to apply K-humate (for soil conditioning) at a rate of 20 litres per hectare, Myconate (to stimulate mycorrhizal fungi growth) at a rate of 50g per hectare, Kiplant - VS-04 (a nematicide) at a rate of 5 litres per hectare, Moncerin at a rate of 1.6 litre per hectare, and Lambda (a pesticide) at a rate of 200ml per hectare, all mixed in a 200-litre drum of water. This spraying is carried out prior to covering the seeds to ensure thorough coverage with the solution. The seeds are then completely covered using hoes.

3.4 Application of Apex 10

Apex 10 biostimulant was utilized in a two-step application procedure. Before planting in the furrows, the initial application was administered as a soil drench treatment. Each treatment received a designated quantity of Apex 10 solution - 0ml, 120ml, 180ml, and 240ml, which were evenly distributed along the furrows to ensure the solution reached the root zone of the butternut plants.

Apex 10 was applied for the second time as a foliar spray, carried out four weeks after the emergence of the butternut plants. The Apex 10 solution was mixed and then uniformly sprayed in amounts of 0ml, 120ml, 180ml, and 240ml onto the foliage of the butternut plants for each treatment. A knapsack sprayer was used for the application, ensuring complete coverage of the leaves and stems.

***Table 2*:** Field layout and biostimulant application rate

WEEKS	T1	T2	T3	T4
0 4	0 0	120mls 120mls	180mls 180mls	240mls 240mls
TOTAL	0	240mls	360mls	480mls

3.5 Irrigation aspects

Irrigation of butternut was done using a bucket. On day of planting, the butternuts were irrigated to field capacity ensuring a uniform distribution of water in all plots. The irrigation depended on the stage of crop, and on the flowering stage the butternuts were irrigated every day to ensure formation of fruits. The application of water for irrigation were adjusted based on the specific water requirements of the crop, which can depend on factors such as their size, growth stage, maturity length, and the time of year with the most growth.

3.6 Weed control

Weed control was done manually using a garden hoe. Hoeing was done between rows and weeds in the rows were pulled by hand. It was done 2 weeks after seed emergence. It was repeated after another 2 weeks, to avoid competition with the crop for nutrients, moisture and sunlight

Trellising was performed once, followed by a mixture of fungicide and pesticide application. The fungicides were rotated to prevent resistance. Applying the chemicals after trellising is necessary because the branches can be damaged during this process, which can attract fungal infections.

3.7 Data collection:

Throughout the growing season, data collection was done to evaluate the effectiveness of Apex 10 on the growth rate and yield of butternut. Parameters measured were stem length, size of butternut fruits, number of butternut fruits and yield of butternuts in kilograms.

Plant length was measured using tape measure. Size of butternut fruits was measured using a string and a ruler. Number of butternut fruits was measured by counting using a counter. Yield was obtained by weighing mature fruits on a scale.

3.8 Statistical Analysis:

The data that was gathered underwent statistical analysis using suitable methods. An analysis of variance (ANOVA) was carried out to identify any significant differences between the treatment groups. All of the collected data underwent analysis of variance for a fully randomized design at a significance level of 0.05, as outlined by Steel and Torrie (1980).

CHAPTER 4: RESULTS

4.1 Effect of Apex 10 biostimulant application rates on butternut growth rate

There was highly significant difference ($p<0.001$) in vine length of the butternut among the different Apex 10 application rates. The plant vine length increased as the Apex 10 biostimulant application rate increased from 0% to 100%. The highest plant vine length is observed at the 100% treatment level, with a length of 65.44cm. The lowest plant length is observed at the 0% treatment level, with a length of 60. 96cm (Figure 1).

