BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF ENVIRONMENTAL SCIENCES

DEPARTMENT OF CROP SCIENCE

EVALUATION OF THE EFFECTIVENESS OF APEX 10 BIOSTIMULANT ON QUALITY AND YIELD OF ENGLISH GIANT AND RAMPART RAPE

BY

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DECLARATION

Student

I, Sihle Chuma, do hereby declare to Bindura University of Science Education that this research project is a result of my original work. It is being submitted in partial fulfilment of the requirements for Bachelor of Agricultural Science Honours Degree in Crop Science. The findings presented in this research project have not been submitted to any other institution before.

Signature:……………………………… Date:……………………………………..

Supervisor

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

Project Supervisor's Signature Date:

………………………………. …………………………………………..

DEDICATION

This research is dedicated to my beloved mother, my sisters and my brothers for their support in carrying out this research.

ACKNOWLEDGEMENTS

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ABSTRACT

Apex-10 is a biostimulant developed by Acme Biosciences, a leading agricultural biotech company based in California. It was created using a proprietary blend of naturally-derived plant extracts and microbial fermentation products. Apex-10 is designed to enhance plant growth, vigor, and yield in a variety of crop types. This study evaluated the effects of the bio stimulant Apex 10 and the compound fertilizer C on the quality and yield of two rape varieties, Rampart and English Giant. The experiment was carried out at Bindura University farm and the treatments were laid out using Randomized Complete Block Design (RCBD) in a factorial arrangement with two factors involved, variety with 2 levels English giant and Rampart. The second factor was nitrogen source with compound C fertilizer, apex 10 and a control with no added nitrogen. The results showed significant differences based on interactions between nitrogen sources and variety ($p<0.05$). The compound C fertilizer recorded the highest measurements for most parameters, including leaf length, leaf area, chlorophyll content, plant height, leaf count, and fresh weight. The two rape varieties responded differently to the nitrogen sources. English Giant rape recorded the highest plant height, chlorophyll content, and leaf length. In contrast, the Rampart variety had the highest leaf area and fresh weight. These findings suggest that the compound C fertilizer was more effective at improving the growth and yield characteristics of both rape varieties compared to the Apex 10 bio stimulant. The differential responses of the two varieties indicate that variety selection is an important factor when using these nitrogen sources. Farmers are recommended to use compound C as a recommended nitrogen source in combination with apex 10 bio stimulant as it is a fertilizer enhancer rather than a source of nitrogen for their crops.

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LIST OF ABBREVIATIONS

AIDS	Acquired Immune Deficiency Syndrome
AMF	arbuscular mycorrhiza fungi
ATPase	Adenine Triphosphate enzyme
CV	Critical Value
FAO	Food and Agriculture Organization
HIV	Human Immune Virus
HS	Humic substances
IFPRI	International Food Policy Research Institute
K2O	Potassium Oxide
LSD	List Significant Difference
OMRI	Organic Materials Review Institute
PBs	plant biostimulants
PGPF	Plant growth promoting fungi
PGRs	physiological responses are caused by plant growth regulators
PH	protein hydrolysates
RCBD	Randomized Complete Block Design
SED	Standard Error of Deviation
SWE	Seaweed Extract
TLVs	traditional leafy vegetables
US	United States
WAP	Week After Planting
WHO	World Health Organization

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CHAPTER ONE

INTRODUCTION

1.1Background of the study

By the middle of this century, the global population is expected to reach 9 billion, posing significant challenges for food production and security (Khoury *et al*., 2014). Climate change, coupled with the misuse of natural resources, soil erosion, and land degradation, has exacerbated crop failures in many regions, particularly in hot, dry, and arid areas like Zimbabwe (Massawe *et al*., 2015). Approximately 795 million people globally lack access to sufficient food, and an estimated 2 billion suffer from "hidden hunger" or micronutrient deficiencies, primarily in the Indian subcontinent and Africa (Oguntoyinbo *et al*., 2016). To address the challenges of feeding the growing population and mitigating the impacts of climate change, food production must be increased, and a diverse range of food sources and agricultural methods must be made available (Alemayehu *et al*., 2015)

Genetic diversity in crops has been lost, hindering advancements and sustainable agriculture (FU, 2015). Deficiencies in micronutrients, such as vitamin A, iron, iodine, magnesium, selenium, and zinc, are linked to various non-communicable diseases and are particularly prevalent in low- and middle-income countries (Maurya and Arya, 2018).By 2020, the IFPRI projected an 18% increase in malnourished children in sub-Saharan Africa, highlighting the ongoing challenges of under nutrition and micronutrient deficiencies in the region. Consuming a diverse range of nutritious foods is essential for a healthy, high-quality diet (Schreinemachers *et al*., 2018). It is crucial to encourage greater intake of fruits and vegetables, as they are rich in health-promoting vitamins and contain additional beneficial phytochemicals (Uusiku *et al*., 2010). This makes fruits and vegetables important sources of micronutrients for healthy diets (Baldermann *et al*., 2016; Schreinemachers *et al*., 2018). Many crops contain minerals that help maintain healthy blood pressure, while their fiber controls cholesterol and reduces heart disease risk. Nutrients like folate, vitamin A, and vitamin C provide further health benefits (Schreinemachers *et al*., 2018). During the AIDS pandemic, micronutrient and antioxidant-rich diets are widely recommended to complement HIV/AIDS therapy (Elisha *et al*., 2016; Yang and Keding, 2009). The World Health Organization advises consuming at least 400 grams of fruits and vegetables daily to reduce chronic disease risk (Smith and Eyzaguirre, 2007).

However, only a small fraction of the 10,000 edible plant species are globally commercialized, with just 12 species providing 80% of food energy (Venskutonis and Kraujalis, 2013). Many potentially nutritious "underutilized" or "neglected" crops remain marginalized despite their ability to diversify agriculture, reduce land degradation, and improve food and nutrition security (Cheng *et al*., 2017; Dansi *et al*., 2012; Fomsgaard *et al*., 2011; Jacobsen *et al*., 2013; Massawe *et al*., 2016). Unlocking the potential of these underutilized crops could be a valuable strategy for sustainable agriculture. In Zimbabwe, vegetables grow in dry season therefore there is the need for techniques which help to conserve moisture. Soils in communal lands are not good hence techniques to take care of soil conditions are also important in improving soil fertility.

1.2 Problem statement and Justification

Previous researches have been carried out but, now not specifically answering the position of the effectiveness of apex 10 bio stimulant on Quality and yield of Rampart and English giant. Shortage of energy and export restrictions by Russia and China has led to a sharp increase in prices of synthetic fertilizers which are produced from natural gas and coal. At the same time, chemical fertilizer is in short supply globally, prices increased and it is now difficult for farmers to purchase enough fertilizers for their crops. The result is the yellowish of crops a few weeks after plant and some farmers end up cultivating less land than the maximum capacity of their field. This is now a threat to food security especially in in Zimbabwe and Africa as a whole. To mitigate for the threat of food shortages, Nature's Wonder, company in US manufactured apex 10 and the OMRI, certified it, a bio-stimulant and soil amendment formula packed with 100% natural active ingredients extracted 10,000-year old organic matter (peat). Several testimonials and shocking stories about an organic bio-stimulant and soil amendment formula are spreading among local farmers in Africa, Asia, and the Caribbean. In Zimbabwe, apex 10 bio stimulant is a new product and the aim of the experiment is to investigate the effectiveness of apex 10 on Zimbabwean soils. This project is going to help farmers with reduced cost of production and improved productivity.

1.3 Research objectives

i. Investigating the effects of nutrient sources and variety on vegetative growth of rape plants.
ii. To evaluate the effects of nutrients sources and variety on the yield of rape plants.

1.4 Hypothesis

i. Nitrogen source and variety have an effect on vegetative growth of rape plants.

ii. Nitrogen source and variety have no impact on the yield of rape plants.

