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CROP SCIENCE DEPARTMENT

BRANDON MUREFU

(B211789B)

A COMPARATIVE STUDY OF FOLIAR FERTILIZER (PFLANZEN BOOSTER) WITH CONVENTIONAL GRANULAR INORGANIC FERTILIZER EFFECTS ON MAIZE (*ZEA MAYS L*) PRODUCTION

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF THE BACHELOR OF AGRICULTURAL SCIENCES (CROP SCIENCE)

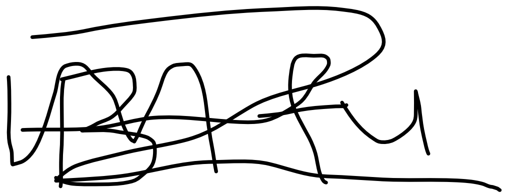
SUPERVISOR: MS KAMOTA

DECLARATION

I, Murefu Brandon do hereby declare that dissertation was the result of my own work and research. All other sources used were acknowledged by references.

MUREFU BRANDON

B211789B



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CERTIFICATION OF THE DISSERTATION

Bindura University of Science Education

Department of Crop Science

The undersigned certify that they have read and recommended to the Bindura University to accept a dissertation entitled:

A COMPERATIVE STUDY OF FOLIAR FERTILIZER (PFLANZEN BOOSTER) WITH CONVENTIONAL GRANULAR INORGANIC FERTILIZER EFFECTS ON MAIZE (*ZEA MAYS L*) PRODUCTION

Submitted by

MUREFU BRANDON

B211789B

In partial fulfilment of the requirements for the Bachelor of Agricultural Science in Crop Science.

SUPERVISOR………………………………………………….

DATE………………………………………………………...

CHAIRMAN………………………………………………….

DATE………………………………………………………...

DEDICATION

This study is dedicated to my family, especially my mother Rhodha Muchada and to the friends who became family at university.

ACKNOWLEDGEMENT

I am forever grateful to the Almighty God for his interminable faithfulness, guidance and protection throughout the four years of study.

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ABSTRACT

In modern agriculture, fertilizers play a critical role in enhancing crop productivity, yet the overreliance on conventional inorganic fertilizers has raised significant environmental and economic concerns. This study evaluated the effectiveness of a foliar fertilizer, Pflanzen Booster, compared to Ammonium Nitrate (a conventional granular inorganic fertilizer), and a combined application of both, on the growth, phenology, and yield of maize (Zea mays L.). The experiment was conducted using a randomized complete block design (RCBD) with four treatments: (1) Control (no top dressing), (2) Ammonium Nitrate, (3) Pflanzen Booster, and (4) a combination of Ammonium Nitrate and Pflanzen Booster. Treatments were replicated three times. Key agronomic parameters measured included leaf length, plant height, cob length, number of days to 50% flowering, and final grain yield. Data were analyzed using one-way ANOVA in GenStat (17th Edition). The results showed that Pflanzen Booster significantly enhanced vegetative growth, led to earlier flowering, and achieved the highest grain yield, statistically comparable to Ammonium Nitrate. The combined treatment did not yield additive benefits, often underperforming due to potential nutrient antagonism or over-application stress. These findings indicate that foliar fertilization is not only a viable alternative to conventional fertilizers but may offer greater efficiency, reduced environmental impact, and cost-effectiveness, especially for smallholder farmers. The study concludes that Pflanzen Booster foliar fertilizer can be effectively integrated into sustainable maize production systems, supporting both food security and environmental stewardship.

Key words: Pflanzen Booster, Ammonium Nitrate, Leaf length, Plant height, Cob length, Number of days to 50% flowering, Final grain yield

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ABBREVIATIONS

ANOVA:	ANALYSIS OF VARIANCE
WATD:	Weeks After Top Dressing
A.N:	Ammonium Nitrate
P.B:	Pflanzen booster
FAO:	Food and Agriculture Organization
s.e.d:	Standard errors of difference

CHAPTER 1

1.1 Introduction

Maize (*Zea mays L*) is among the mostly grown cereal crops globally after rice and wheat. According to Gumbeze *et al*, (2023), approximately one billion tonnes of the crop are produced per annum in over 170 countries on over 180 million hectares worldwide. Maize extend over 60% of the agricultural lands in Zimbabwe, covering approximately 80% - 90% of the grown acreage under cereals. Maize is the chief food for over a billion people worldwide and is also an important feed for animals. The maize crop is also an important raw material being used in the industry as a source of starch and alcohol. The stocks are also indispensable as they are used for staking, fencing, mulching and livestock fodder (Ogunboye *et al*, 2020). Subsequently, maize adds approximately 14% of Zimbabwe's national Gross Domestic Product (GDP).