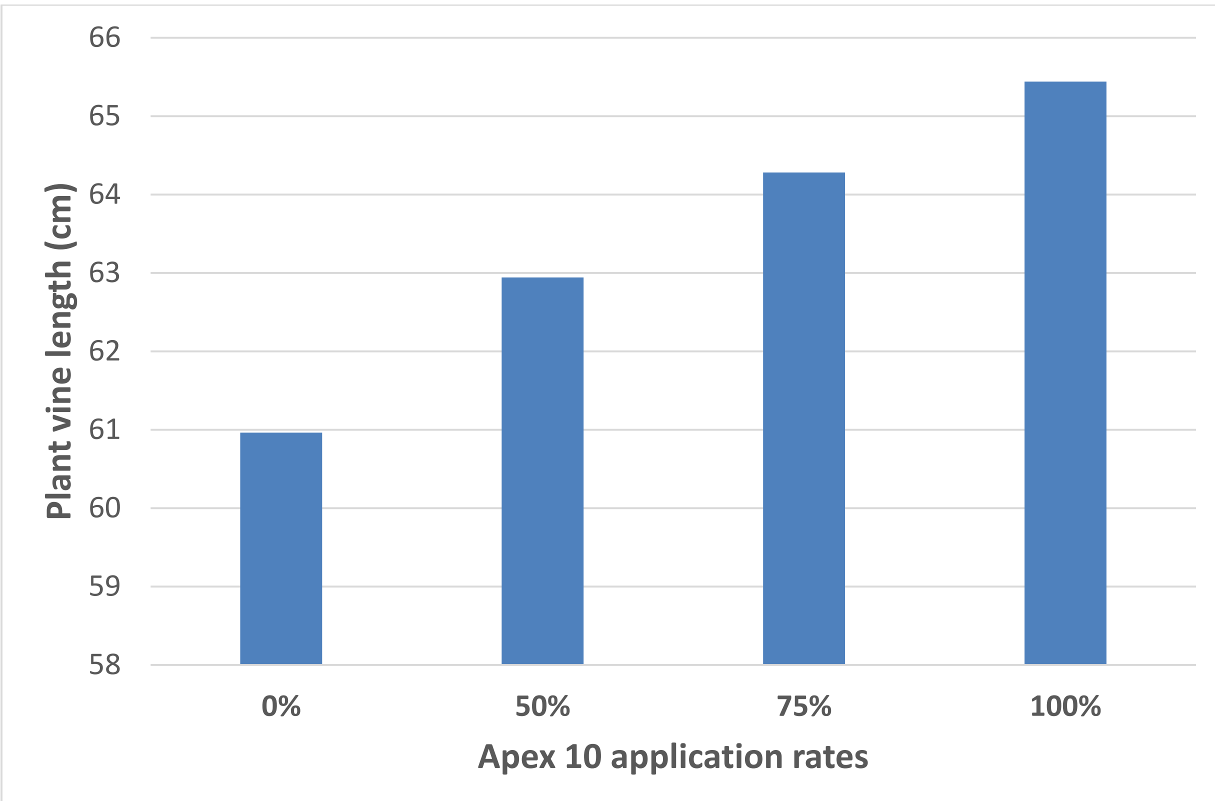

Figure 1. Effects of Apex 10 biostimulant application rates on butternut growth rate