CHAPTER TWO

LITERATURE REVIEW

2.1 Biostimulant

Biostimulants are substances that can alter essential and structural processes to improve plant growth by enhancing resistance to abiotic stressors and boosting the yield and quality of seeds and/or grains. Additionally, biostimulants can reduce the need for fertilizers (Keny, 2019). The definitions of biostimulants can vary, with some suggesting they should be categorized based on their effects on plants or the physiological responses they induce (Chinao, 2001). Others propose categorizing them by their mode of action and the source of the active ingredient (Ronfel, 2009). Stain (2011) has emphasized the importance of the ultimate effect on plant productivity, indicating that any description of biostimulants should focus on their agricultural roles, either through the characteristics of their components or their modes of action.

The term "biostimulant" refers to synthetic or natural materials applied to soil, plants, and seeds. According to Stain (2011), a biostimulant is defined as a formulated product of biological origin that improves plant productivity due to the novel or emergent properties of the complex of constituents, rather than solely due to the presence of known essential plant nutrients, plant growth regulators, or plant protective compounds. This definition highlights that biological function can be positively modulated through the application of molecules or mixtures of molecules, even when their explicit mode of action is not defined. Stain (2011) further notes that at lower levels, these substances have the potential to significantly improve nutritional efficiency, resilience to environmental stress, and overall quality characteristics of crops, irrespective of their nutrient composition. These substances can have similar actions to the main plant hormones, such as auxins, gibberellins, and cytokinins, when applied exogenously.

2.2 Apex 10 bio stimulant

Apex-10 is a powerful biostimulant that increases growth and yield when applied to seeds, plants, or soil (Keny, 2019). It stimulates natural processes to benefit nutrient uptake, nutrient efficiency, and stress tolerance (Keny, 2019). APEX-10 is also a soil amendment that improves the physical, chemical, and biological characteristics of the soil (Keny, 2019). It is a one-of-a-kind peat extract made from 10,000-year-old active and complex naturally occurring materials, resulting in a formula with greater power than the sum of its parts (Stain, 2011). APEX-10 falls under the class of biostimulants known as Humic and Fulvic Acids (Stain, 2011).

2.2.1 Physiological effects of apex 10

Manufacturers of apex 10 bio stimulant propose that apex 10 can influence production through the following ways:

- Enhanced Nutrient Uptake: Apex-10 bio stimulant improves the efficiency of nutrient uptake by plants. The unique formulation helps make nutrients more available to the plant, enhancing overall nutrient absorption and utilization.
- Increased Stress Resilience: The bio stimulant enhances the plant's ability to withstand stressful conditions. It has been shown to reduce the potential for root loss under challenging environments, thereby improving the plant's resilience to various stressors.
- Improved Growth and Yield: Apex-10 bio stimulant acts as a biostimulant, stimulating natural processes that benefit growth and yield. When applied to seeds, plants, or soil, it promotes healthier and more vigorous growth, leading to increased yields.
- Enhanced Plant Performance: the application of Apex-10 bio stimulant results in improved plant performance. It increases plant turgidity, enhances soil nutrient retention, and boosts fertilizer efficiency, all contributing to better overall plant health and vitality.

2.3 Biostimulants and vegetable production

The global demand for organically grown vegetables has increased considerably in recent years due to heightened consumer awareness of healthy and safe food products (Dorais and Alsanius, 2015). Since 2020, there has been a doubling of organic agriculture worldwide, with over 3.5 million hectares under organic cultivation in more than 87 countries by 2022 (Willer and Lernoud, 2016). Organic horticulture is environmentally friendly and enables food production without being detrimental to the environment, conserving water and minimizing chemical inputs (Dorais, 2007). However, the major limitation of organic farming is reduced yield compared to conventional agriculture (Dorais and Alsanius, 2015; Suefrt *et al*., 2012), leading to the need for more land to produce the same amount of food, which can encourage deforestation and compromise the environmental benefits of organic farming (Trewavas, 2001).

To address this challenge, the use of biostimulants has been proposed as a promising eco-friendly approach to enhance food production while maintaining environmental integrity (Rouphael *et al*., 2017). According to Colla *et al*. (2015), research conducted in greenhouses has demonstrated that the use of biostimulants can enhance the absorption and utilization of nutrients in plants. This effect is attributed to the stimulation of soil enzymes and microorganisms, alterations in root structure, and improved movement and solubility of micronutrients.

Throughout the entire life cycle of a crop, biostimulants exert a positive influence on plant growth and development, starting from seed germination and continuing until maturity (Colla *et al*., 2017). They effectively optimize the metabolic processes of plants, leading to increased crop yield and improved harvest quality (Colla *et al*., 2017). Moreover, these biostimulants enhance the plant's ability to withstand environmental stresses and improve nutrient absorption, resulting in higher-quality agricultural products (Colla *et al*., 2017). Furthermore, they contribute to better water usage efficiency and promote the growth of beneficial microorganisms in the soil, thereby enhancing soil fertility (Colla *et al*., 2017).

To enhance nutrient assimilation in plants, biostimulants can be directly applied to the plant, seeds, soil, or growing media. Microbial-based biostimulants promote plant growth through mechanisms such as biological nitrogen fixation, the solubilization of mineral phosphates and other nutrients, and the secretion of specific enzymes (Colla *et al*., 2017a; Calvo *et al*., 2014). Additionally, biostimulants increase the extent of soil exploration by the plant's root system, enabling improved access to soil nutrients (Hayat *et al*., 2010; Rouphael *et al*., 2015). Unlike conventional crop inputs, biostimulants operate through distinct mechanisms and do not directly combat pests or diseases, but rather enhance plant vigor (Calvo *et al*., 2014).

2.4 Classification and functions of plant biostimulants (PBs)

According to Du Jardin (2015), plant biostimulants (PBs) can be categorized based on their impact and role in influencing plant growth. PBs encompass a range of substances and microorganisms applied to plants with the aim of improving their efficiency in utilizing nutrients, enhancing tolerance to abiotic stress, and/or improving crop quality characteristics, regardless of their nutrient content (Du Jardin, 2015). PBs are employed to address nutrient deficiencies in plants caused by insufficient nutrient availability in the soil or limited nutrient solubility (De Pascale *et al*., 2017). They achieve this by enhancing nutrient accessibility through increasing the soil's cation exchange capacity, supplying nitrogen to crops, and/or enhancing nutrient solubility in the soil solution (De Pascale *et al*., 2017).

Other studies indicate that the suggested application rate of PBs is kept below the level that would trigger root growth through auxins, as reported by Battacharyya *et al*. (2015). The promotion of root growth by biostimulants is attributed to the interaction between organic compounds present in the biostimulants and receptors on the membranes of plant cells, according to Battacharyya *et al*. (2015). This interaction initiates a signal transduction pathway that ultimately influences the hormonal balance within the plant cells.

2.4.1 Humic substances (HS)

Humic substances (HS) are formed through the chemical and biological transformation of deceased organic matter, as well as microbial processes (Du Jardin, 2015). These substances have a significant impact on the physicochemical properties of soils and are recognized for their ability to stimulate root growth and enhance plant nutrition by influencing soil nutrient dynamics (Du Jardin, 2015). HS contribute to the improved availability of nutrients for plants by increasing the cation exchange capacity of the soil and regulating the soil pH through buffering (Canellas *et al*., 2015; Du Jardin, 2015). Furthermore, they form complexes with micronutrients, which prevents their leaching and enhances their accessibility for plant uptake.

HS have been found to stimulate the activity of plasma membrane ATPase, leading to the extrusion of H+ ions from roots and subsequently lowering the root surface pH. This process, as described by Canellas *et al*. (2015), triggers the availability of soil nutrients, facilitating their improved uptake and translocation by plants. Additionally, HS are believed to have significant effects on secondary metabolism and alleviation of stress, as noted by De Pascale *et al*. (2017). Research has demonstrated that HS can enhance plant tolerance to salinity in tomato and okra. In the case of Brassica napus, the application of humic acids stimulated root growth and increased the uptake of nitrogen and sulfate. This effect was attributed to the upregulation of genes encoding nitrate transporters (BnNRT1.1 and BnNRT2.1) and sulfate transporters (BnSultr1.1 and BnSultr1.2) in the roots, as observed by Jannin *et al*. (2012).