Both macronutrients and micronutrients applications are essential for increasing maize grain yield. Nitrogen is an essential macronutrient with general recommendation application in high yielding maize of 60-150 kg per hectare while phosphorous is the second important macronutrient responsible for optimal growth and biomass production and lastly potassium which is essential for physiological processes, enzyme activation and photosynthesis in crop plants (Gumbeze *et.al*, 2023). Farmers encounter the challenge of escaping causing destruction to the environment and producing agricultural products sustainably while upholding high plant yields (Mahmoodi *et al*., 2020).

Farmers normally rely on conventional inorganic fertilizers to increase crop yields and productivity. Over 50% of the fertilizers in Zimbabwe are utilized in the maize production. Inorganic fertilizers are commonly applied in the soil and this depends on moisture availability (Gumbeze et al, 2023). These inorganic fertilizers have been monitored over-time and have been detected to be causing environmental negative impacts such as soil degradation, acidifying soils, secondary salinization, nutrient imbalance particularly caused by abnormal imbalances of nitrogen and potassium (Cai, 2019; Niu *et al*, 2020) which disrupts the biological activities of microorganisms which are essential on nutrient recycling through decomposition (Gumbeze *et al*, 2023).

Additionally, the high costs of farming inputs in Zimbabwe has complicated farming activities such as purchasing fertilizers (Dugbazah *et al*, 2022). According to Gumbeze *et.al*, 2023, the prices of a bag of 50kg fertilizer, specifically compound D is around $41.00 USD and these high prices apparently affect the profits margin on agricultural production and also food security in Zimbabwe. Therefore, these rising concerns over the issue of soil health, environmental impacts and the costs of chemical fertilizers have urged some reconsiderations of fertilization strategies. Therefore, these rising concerns over the issue of soil health, environmental impacts and the costs of chemical fertilizers have urged some reconsiderations of fertilization strategies.

Foliar application of fertilizers allows for rapid nutrient absorption through the stomata and cuticle, unlike the conventional soil applied fertilizers which can go through soil-related inefficiencies. Foliar fertilizers are applied directly on the leaves of the crops and therefore there is fast absorption and reduced soil pollution while providing essential micro and macro nutrients for growth and development (Chakanyuka *et al*, 2019). Foliar fertilization can improve maize crop performance, resulting in higher yields and productivity as the crops have immediate access to the nutrients as compared to the conventional fertilizers which are subjected to high leaching levels and low cation exchange capacity in the soil thus making most crops have limited nutrient uptake as in soils.

The absorption of nutrients via foliar pathways is often more rapid than soil uptake, particularly under conditions where root uptake is impaired due to drought stress or poor soil structure (Fernández et al., 2013). The presence of micronutrients, particularly zinc, copper and iron which are referred to as trace elements in foliar fertilizers is crucial for the maintenance of physiological balances (Chakanyuka *et.al*, 2019). This method is particularly useful for correcting micronutrient deficiencies and supplementing macronutrients during critical growth stages. According to University of Michigan research, foliar-applied fertilizers had a 90% nutrient uptake rate, far surpassing the 10% uptake rate of soil applied fertilizers (Chakanyuka *et.al*, 2019). In the same study, under sandy soil treatment, the foliar fertilizer effectiveness was 20 times even higher.

However, in spite of the possible benefits of foliar fertilizers, this comparative study intends to compare their effectiveness with conventional inorganic fertilizers in maize production. The study aims to investigate the effects of Pflanzen booster foliar fertilizer on maize growth and yield as well in comparison with the results obtained from the crops grown using conventional inorganic fertilizers. The results will provide valuable understandings into the potential of foliar fertilizers as a sustainable and environmentally friendly substitute fertilizer to conventional inorganic fertilizers in maize production in Zimbabwe.

1.2 Problem statement

Failure by maize to uptake all the nutrients from the applied conventional inorganic fertilizers due to leaching, volatilization and soil fixation has become a problem in agriculture. The inefficient uptake can lead to soil degradation thus reducing soil fertility, polluting environment and economic losses. Amid these mounting challenges, foliar fertilizers have been introduced to address the problems but there is still little knowledge about foliar fertilizers efficacy on yield outcomes, cost effectiveness and environmental sustainability.

1.3 Justification

Foliar fertilizers are promising alternatives and solution to the problems of productivity and environmental sustainability on reduced production costs. There is a high potential of mitigating environmental degradation through the use of foliar fertilizers. This study is not only timely but also critical for evidence-based decision-making. By evaluating the performance of Pflanzen Booster foliar fertilizer relative to conventional inorganic options, the research will provide a robust knowledge base to inform agricultural policy, extension services, and farmer decision-making. It will also offer insights into how Zimbabwe can achieve a sustainable maize production model that balances productivity, economic viability, and environmental health.