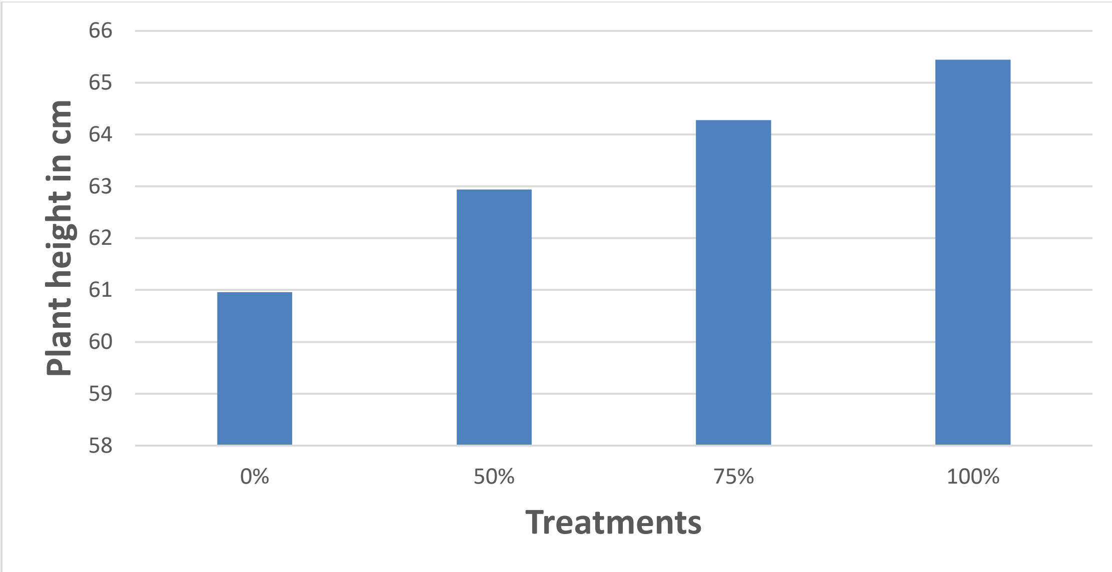

Figure 2**:** Effect of Apex 10 application rate on butternut vine length

4.2 Effect of Apex 10 biostimulant application rates on butternut fruit size and number

4.2.1 Fruit size (diameter)

The application rates of Apex 10 had a highly significant effect ($p<0.001$) on butternut fruit size. Fruit diameter increased with increasing application rates of apex 10. The highest fruit diameter of 6.7 cm was observed at 100% application rate (Figure 4.2).

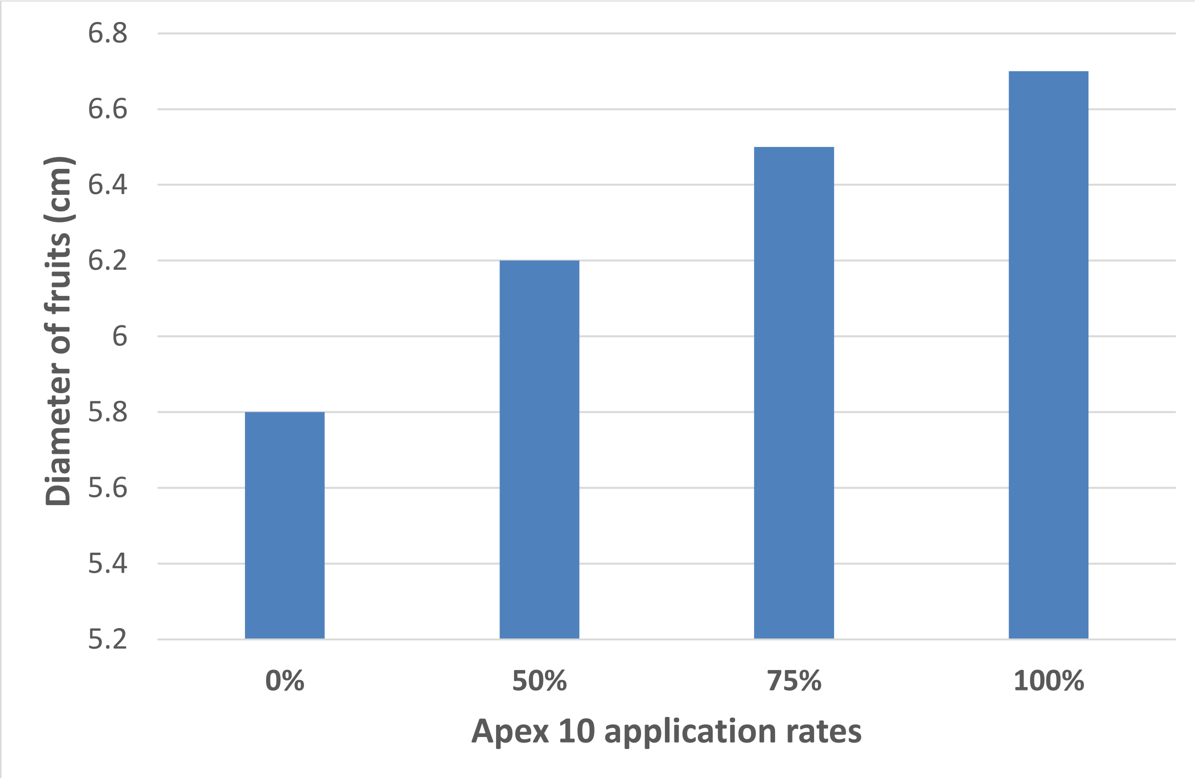

Figure 3**:** Effect of Apex 10 application rate on butternut fruit diameter

4.2.2 Fruit number

Treatment had a significant effect (p = 0.002) on the number of fruits produced per plant. The number of fruits increased with increasing levels of Apex 10 application, with the 100% treatment producing the highest mean fruit count (6.33 fruits per plant). Increased levels of Apex 10 biostimulant application rate led to an increased number of fruits per plant (Figure 4.3).