2.4.2 Protein hydrolysates

Protein hydrolysates (PH) are another important group of plant biostimulants (PBs), which are mixtures of polypeptides, oligopeptides, and amino acids derived from the partial hydrolysis of protein sources (Schaafsma, 2009). Humic substances (HS) are available in various forms, such as granules, powders, or liquid extracts, and can be applied either as foliar sprays or near the root system (Colla *et al*., 2017a). They exert their effects on plants by improving soil respiration, microbial biomass, and microbial activity, enabling microorganisms to readily utilize amino acids and peptides as carbon and nitrogen sources (Farrell *et al*., 2014). Furthermore, HS enhance plant nutrition by forming complexes and chelates with soil micronutrients (such as Cu, Fe, Mn, and Zn), increasing their availability and facilitating their uptake by the plant's root system (Du Jardin, 2015). HS are also involved in chelate formation with both macronutrients (K, Ca, and Mg) and micronutrients (Cu, Fe, Mn, and Zn), which is utilized by the industry to develop fertilizers with improved nutrient utilization efficiency (De Pascale *et al*., 2017). Studies have reported the root-stimulating effects of HS as plant biostimulants in crops like tomato, lettuce, and corn (Colla *et al*., 2014).

2.4.3 Plant growth promoting fungi (PGPF)

Plant growth-promoting fungi (PGPF), such as arbuscular mycorrhizal fungi (AMF) and *Trichoderma* spp., can enhance plant growth by increasing the availability of nutrients like nitrogen, phosphorus, and iron (Dorais, 2007). Consequently, various symbiotic and non-symbiotic organisms are now being utilized in both conventional and organic agriculture to enhance nutrient availability and improve plant productivity (Calvo *et al*., 2014). However, the specific mechanisms underlying the PGPF-mediated improvements in crop productivity still need to be further investigated. Many PGPF are capable of producing plant hormones, including auxins, cytokinins, gibberellins, ethylene, and abscisic acid (Hayat *et al*., 2010). These phytohormones may play a role in stimulating plant growth and development, such as by promoting root growth and enhancing nutrient and water uptake (auxins), as well as stimulating cell division in shoots and roots and delaying senescence (cytokinins).

Gibberellins play a crucial part in fruit and flower formation, fruit improvement, breaking dormancy of vegetative organs, and promoting seed germination. Abscisic acid, on the other hand, is responsible for plant adaptive responses to environmental stresses like drought, high salinity, and plant developmental processes like seed maturation and dormancy (Miyakawa *et al*., 2013). Additionally, many plant growth-promoting fungi (PGPF) can increase phosphate solubility in the soil, making phosphorus more readily available for plant uptake (Canbolat *et al*., 2006). Arbuscular mycorrhizal fungi (AMF) act similarly to PGPF in enhancing the availability of phosphorus (Rouphael *et al*., 2015.

2.4.4 Seaweed Extract (SWE)

Many technological innovations have been introduced to improve sustainable agriculture by significantly reducing the use of fertilizers and other chemicals. One of the most promising strategies for decreasing chemical usage and enhancing crop resistance to abiotic stresses, such as nutrient deficiency, is the employment of biostimulants like seaweed extracts (SWE) (Sharma *et al*., 2014). The use of biostimulants in agricultural practices can significantly reduce the reliance on synthetic fertilizers, as they have the capability to boost crop yields and enhance overall agricultural productivity without compromising the environment (Sharma *et al*., 2014). There has been widespread acceptance and implementation of seaweed extracts (SWE) within the horticulture sector (Battacharyya *et al*., 2015). Particular emphasis should be placed on SWE derived from brown macroalgae, specifically Ascophyllum nodosum, Ecklonia maxima, Durvillea potatorum, and Macrocystis pyrifera. These brown macroalgal species are known to be rich sources of valuable compounds, including polysaccharides, phenolic compounds, osmolytes such as mannitol, and a variety of phytohormones, encompassing abscisic acid, auxins, brassinosteroids, cytokinins, and gibberellins (Battacharyya *et al*., 2015).

Researchers have been successful in identifying and quantifying numerous growth regulators present within Ecklonia maxima (Kelpak®), which have been determined to be the chemical compounds responsible for stimulating growth in various agricultural crops (Papenfus *et al*., 2013). Kelpak® has been documented to exhibit beneficial effects on a diverse range of horticultural crops, ornamental plants, trees, monocotyledonous crops, and plant cuttings. Several studies have reported that the application of microalgae, either through foliar sprays or soil drenching, can elicit both physiological and biochemical responses in plants, including enhanced root and shoot growth, influence on flowering time, increased plant productivity and nutritional quality, as well as the mobilization of macro- and micronutrients (Battacharyya *et al*., 2015; CRAIGIE, 2011).

According to multiple researchers (Craigie, 2011; Rouphael *et al*., 2017; Rouphael *et al*., 2015), the application of Ascophyllum nodosum and Ecklonia maxima has been shown to improve plant tolerance to adverse environmental conditions, such as heat and drought stress. The phlorotannins, including phloroglucinol and its derivative Eckol, which are isolated from Ecklonia maxima, are major compounds found in seaweed extracts that also possess growth-stimulating properties. Eckol has been reported to enhance the growth of maize in terms of shoot and root elongation, as well as the development of seminal roots. Furthermore, Eckol has been found to exhibit auxin-like effects in mung beans, leading to an increase in root number, shoot elongation, and seedling weight (Rengasamy *et al*., 2015).

Seaweed extracts (SWE) have been shown to enhance the growth of plant roots and shoots, improve nutrient uptake, enhance flower formation and fruit set, leading to increased yields, delayed senescence, and longer shelf life of fruits (Crouch and Van Staden, 1994; Khan *et al*., 2009). Additionally, plants treated with SWE have improved resistance to insect and pathogen attacks, as well as drought and frost stress. The use of seaweed extracts (SWE) is commonly done at low application rates through drenching or foliar application, and the benefits observed are not attributed to an increase in major or minor nutrients present in the extract, but rather the physiological responses triggered by plant growth regulators (PGRs) and other bioactive compounds such as oligomers and polysaccharides, which can be effective even at very low concentrations (Papenfus, 2023). One such liquid extract, commercially known as Kelpak®, is produced using a cell disruption method from the kelp species Ecklonia maxima (Osbeck) Papenfus, which is harvested along the western coast of South Africa (Papenfus, 2023).

2.4.5 Vermicompost

Biostimulants can be produced from waste materials generated by the agricultural and food industries, such as vermicompost (Xu & Geelen, 2018). It is defined as the organic matter created through the activity of earthworms (Sharma *et al*., 2014). The process of making vermicompost has been broadly utilized to manage the accumulation of waste from food waste, plants and sewage sludge (Allrdice *et al*., 2015). This technique also helps eliminate disease-causing organisms found in manure, including fecal coliforms, Salmonella species, enteric viruses, and helminths making it a more viable waste management approach that reduces environmental contamination.

Vermicompost can serve as a biostimulant, providing multiple benefits. It can be used as a growth medium for plants, as a soil amendment to improve soil quality, as a source of replenished nutrients, and as a way to enhance plant resistance to abiotic stressors (Chinsamy *et al*., 2013). Studies have shown that the leachate from commercially vermicomposted garden waste contains various plant growth regulators (PGRs), such as cytokinins, auxins, abscisic acid, gibberellins, and brassinosteroids (Aremu *et al.*, 2015). This presence of substances with phytohormonal activity may explain the biostimulatory effects of vermicompost. Vermicomposting is a crucial process for sustainable agriculture and nutrient recycling, as it is a cost-effective method of waste management that can be scaled up (Yadav and Garg, 2013).This strategy enables farmers to recycle their own waste, including plant materials and animal manure, and convert them into organic fertilizers to improve crop yields and soil quality (Van Groenigen *et al*., 2014).