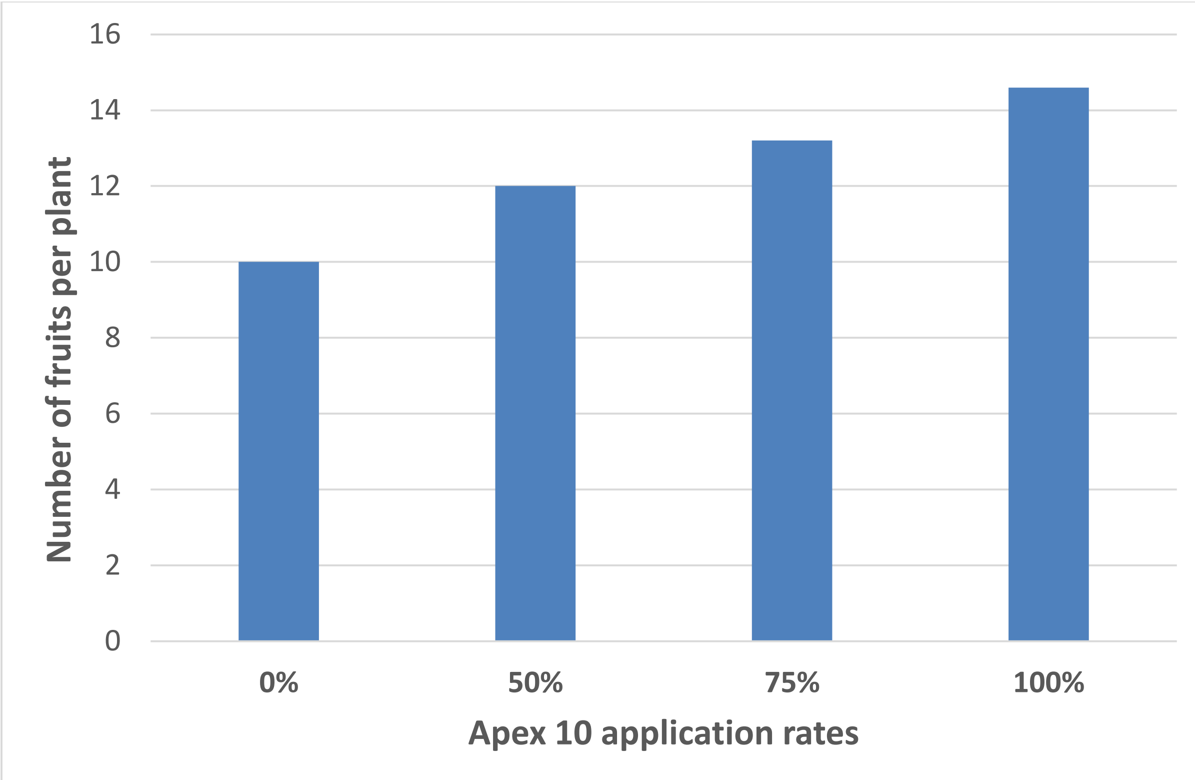

Figure 4**:** Effect of Apex 10 application rate on butternut fruit number

4.3 Effect of Apex 10 biostimulant application rates on butternut fruit yield

There was highly significant difference ($p<0.001$) in fruit yield of the butternut among the different Apex 10 biostimulant application rates. Yield increased with increasing application rates of Apex 10. The 100% application resulted in the highest yield (5.00 kg per plot), which was significantly greater than the control.

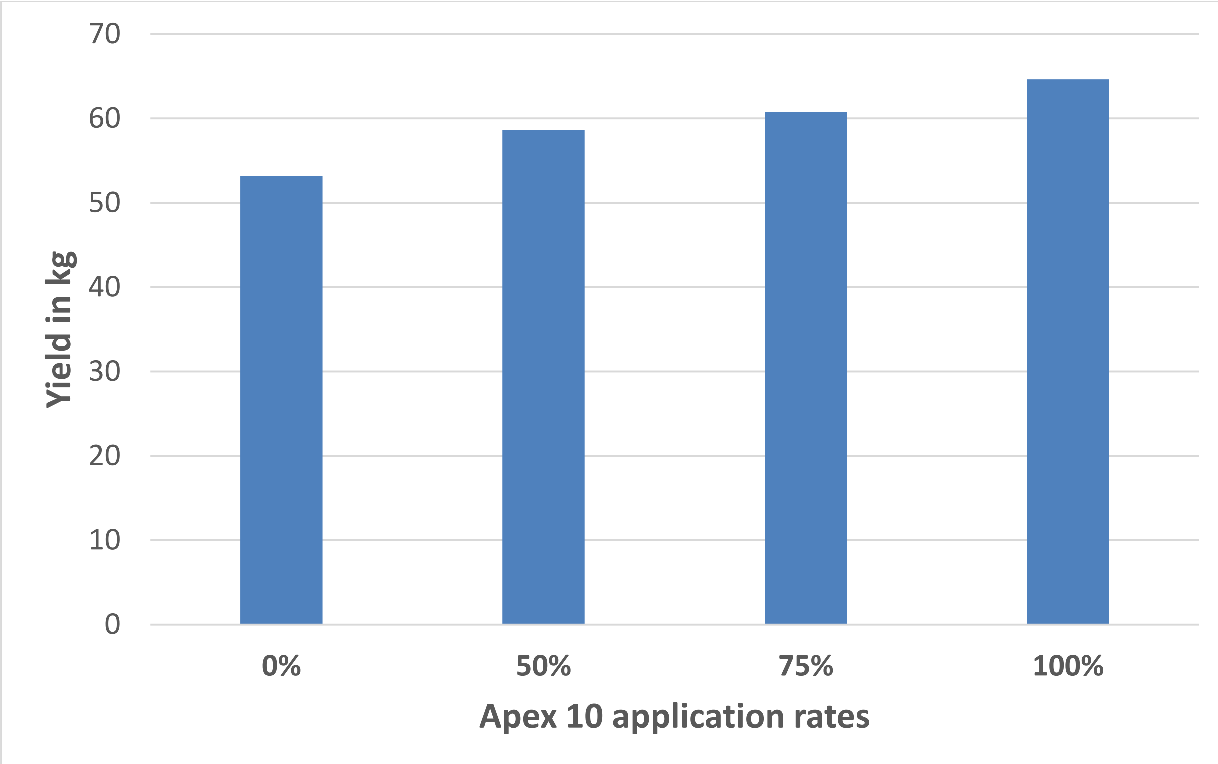

Figure 5**:** Effect of Apex 10 application rate on butternut fruit yield

CHAPTER 5: DISCUSSION

5.1 Effect of Apex 10 biostimulant application rates on butternut growth rate

Biostimulants are known to enhance plant growth by increasing nutrient uptake thereby improving the efficiency of nutrient absorption, leading to healthier plants. They also promote root development by stimulating root growth, which enhances water and nutrient absorption. Biostimulants enhances stress tolerance therefore assisting plants in acclimatization to environmental stresses, such as drought or adverse temperatures. They also boost photosynthesis, increasing photosynthetic efficiency, leading to improved growth rates. (Spooner *et al,* 2005)

Some studies on biostimulants in various crops have shown increased yields by an average of 17.9% and also improved growth parameters. Research on butternuts plants treated with a biostimulant based on enzymatic hydrolyzed animal protein showed increased vine length.

The results revealed that Apex 10 significantly influenced vine length of butternuts. Plants treated with 100% Apex 10 recorded the highest mean vine length (27.33 cm), while untreated plants had the shortest vines (23.07 cm). The increasing trend in vine length with higher Apex 10 rates suggests that the biostimulant enhances cell elongation and expansion, likely due to the presence of growth-promoting substances such as humic acids, amino acids, and naturally occurring plant hormones. Larger vines increase photosynthetic surface area, which in turn boosts plant growth and development. These findings are consistent with studies that highlight biostimulants as enhancers of vegetative biomass and nutrient assimilation. (Kramer *et al*, 1983)

The number of fruits per plant also responded significantly to the biostimulant treatments. The 100% Apex 10 rate yielded the highest average fruit count (6.33), while the control yielded only 3.67. This indicates that Apex 10 plays a key role in improving flowering, fruit set, and reducing flower abortion. This could be attributed to enhanced hormonal balance and improved nutrient uptake facilitated by the biostimulant. More fruits per plant contribute directly to higher marketable yield, making this parameter critical in evaluating productivity. Russo *et al,* 1990)