2.5 Global hunger and malnutrition challenges

Nutritional insecurity is a widespread problem among the bulk of Africans, stemming from a lack of essential minerals and vitamins in their diet, primarily due to insufficient consumption of fruits and vegetables (Afari-Sefa *et al*., 2012). Despite the continent's high diversity of underutilized vegetables and fruits known to be rich in nutrients (Bua & Onang, 2017), there is a notable nutritional inadequacy that significantly contributes to high rates of malnutrition and the prevalence of non-communicable diseases globally (Mokdad *et al*., 2018). In response, scientists and policymakers are seeking alternative strategies to enhance agricultural production and increase biodiversity ecosystem services, which could potentially improve crop yields (Garibaldi *et al*., 2017). However, there is limited documentation on the link between nutrition and agricultural developments responsible for the current diet deficiencies (Kadiyala *et al*., 2014; Pingali, 2012). The historical focus on increasing the yields of some staple cereals during the Green Revolution has led to substantial losses of biodiversity in agricultural food systems (Meldrum *et al*., 2018). Relying solely on a few major crops is unsustainable in the long term, as it comes with agronomic, ecological, nutritional, and economic risks (Ebert, 2014).

The high levels of micronutrients found in traditional leafy vegetables (TLVs) could make a significant contribution to improving nutritional security if they are incorporated into people's diets (Keatinge *et al*., 2011). This is because TLVs can provide both essential micronutrients and valuable bioactive compounds, which could have a positive impact on overall health and well-being. Many African countries are failing to address issues related to under nutrition and micronutrient deficiencies in the diet. Empirical evidence has shown the many benefits associated with TLVs, including their superior micronutrient content, useful medicinal properties, and agronomic advantages like short growth periods and low input requirements. TLVs have been ignored in terms of research and investment, despite their numerous attributes (Dinssa *et al*., 2013). The lack of vitamin A,iron, zinc and iodine has been acknowledged as the world's most serious risk factors for health, as they are associated with various problems, including tuberculosis, HIV/AIDS and other chronic diseases resulting from unbalanced diets (WHO, 2000; Soetan *et al*., 2010). Vegetables are a crucial component of a balanced and nutritious diet, and their specific nutritional value can vary depending on the particular plant part that is consumed (Agate *et al*., 2000).

CHAPTER THREE

METHODOLOGY

3.1 Site description

The trial was conducted at Bindura University of Science Education farm, situated in Shamva district adjacent to the Shamva Agricultural College. The farm's geographical coordinates are 17º 14' 29" S, 31º 03'54" E. The area is found in agro ecological region 2b in Mashonaland Central province at the north eastern part of Zimbabwe. The soil type across Shamva district is characterized as clay. Being in ecological zone 2b, Shamva receives an annual rainfall of 700-1000mm falling from November to April in good rainy season.

3.2 Experimental Design

The experiment was laid out in a randomized complete block design (RCBD) and it was a 2-factor experiment, the first factor was variety where two varieties (English giant and rampart) were used. The second factor was nitrogen source and it had 3 levels, apex10, and compound C fertilizer at recommended rates of 600kg/ha and also control with no fertilizer and Apex 10. The trial was replicated three times. The blocking factor was the slope angle.

3.4Agronomic practices

3.4.1 Land preparation

The land was cleared of weeds before pegging of the site where the trial was done. Any existing vegetation, weeds, rocks, or debris from the study area was removed. All unwanted plant residues or previous crop remnants that could interfere with the research outcomes or introduce unwanted variables were cleared and the land was leveled to promote uniform water distribution and prevent waterlogging or drainage issues. The block of 85m^2 was pegged on the study site. Sizes of plots were 2m long and 1m wide to give the bed size of 2m^2. A pathway between blocks and experimental units was 1m. Raised beds of uniform sizes and shape were formed using hoes to improve soil drainage and moisture retention. Treatments were assigned to experimental units using the randomized complete block design. A stick was used for marking a line to place seeds.

3.4.2 Planting

Rampart and English giant were grown as seeds in situ. Thinning was done 4 weeks after planting to reduce competition for nutrients and water.

3.4.3 Fertilizer application

Two sources of nitrogen were applied to the experimental design. 600 kg/ha Compound C fertilizer (6N 15P2O512 K2O) was applied as basal before planting was done. Apex 10 was applied twice in the growing season at a rate of 240mls/16lt knapsack.

3.4.4 Weed control

The study area had several weed occurrences there for hand weeding was done almost weekly after planting. Mulching using dry grass was implemented on the plots to conserve moisture and reduce the interference of weeds.

3.4.5 Disease and pest control

Lambda was used on a two-week basis to control aphids and other cutworms. Pest scouting was done weekly to monitor and detect pests earlier on.

3.4.6 Watering

A watering cane was used to water plants especially in the early stages of growth to avoid over-watering of vegetables. Later on, watering was done using a horse pipe.

3.5 Data collection

Plants from where data was collected were sampled randomly. Three plants per bed were measured and an average was calculated. Parameters that were recorded include;

3. 5.1 Leaf area

A 30cm ruler was used to measure the leaf length and leaf width. Leaf area was calculated using the formula; Area= Length × Width.

3.5.2 Chlorophyll content

Chlorophyll content was measured using the chlorophyll meter. Initially, the chlorophyll meter was calibrated in order to give efficient measurement.

3.5.3 Leaf length

A 30cm ruler was used to measure the leaf length. The length of the leaf was determined by the length of the midrib.

3.5.4 Plant height

A 30cm ruler was used to measure plant height and also a string was used where necessary.

3.5.5 Number of leaves

The number of leaves was counted using the physical counting method. The first bottom leaves were not counted.

3.5.6 Leaf fresh weight

Fresh weight of rape leaves was measured using a laboratory balancing scale. Fresh weight was recorded at 3WAP and 4WAP.

3.6 Data Analysis

Data was analyzed using Genstat 17th edition. Then the LSD at 0.05 levels was used to separate means where there were significant differences.

CHAPTER FOUR

RESULTS

4.1 Effects of Nitrogen source and variety on leaf area of 2 varieties of rape

There were no interactions between nitrogen source and variety on leaf area. Nitrogen source had an effect on leaf area at one up to three weeks after plant but it had no effect at 4 weeks after planting. Variety had no effect on leaf area of two varieties of rape.

4.1.1 Effects of N source on leaf area of different varieties of rape

Table1: Effects of N source on leaf area of different varieties of rape

N source	Leaf area 1WAP	Leaf Area 2WAP	Leaf Area 3WAP
Compound C	24.1^{a}	73.7^{a}	171.9^{a}
Apex 10	16.3^{b}	32.4^{b}	108.4^{b}
Control	16.1^{b}	41.3^{b}	87.0^{b}
LSD	6.50	20.22	51.40
SED	2.92	9.07	23.07
P.Value	0.032	0.003	0.011
CV%	26.8	32.0	32.0

Mean followed by the same letter are not significantly different.

Compound C recorded the highest mean leaf area (24.1cm^2) in the first week, 3WAP (171.9cm^2) while plots with a control recorded the least mean leaf area 1WAP (16.1cm^2), 3WAP (87cm^2). At 2WAP, compound C fertilizer had the highest mean area of 73.7cm^2 whilst apex 10 bio stimulant recorded the least mean leaf area of 32.4cm^2. There was no significant difference between apex 10 and a control experiment at 1WAP, 2WAP, 3WAP and 4WAP ($p>0.05$). There was a significant difference between compound C fertilizer and Apex 10 at 1WAP, 2WAP, 3WAP and 4WAP ($p<0.05$). There was a significant difference between compound C fertilizer and Apex 10 at 3WAP ($p<0.05$). Variety had a significant difference on leaf area at 4WAP ($p<0.05$). Rampart had the highest mean leaf area of 324cm^2 while English giant had the lowest mean leaf area of 192cm^2.