5.2 Effect of Apex 10 biostimulant application rates on butternut fruit size and number

Bio stimulants containing auxins, like Aminozime Ultra, can stimulate cell elongation, leading to increased fruit weight, size and diameter. Bio stimulants can improve fruit physical and chemical characteristics such as weight, size, diameter and firmness. (Agrochemicals Inc., 2022). Fruit yield showed a highly significant positive response to increasing Apex 10 application. The 100% treatment produced the highest yield (5.00 kg per plot), while the control had the lowest yield (3.10 kg). This marked improvement in yield can be explained by the cumulative benefits of larger leaf area (increased photosynthesis), more fruits per plant, and possibly better translocation of assimilates to the fruits. The positive effect of Apex 10 on yield aligns with its physiological role in enhancing water use efficiency, stress tolerance, and overall metabolic function in plants.

The findings demonstrate the value of Apex 10 as a biostimulant for butternut production. Given its ability to boost both growth and yield, its adoption could enhance food security and income for smallholder farmers in semi-arid regions like Uzumba Maramba Pfungwe. Additionally, as a non-synthetic product, Apex 10 supports environmentally sustainable agricultural practices

5.3 Effect of Apex 10 biostimulant application rates on butternut fruit yield

Studies on butternut production showed a 35,4% increase in plant yield and a 36,2% enhancement in productivity efficiency with biostimulant application. Biostimulants improves fruit quality by enhancing fruit diameter, weight and sugar content. Butternut squash plants can yield 3-6 fruits per plant or 10-20 with proper care (FAO, 2022)

.Apex 10 contains valuable ingredients that contributes to its effectiveness .While the exact composition may vary, bio stimulants often include micronutrients such as boron and zinc, which play crucial roles in plant growth and development .Alginic acid , a natural compound that can stimulate plant growth and improve nutrient uptake is contained in bio stimulants .Living organisms like trichoderma, which can promote root growth and enhance plant resistance to stress is also found in bio stimulants.Bio stimulants also contain plant growth regulators such as auxins , cytokinins, gibberellins and abscisic acids which regulate various physiological proceses in plants,Building blocks of proteins as well as polyphenols are present in bio stimulants to improve nutrient utilization and enhances stress tolerance.These compounds can work together to enhance plant growth, improve soil structure , increase nutrient uptake and increase yields(Yildrin, 2002)

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The study successfully demonstrated that Apex 10 biostimulant significantly influences the growth and yield of butternuts. Plant growth parameter (vine length) and yield parameters (fruit size, fruit number and fruit mass) responded positively to increasing Apex 10 biostimulant application rates. The 100% application rate is the most effective. These findings confirm that Apex 10 enhances both vegetative and reproductive development in butternut plants, leading to increased productivity. Therefore, Apex 10 biostimulant at 100% application rate can be recommended as an effective agronomic input for improving butternut production under field conditions in Zimbabwe.

6.2 Recommendations

Based on the research findings, farmers are recommended to:

- Adopt Apex 10 at 100% rate to maximize butternut yield, particularly in areas with similar agro-climatic conditions.
- Integrate Apex 10 with basal and top-dressing fertilizers for balanced nutrient supply and improved efficiency.
- Apply the biostimulant both at planting and at 4 weeks after emergence, as done in this study, to ensure optimal crop response.
- Monitor crop growth regularly to adjust other agronomic practices (e.g., irrigation, pest management) and fully exploit Apex 10’s benefits

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APPENDICES

Appendix 1: Analysis of Variance for vine length (cm)

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	2	0.74	0.37	0.61	0.566
Treatment	3	42.62	14.21	23.59	<0.001
Residual	6	3.61	0.60		
Total	11	46.97			

Apendix 2 : Analysis of variance for Fruit Diameter (cm)

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	4	0.082	0.0205	0.63	
Treatment	3	2.0175	0.6725	20.69	<.001
Residual	12	0.39	0.0325		
Total	19	2.4895			

Appendix 3: Analysis of Variance for Fruit Count per Plant

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	2	0.50	0.25	0.50	0.620
Treatment	3	20.25	6.75	13.50	0.002
Residual	6	3.00	0.50		
Total	11	23.75			

Appendix 4: Analysis of Variance for Fruit Yield (kg per Plot)

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	2	0.06	0.03	0.47	0.645
Treatment	3	5.12	1.71	30.18	<0.001
Residual	6	0.34	0.06		
Total	11	5.52			

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