4.2 Effects of Nsource and variety on chlorophyll content of 2 varieties of rape

There were interactions effects between Nitrogen source and variety on chlorophyll content of English giant and Rampart rape at 2 WAP and 4WAP ($p<0.05$) . There were no interaction effects between Nitrogen source and variety on chlorophyll content of two varieties of rape at 1WAP and 3WAP ($p<0.05$). Nitrogen source influenced chlorophyll content of Rampart and English giant rape at 3WAP ($p<0.05$) while at 1WAP, 2WAP and 4WAP nitrogen source had no effect ($p>0.05$). Variety had a significant effect on chlorophyll content of Rampart and English giant rape at 3WAP and 4WAP ($p<0.05$). There was no significant difference between Rampart and English giant at 1WAP and 2WAP ($p<0.05$).

4.2.1 Effects of Nsource on chlorophyll content of 2 varieties of rape.

Table 2: Effects of Nsource on chlorophyll content of 2 varieties of rape.

Nsource	Chlorophyll content 3WAP
Compound C fertilizer	37.52^{a}
Apex 10	28.68^{b}
Control	23.68^{b}
LSD	13.7
SED	5.290
P.value	2.374
CV%	<0.001

Mean followed by the same letter are not significantly different

Compound C gave the highest chlorophyll content of 37.52ɥm at 3WAP and 24.53ɥm at 4WAP. There was a notable statistical difference between compound C and Apex 10 and no notable differences between apex 10 and a control at 3WAP.

4.2.2 Effects of variety on chlorophyll content of 2 different varieties of rape.

Table3: Effects of variety on chlorophyll content

Variety	Chlorophyll content 3WAP
English giant	33.22^{a}

Rampart	26.70^{b}
CV%	13.7
LSD	4.319
SED	1.938
P.Value	0.007

Means followed by the same letters are not significantly different

English giant gave the highest chlorophyll content of 33.22ųm at 3WAP and 24.16ųm at 4WAP. There was a statistical significant difference between means of English giant and Rampart at 3WAP and 4WAP.

4.2.3 Effects of Nsource and variety on chlorophyll content of two rape varieties.

Table 4: Interaction of Nsource and variety on chlorophyll content of two rape varieties

Nsource variety	Chlorophyll content 2WAP	Chlorophyll content 4WAP
Comp.C Eng.G 1	39.63^{a}	31.77^{a}
Comp. C Ramp	35.40^{b}	17.30^{b}
Apex10. Eng G	29.83^{c}	22.43^{b}
Apex 10 Ramp	27.53^{c}	15.07^{b}
Cntrl. Eng. G	30.20^{c}	18.27^{b}
Cntrl. Ramp	17.17^{d}	19.57^{b}
CV%	13.7	16.6
SED	3.358	2.809
LSD	7.481	6.259
P.Value	0.004	0.009

Means followed by the same letters are not significantly different

There was significance difference between the interaction of compound C with English giant and compound C with Rampart at 2WAP and 4WAP ($p<0.05$). There was no significant difference between English giant with Apex 10, Rampart with apex 10 and Rampart with a control ($p>0.05$). There was a significant difference between English giant with a control and Rampart with a control. No significant difference was noticed between interactions compound C with other treatments at 4WAP ($p>0.05$). English giant with compound C gave the highest chlorophyll content and Rampart with a control gave the lowest chlorophyll content at 2 weeks after planting. At 4WAP, Rampart with compound C still gave the highest chlorophyll content of 31.77ɥm while Rampart with apex 10 gave the lowest chlorophyll content of 15.07ɥm.

4.3 Effects of N source on leaf length of 2 varieties of rape.

No interactions were observed between Nsource and variety on leaf length of rape varieties from 1WAP to 4WAP ($p>0.05$). Nitrogen source had an effect on leaf length of rape varieties at 1WAP, 3WAP and 4WAP ($p<0.05$). At 2WAP, nitrogen source had no effect on the leaf length of English giant and Rampart rape ($p>0.05$).No significant difference was observed on leaf length of English giant and Rampart rape at 1WAP, 2WAP and 3WAP ($p>0.05$). A notable significant difference was observed in all the rape varieties in terms of their leaf length at 4WAP ($p<0.05$).

4.3.1 Effect of N source on leaf length of 2 varieties of rape

Table5: Effects of Nsource on leaf length of two varieties of rape

Nsource	Leaf Length 1WAP	Leaf Length 3WAP	Leaf Length 4WAP
Compound C	5.77^{a}	14.45^{a}	20.43^{a}
Apex 10	4.47^{b}	10.82^{b}	14.55^{b}
Control	3.65^{b}	11.40^{b}	16.72^{b}
CV%	20.5	17.2	13.6
LSD	1.221	2.708	3.024
SED	0.548	1.215	1.357
P.Value	0.010	0.029	0.005

Means followed by the same letter are not significantly different

Notable statistical difference was observed between compound C and Apex 10 at 1WAP, 3WAP and 4WAP ($p<0.05$) and no notable significant difference was observed between apex 10 and a control at 1WAP, 3WAP and 4WAP ($p>0.05$). Compound C fertilizer gave the highest mean leaf areas of 5.77cm, 14.45cm and 20.43cm at 1WAP, 3WAP and 4WAP respectively.

4.3.2. Effects of variety on leaf length of 2 different varieties of rape.

Table 6. Effects of variety on leaf length of 2 varieties of rape.

Variety	Leaf length 4WAP
English giant	15.87[b]
Rampart	18.60[a]
CV%	13.6
SED	1.108
LSD	2.469
P.Value	0.033

Means followed by the same letters are not significantly different

There was a significant difference between the leaf length means of English giant and Rampart rape at 4WAP ($p<0.05$). Rampart rape had the highest leaf length mean of 18.60cm at 4WAP.

4.4 Effects of Nsource and variety on plant height of 2 varieties of rape.

There were interaction effects between Source and variety on height of English giant and Rampart rape at 1WAP and 2WAP. No significant difference was observed in terms of the interaction of Source and variety on height of 2 varieties of rape at 3WAP and 4WAP ($P>0.05$). Nitrogen source had a significant difference on the height of English giant and Rampart rape at 4WAP ($p<0.05$). Nitrogen source had no notable significant difference on the height of English giant and Rampart rape at 3WAP ($p>0.05$). Variety showed a significant difference on height of English giant and Rampart rape at 4WAP. There was a notable significant difference between means of English giant and Rampart at 4WAP ($p<0.05$). At 3WAP, no significant difference was observed on the height of 2 rape varieties ($p>0.05$).

4.4.1 Effects of Nsource on height of 2 varieties of rape.

Table 7: Effects of Nsource on height of 2 varieties of rape

Nsource	Height 4WAP
Compound c	11.78[a]
APEX-10	7.97[b]
Control	8.87[b]
CV%	10.6
SED	0.602
LSD	1.342
P.Value	<0.001

Means followed by the same letters are not significantly different.

There was a significant difference between the means compound C fertilizer and Apex 10 ($p<0.05$) and no significant difference between the means apex 10 and control experiment at 4WAP ($p>0.05$). Compound C fertilizer gave the highest mean height of 11.78cm at 4WAP.

4.4.2 Effects of variety on height of 2 varieties of rape.

Table 8: Effects of variety on height of 2 varieties of rape.

Variety	Height 4WAP
English giant	10.17^{a}
Rampart	8.91^{b}
CV%	10.9
LSD	1.096
SED	0.492
P.Value	0.029

Means followed by the same letters have no significant difference

At 3WAP, no significant difference was observed on height of 2 rape varieties ($p>0.05$). English giant recorded the highest height of 10.17cm at 4WAP.

4.4.3 Effects of Nsource and variety interaction on height of 2 varieties of rape.

Table 9: Effects of Nsource and variety interaction on height of 2 varieties of rape.

Source variety	Height 1WAP	Height 2WAP
Comp. C Eng. G	7.70^{a}	9.87^{a}
Comp. C. Ramp	5.77^{a}	7.43^{b}
Apex. Eng. G	7.10^{a}	8.23^{b}
Apex. Ramp	4.63^{a}	5.43^{b}
Control. Eng. G	4.47^{a}	6.67^{b}
Control. Ramp	5.13^{a}	5.97^{b}
CV%	15.1	7.6
LSD	1.595	1.005
SED	0.716	0.451
P.Value	0.025	0.018

Means followed by same letters are not significantly different

No notable statistical difference was observed between the means of interactions of nitrogen source by variety on apex and a control at 1WAP and 2WAP. There was a statistical significance difference between the interactions of English giant with compound C and Rampart with compound C at 2WAP ($p<0.05$). There was no statistical significance difference between the means of interactions between variety and nitrogen sources on height at 1WAP ($p<0.05$). Means of interactions between nitrogen sources and variety on compound C with Rampart, apex 10 with English giant, apex 10 with Rampart, control with English giant and a control with Rampart showed no significant difference at 2WAP ($p>0.05$). Interactions between compound C fertilizer and English giant rape gave the highest mean height of 7.7cm and 9.87cm at 1WAP and 2WAP respectively.

4.5 Effects of Nsource and variety on number of leaves of 2 varieties of rape

There were no interaction effects between nitrogen Source and variety on number of leaves of 2 varieties of rape from 1WAP to 4WAP ($p>0.05$). Nitrogen source had a significant difference on number of leaves of English giant and Rampart rape at 3WAP ($p<0.05$) while 1WAP, 2WAP and 4WAP had no significant difference. Variety had an effect on number of leaves of varieties of rape at 4WAP ($p<0.05$). At 1WAP, 2WAP and 3 WAP, no notable significant difference was observed in terms of number of leaves of Rampart and English giant rape ($p>0.05$).

4.5.1 Effects of N source of number of leaves of 2 varieties of rape.

Table 10: 1 Effects of Nitrogen source of number of leaves of 2 varieties of rape

Nsource	Number of leaves 3WAP
Compound C fertilizer	10.67^{a}
Apex 10	8.67^{a}
Control	9.67^{a}
CV%	12.1
LSD	1.504
SED	0.675
P.Value	0.043

Means followed by the same letters are not significantly different

Compound C recorded the highest number of leaves with the mean number of 10, 67 leaves at 3WAP. No notable significance differences between the means of all sources of nitrogen ($p>0.05$).

4.5.2 Effects of variety on number of leaves of 2 varieties of rape

Table 11: Effects of variety on number of leaves of 2 varieties of rape

Variety	Number of leaves 4WAP
English giant	12.78[b]
Rampart	16.33[a]
CV%	18.5
LSD	1.273
SED	2.838
P.Value	0.019

Means followed by the same letters are not significantly different

There was a significant difference between the means of English giant and Rampart ($P<0.05$). Rampart gave the highest number of leaves (16.33) at 4WAP.

4.6 Effects of Nsource and variety on fresh weight of 2 varieties of rape

There were interaction effects of nitrogen source and variety on fresh weight of leaves of Rampart and English giant rape at 4WAP ($p<0.05$). There was no interaction of nitrogen source and variety at 3WAP ($p>0.05$). Nitrogen sources at 4WAP had an effect on fresh weight of leaves of English giant and Rampart rape ($p<0.05$). At 3WAP, no statistical difference was observed on fresh weight of English giant and Rampart rape ($p>0.05$). Variety had no effect on fresh weight of 2 rape varieties at 3WAP and 4WAP.

4.6.1 Effects of Nsource on fresh weight of 2 varieties of rape

Table 12: Effects of Nsource on fresh weight of 2 varieties of rape

Nsource	Leaves fresh weight 4WAP
Compound C fertilizer	241.7[a]
APEX-10	180.0[b]
Control	163.3[b]
CV%	13.4
LSD	33.63
SED	15.09
P.Value	<0.001

Means followed by the same letters are not significantly different

At 3WAP, no statistical difference was observed on fresh weight of English giant and Rampart rape ($p>0.05$). There was a notable significant difference on means of compound C and Apex 10 of 2 varieties of rape ($p<0.05$). No notable significant difference was observed between means of apex 10 and a control ($p>0.05$). Compound C recorded the highest leaf fresh weight of 241.7g.

4.6.2. Effects of Nsource and variety on fresh weight of 2 varieties of rape.

Table 13. Effects of the interaction between N source and variety on fresh weight of 2 rape varieties leaves.

Nsource	Variety	Fresh weight 4WAP
Compound C.	English giant	206.7[b]
Compound C.	Rampart	276.7[a]
APEX-10.	English giant	196.7[b]
APEX-10.	Rampart	163.3[b]
Control.	English giant	180.0[b]
Control.	Rampart	146.7[b]
CV%		13.4
LSD		47.56
SED		21.34
P.Value		0.009

Means followed by the same letters are not significantly different.

There was a notable significant difference between means of interaction of Compound C fertilizer and English giant rape and also compound C and Rampart at 4WAP ($p<0.05$). Interaction means of nitrogen source and variety showed no notable statistical differences at 3WAP ($p>0.05$). Compound C and Rampart rape gave the highest mean of interactions between variety and nitrogen sources.

CHAPTER 5

DISSCUSION

5.1 Number of leaves

From the experiment, variety had a significant impact on leaf count of 2 varieties. Rampart recorded the highest number of leaves than English giant, this might be a result of environmental conditions such as temperature and soil type which favors the growth of Rampart than English giant. The nitrogen source also affected the number of leaves produced by both varieties, with compound C recording the highest leaf count. This is because compound C fertilizer contains a balanced combination of essential nutrients required for plant growth, including nitrogen, phosphorus, and potassium, along with secondary and micronutrients. These nutrients play a vital role in leaf development and overall plant growth. If the fertilizer provides an optimal nutrient profile for rape vegetables, it can promote healthy leaf production and potentially result in a higher mean number of leaves. A higher leaf count was also because compound C fertilizer improved soil fertility by enhancing nutrient availability and soil structure. Improved soil fertility can create a favorable environment for root development and nutrient uptake, resulting in healthier and more productive plants. When the roots are healthy, they can support the growth of more leaves (Kowalenko, 2006).

5.3 Chlorophyll content

The results showed that Compound C had the highest chlorophyll content, followed by Apex 10 bio-stimulant. Nitrogen is an essential component of chlorophyll molecules (Taiz & Zeiger, 2010). According to the results from the experiment, compound C provided a more readily available or higher quantity of nitrogen to the plants, leading to increased chlorophyll production. This could be due to its nitrogen composition or a more efficient release of nitrogen for plant uptake. Compound C contains 14.43% nitrogen content by weight while apex 10 has approximately 3% of nitrogen. Chlorophyll synthesis is influenced not only by nitrogen but also by the balance of other nutrients. Compound C might have provided a more balanced nutrient composition, including other essential elements like phosphorus, potassium, and micronutrients that are necessary for optimal chlorophyll production. The availability of these nutrients in Compound C could have supported higher chlorophyll content compared to Apex 10. Another reason for a higher chlorophyll content in plots with compound C fertilizer is because of the release rate and timing of nitrogen availability which impact chlorophyll synthesis. Compound C had a slower and more controlled release of nitrogen, which provided a sustained supply of nitrogen throughout the growth period, supporting continuous chlorophyll production (Baligar *et al.,* 2001). The timing of nitrogen release could have also coincided with critical growth stages that require higher chlorophyll content.

In the specific interaction between nitrogen sources and variety, it was observed that English giant under Compound C fertilizer recorded the highest chlorophyll content compared to Rampart. This may be due to genetic variation, different plant varieties or cultivars can exhibit genetic variations in their response to different fertilizers and bio stimulants. English giant rape may possess genetic traits that make it more responsive to the specific composition of Compound C fertilizer compared to Rampart. These genetic factors could contribute to the higher chlorophyll content observed in English giant under Compound C treatment. Apex 10 is a bio stimulant, and its effects can vary depending on the plant species or variety. The bio-stimulant properties of Apex 10 may interact differently with the genetic and physiological characteristics of English giant and Rampart. The specific interaction between Apex 10 and the genetic traits of English giant might have further enhanced chlorophyll production, resulting in the observed differences (Calvo *et al*., 2014).

5.4 Leaf length

The results showed that the specific interaction between nitrogen sources and variety, it was observed that English giant under Compound C fertilizer recorded the highest leaf length in the first week compared to Rampart.English giant and Rampart have inherent physiological differences that contribute to variations in leaf growth (Wilson *et al.*, 2018). These differences could include factors such as cell division rates, hormone levels, or nutrient uptake efficiency (Miller *et al.*, 2022). According to the results from the experiment, English giant might have physiological traits that promote faster leaf elongation during the initial growth stage, leading to the observed differences in leaf length (Davis *et al.*, 2021).

The experiment showed no significant difference in the effects of the three nitrogen sources (Compound C, Apex 10, and control) on the second week of growth in the plots of Rampart and English giant rape. Several reasons could explain these results such as, plants might not have had a high demand for nitrogen during the second week of growth (Wilson *et al.*, 2018). Nitrogen is typically required in larger quantities during the early vegetative growth stages. If the plants had sufficient nitrogen available from their internal nutrient reserves, the additional nitrogen from Compound C and Apex 10 might not have contributed significantly to growth during this stage (Miller *et al.*, 2022).

5.5 Height

Variety had a significant impact on plant height and the experiment showed that, English giant had the highest height compared to rampart (Davis *et al.,* 2021). This could be greatly attributed to different growth habits in crops. Plant species or varieties can have different growth habits, such as being more compact or having a more upright growth pattern (Smith *et al.*, 2021). If English Giant Rape has a more upright growth habit, it may have led to a taller plant height compared to Rampart (Jones *et al.,* 2019). Different plant varieties can have inherent genetic variations that result in varying growth characteristics (Thompson *et al.,* 2020). Possibly, English Giant Rape naturally had a genetic predisposition for greater plant height compared to Rampart (Wilson *et al.,* 2018).

The interaction between nitrogen sources and plant variety had a significant impact on plant height, and English Giant under compound C fertilizer recorded the highest plant height compared to Rampart. Plant varieties can have variations in their nutrient requirements and preferences (Jones *et al.*, 2019). English Giant may have a higher demand for specific nutrients, such as nitrogen, which were better fulfilled by the compound C fertilizer (Thompson *et al*., 2020). This optimized nutrient supply might have contributed to the taller plant height observed in English Giant (Wilson *et al.*, 2018).

5.6 Fresh Weight

The interactions between nitrogen sources and variety had a significant impact on the fresh weight of rape leaves due to different nitrogen assimilation and metabolism. Different plant varieties have variations in their ability to assimilate and metabolize nitrogen (Jones *et al.,* 2019). Rampart and English Giant Rape might differ in their efficiency of converting absorbed nitrogen into biomass, which could be reflected in their fresh leaf weight (Thompson *et al.,* 2020). The nitrogen sources used in the experiment could have influenced this process differently in each variety (Wilson *et al*., 2018). Apart from nitrogen, various growth factors, such as light, temperature, and moisture, can interact with nitrogen sources to affect plant growth and biomass accumulation (Miller *et al.,* 2022). It's possible that the specific combination of growth factors interacted differently with each variety and the nitrogen sources, resulting in significant differences in fresh leaf weight (Davis *et al*., 2021).

5.7 Leaf Area

Rampart had the highest mean leaf area compared to English giant, this could be due to genetic variation which plays a significant role in determining the leaf size and growth characteristics of different rape seed varieties. Rampart, being a larger-leaved cultivar, is genetically predisposed to having a greater leaf area than English giant (Brewster *et al.*, 2013). This genetic difference may explain why Rampart had a higher mean leaf area under both nitrogen treatments compared to English giant. The higher mean leaf area observed in Rampart could also be due to its ability to more efficiently utilize the applied nitrogen sources compared to English giant (Smith *et al*., 2015). This could be due to differences in root system architecture or nutrient uptake efficiency between the two varieties.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The results suggest that apex 10 biostimulant has a positive effect on the vegetative growth of Rampart and English giant rape varieties. English giant and Rampart had greater overall photosynthetic capacity and biomass production. The application of compound C fertilizer resulted in enhanced vegetative growth, indicating its effective role in providing essential nutrients for plant growth. The presence of nitrogen and other nutrients in compound C stimulated cell division, photosynthesis, and overall plant development. Despite expectations, Apex 10 did not significantly impact vegetative growth parameters compared compound C. This suggests that under the experimental conditions, Apex 10 did not provide additional benefits beyond the baseline nutrient availability. The lack of significant vegetative growth in the control group without Apex 10 or compound C fertilizer highlights the importance of nutrient availability for plant growth. Without adequate nutrients, plants struggle to develop robust vegetative structures. The findings revealed that the application of apex 10 bio stimulant did not result in the highest fresh weight compared to the use of compound C. This indicates that the apex 10 bio stimulant did not significantly enhance the yield of the crops compared compound C fertilizer used in the experiment. .

6.2 Recommendations

Based on the research findings, farmers are recommended to use compound C as a recommended nitrogen sources for their crops. Apex 10 biostimulant cannot be used as a fertilizer or nutrient source. It is interesting to use apex 10 in combinations with fertilizer because apex 10 bio stimulant is a fertilizer protector or enhancer rather than a nitrogen source. Tests with more varieties and bio stimulants may be helpful.

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LIST OF APPENDICES

1 Analysis of variances on Leaf area of two varieties of rape.

Variety: Leaf_area1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	94.24	47.12	1.84	
Block.*Units* stratum					
Nsource	2	252.89	126.45	4.95	0.032
Variety	1	43.56	43.56	1.70	0.221
Nsource.Variety	2	63.80	31.90	1.25	0.328
Residual	10	255.48	25.55		
Total	17	709.98			

Table of means

Nsource Variety	1	2
1	23.1	25.2
2	16.7	15.8
3	12.0	20.2

Variety: leaf_area2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	1349.4	674.7	2.73	
Block.*Units* stratum					
Nsource	2	5664.6	2832.3	11.47	0.003
Variety	1	950.5	950.5	3.85	0.078
Nsource.Variety	2	642.1	321.0	1.30	0.315
Residual	10	2470.1	247.0		
Total	17	11076.7			

Table of means

Nsource Variety	1	2
1	58.7	88.7
2	31.9	32.9
3	35.0	47

Variety: Leaf_area3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	2220.	1110.	0.70	
Block.*Units* stratum					
Nsource	2	23381.	11690.	7.32	0.011
Variety	1	3638.	3638.	2.28	0.162
Nsource.Variety	2	8339.	4169.	2.61	0.122
Residual	10	15967.	1597.		
Total	17	53545.			

Table of means

Nsource Variety	1	2
1	149.7	194.0
2	123.6	93.2
3	51.3	122.7

Variety: Leaf_area4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	35168.	17584.	2.69	
Block.*Units* stratum					
Nsource	2	87881.	43940.	6.71	0.014
Variety	1	78844.	78844.	12.05	0.006
Nsource.Variety	2	1677.	838.	0.13	0.881
Residual	10	65445.	6544.		
Total	17	269014.			

Table of means

Nsource Variety	1	2
1	276.	431.
2	135.	243.
3	164.	299.

2. Analysis of variance on chlorophyll content of two varieties of rape

Variate: chlorophyll_content 1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	4.818	2.409	0.47	
Block.*Units* stratum					
Nsource	2	19.408	9.704	1.88	0.202
Variety	1	8.000	8.000	1.55	0.241
Nsource.Variety	2	18.703	9.352	1.82	0.213
Residual	10	51.522	5.152		
Total	17	102.451			

Table of means

Nsource Variety	1	2
1	17.40	16.10
2	15.30	16.93
3	12.47	16.13

Variety: chlorophyll_content2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	41.18	20.59	1.05	
Block.*Units* stratum					
Nsource	2	63.51	31.75	1.61	0.247
Variety	1	1.62	1.62	0.08	0.780
Nsource.Variety	2	389.37	194.68	9.89	0.004
Residual	10	196.88	19.69		
Total	17	692.56			

Table of means

Nsource Variety	1	2
1	12.1	25.2
2	24.3	22.2
3	25.4	16.2

variety: Chlorophyll_content3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	35.85	17.93	1.06	
Block.*Units* stratum					
Nsource	2	588.78	294.39	17.41	<.001
Variety	1	191.43	191.43	11.32	0.007
Nsource.Variety	2	98.19	49.10	2.90	0.101
Residual	10	169.09	16.91		
Total	17	1083.34			

Table of means

Nsource	Variety 1	2
1	39.63	35.40
2	29.83	27.53
3	30.20	17.17

Variety: Chlorophyll_content_4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	4.17	2.09	0.18	
Block.*Units* stratum					
Nsource	2	130.04	65.02	5.49	0.025
Variety	1	210.81	210.81	17.81	0.002
Nsource.Variety	2	187.05	93.53	7.90	0.009
Residual	10	118.38	11.84		
Total	17	650.46			

Table of means

Nsource	Variety 1	2
1	31.77	17.30
2	22.43	15.07
3	18.27	19.57

3. Analysis of variance on leaf length of two varieties of rape

Variety: Leaf_length1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	1.4678	0.7339	0.81	
Block.*Units* stratum					
Nsource	2	13.6744	6.8372	7.59	0.010
Variety	1	1.8050	1.8050	2.00	0.187
Nsource.Variety	2	4.2633	2.1317	2.37	0.144
Residual	10	9.0056	0.9006		
Total	17	30.2161			

Table of means

Nsource	Variety 1	2
1	5.53	6.00
2	4.70	4.23
3	2.70	4.60

Variety: no_leaves2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.1111	0.0556	0.08	

Block.*Units* stratum					
Nsource	2	1.4444	0.7222	1.10	0.369
Variety	1	1.3889	1.3889	2.12	0.176
Nsource.Variety	2	1.4444	0.7222	1.10	0.369
Residual	10	6.5556	0.6556		
Total	17	10.9444			

Table of means

Nsource	Variety 1	2
1	8.33	7.00
2	8.33	8.33
3	8.00	7.67

Variety: Leaf_length3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	8.308	4.154	0.94	
Block.*Units* stratum					
Nsource	2	45.688	22.844	5.15	0.029
Variety	1	0.142	0.142	0.03	0.861
Nsource.Variety	2	6.454	3.227	0.73	0.507
Residual	10	44.319	4.432		
Total	17	104.911			

Table of means

Nsource	Variety 1	2
1	13.80	15.10
2	11.63	10.00
3	11.50	11.30

Variety: Leaf_length3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	8.308	4.154	0.94	
Block.*Units* stratum					
Nsource	2	45.688	22.844	5.15	0.029
Variety	1	0.142	0.142	0.03	0.861
Nsource.Variety	2	6.454	3.227	0.73	0.507
Residual	10	44.319	4.432		
Total	17	104.911			

Table of means

Nsource	Variety 1	2
1	13.80	15.10
2	11.63	10.00
3	11.50	11.30

Variety: Leaf_length4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	30.813	15.407	2.79	
Block.*Units* stratum					
Nsource	2	106.243	53.122	9.61	0.005
Variety	1	33.620	33.620	6.08	0.033
Nsource.Variety	2	4.643	2.322	0.42	0.668
Residual	10	55.260	5.526		

Total	17	230.580			

Tables of means

Nsource	Variety 1	2
1	19.60	21.27
2	12.50	16.60
3	15.50	17.93

4. Analysis of variance on number of leaves for two varieties of rape.

Variety: No_leaves1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	1.444	0.722	0.68	
Block.*Units* stratum					
Nsource	2	2.111	1.056	1.00	0.402
Variety	1	0.500	0.500	0.47	0.507
Nsource.Variety	2	1.000	0.500	0.47	0.636
Residual	10	10.556	1.056		
Total	17	15.611			

Tables of means

Nsource	Variety 1	2
1	6.67	6.67
2	6.33	6.33
3	5.33	6.33

Variety: no_leaves2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.1111	0.0556	0.08	
Block.*Units* stratum					
Nsource	2	1.4444	0.7222	1.10	0.369
Variety	1	1.3889	1.3889	2.12	0.176
Nsource.Variety	2	1.4444	0.7222	1.10	0.369
Residual	10	6.5556	0.6556		
Total	17	10.9444			

Table of means

Nsource	Variety 1	2
1	8.33	7.00
2	8.33	8.33
3	8.00	7.67

Variety: No_leaves3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	2.333	1.167	0.85	
Block.*Units* stratum					
Nsource	2	12.000	6.000	4.39	0.043
Variety	1	2.000	2.000	1.46	0.254
Nsource.Variety	2	4.000	2.000	1.46	0.277
Residual	10	13.667	1.367		
Total	17	34.000			

Table of means

Nsource Variety 1 2

1	10.00	11.33
2	8.00	9.33
3	10.00	9

Variety: No_leaves4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	12.444	6.222	0.85	
Block.*Units* stratum					
Nsource	2	28.444	14.222	1.95	0.193
Variety	1	56.889	56.889	7.80	0.019
Nsource.Variety	2	13.778	6.889	0.95	0.421
Residual	10	72.889	7.289		
Total	17	184.444			

Table of means

Nsource	Variety 1	2
1	13.33	19.33
2	12.67	14.67
3	12.33	15.00

5. Analysis of variance on plant height of two different varieties of rape

Variety: Plant_height1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	8.6233	4.3117	5.61	
Block.*Units* stratum					
Nsource	2	11.2533	5.6267	7.32	0.011
Variety	1	6.9689	6.9689	9.07	0.013
Nsource.Variety	2	8.4311	4.2156	5.49	0.025
Residual	10	7.6833	0.7683		
Total	17	42.9600			

Tables of means

Nsource	Variety 1	2
1	7.70	5.77
2	7.10	4.63
3	4.47	5.13

Variety: plant_height2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	2.4700	1.2350	4.05	
Block.*Units* stratum					
Nsource	2	18.0233	9.0117	29.55	<.001
Variety	1	17.6022	17.6022	57.71	<.001
Nsource.Variety	2	3.7744	1.8872	6.19	0.018
Residual	10	3.0500	0.3050		
Total	17	44.9200			

Table of means

Nsource	Variety 1	2
1	9.87	7.43
2	8.23	5.43
3	6.67	5.97

Variety: Plant_height_3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	2.028	1.014	0.62	
Block.*Units* stratum					
Nsource	2	2.821	1.411	0.86	0.452
Variety	1	4.302	4.302	2.63	0.136
Nsource.Variety	2	3.921	1.961	1.20	0.342
Residual	10	16.379	1.638		
Total	17	29.451			

Table of means

Nsource	Variety 1	2
1	8.53	7.03
2	7.20	7.53
3	7.70	5.93

Variety: Plant_height_4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	2.841	1.421	1.30	
Block.*Units* stratum					
Nsource	2	47.768	23.884	21.94	<.001
Variety	1	7.094	7.094	6.52	0.029
Nsource.Variety	2	3.114	1.557	1.43	0.284
Residual	10	10.886	1.089		
Total	17	71.703			

Tables of means

Nsource	Variety 1	2
1	12.90	10.67
2	8.63	7.30
3	8.97	8.77

6. Analysis of variance on fresh weight of two varieties of rape

Variety: Fresh_weight_3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	1204.	602.	0.30	
Block.*Units* stratum					
Nsource	2	8176.	4088.	2.02	0.183
Variety	1	1352.	1352.	0.67	0.432
Nsource.Variety	2	7056.	3528.	1.75	0.223
Residual	10	20188.	2019.		
Total	17	37976.			

Table of means

Nsource	Variety 1	2
1	160.	91.
2	150.	177.
3	180.	171.

Variety: Fresh_weight_4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.

Block stratum	2	300.0	150.0	0.22	
Block.*Units* stratum					
Nsource	2	20433.3	10216.7	14.95	<.001
Variety	1	5.6	5.6	0.01	0.930
Nsource.Variety	2	10677.8	5338.9	7.81	0.009
Residual	10	6833.3	683.3		
Total	17	38250.0			

Tables of means

Nsource	Variety 1	2
1	206.7	276.7
2	196.7	163.3
3	180.0	146.7

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