1.4 Aim

To evaluate the effectiveness of Pflanzen Booster foliar fertilizer on maize (Zea mays L.) growth, flowering and overall yield performance in comparison to conventional inorganic fertilizer, through a randomized controlled experimental design.

1.5 Objectives

i. To compare the vegetative growth performance of maize plants subjected to foliar fertilization, conventional inorganic fertilization, and a combined treatment under field conditions.

ii. To evaluate the impact of different fertilizer treatments on phenological development of maize, particularly the number of days to reach 50% flowering.

iii. To evaluate and compare the grain yield of maize under foliar fertilization versus conventional inorganic fertilization regimes.

1.6 Hypothesis

1. Objective – Plant Growth

- Null Hypothesis (H_0): There is no statistical significant difference in vegetative growth) of maize across the different fertilizer treatment groups.
- Alternative Hypothesis (H_1): There is statistical significant difference in vegetative growth of maize across the different fertilizer treatment groups.

2. Objective – Time to 50% Flowering

- Null Hypothesis (H_0): There is no statistical significant difference in the number of days to 50% flowering among the fertilizer treatment groups.
- Alternative Hypothesis (H_1): There is statistical significant difference in the number of days to 50% flowering among the fertilizer treatment groups.

3. Objective – Yield Performance

- Null Hypothesis (H_0): There is no statistical significant difference in maize yield and yield components across the fertilizer treatment groups.
- Alternative Hypothesis (H_1): There is statistical significant difference in maize yield and yield components across the fertilizer treatment groups.

CHAPTER 2

Literature review

2.1 History of Maize

Maize (Zea mays) is a domestication of a wild grass teosinte which was found in Mexico and Central America as its center of origin about 9000 years ago (Benson et al., 2017). The spread of maize across the globe was successful because of its adaptive and productive traits. The Portuguese were the first to introduce the maize crop in Africa through trade around the 16th century (Miracle, 1996). According to Nyanga *et.al*, 2021, the origins of maize cultivation in Zimbabwe can be drawn back to the pre-colonial era, although the crop gained prominence after the introduction of improved varieties and agricultural practices in the late 20th century. Since then, it has become the staple food in Southern Africa. In Zimbabwe, maize is the most important crop, occupying 50% – 70% of the planted land in natural areas II A, II B and 30% - 55% of the harvested farms in natural regions III and IV (Rukuni *et.al*, 2006).

2.2 Economic importance of Maize

According to Tavuyanago *et.al*, 2010, maize serves the dual purpose as the staple crop and as the cash crop. However, maize is mostly grown for human consumption as well as forage for livestock. With its high grain and forage yields, corn (Zea mays L.) is a significant crop among cereals (Rabbani and Safdary, 2021). Maize is the third main grain after wheat and rice. According to Food and Agriculture Organization, 2021, a stable maize supply is vital for mitigating hunger and poverty.

Maize production is also very important in contributing to the Zimbabwe's economy and also to the country's GDP. According to Food and Agriculture Organization (FAO), 2021, Agriculture is a key sector of Zimbabwe's economy, contributing approximately 12 % – 15 % to the country's GDP, with maize being the most important crop. This is the evidence that maize production contributes a significant percentage of the country's GDP. During the 2020/2021 agricultural season, maize production contributed an estimated 3– 4% to Zimbabwe's GDP, driven by increased yields from government supported programs such as the Pfumvudza/Intwasa conservation agriculture initiative (ZimStat, 2021).

The government of Zimbabwe has therefore recognized the contribution of maize production to the country's economy and in turn implemented beneficial policies and programs in support of farmers. According to Pindiriri *et.al*, 2021, the Government of Zimbabwe introduced 3 input support programs in which the Command Agriculture initiative provides sustainable and affordable subsidies to commercial farmers, aiming to boost staple crop and livestock productivity, ensuring food security. Additionally, the Presidential Input Support and Vulnerable Farmer Input Support programs help vulnerable small-scale and subsistence farmers recover and become self-reliant, ultimately guaranteeing food security. As the primary food for the people of Zimbabwe, maize plays a significant role in ensuring food security, sustaining livelihoods and contributing to the country's GDP.

However, maize production faces many challenges such as climate variability, pest and disease infestations and also more importantly the declining soil fertility. In developing countries such as Zimbabwe, smallholder farmers dominate maize farming but they often face challenges to acquire hybrid seeds, fertilizers and irrigation. Therefore, soil nutrient exhaustion, mainly on the macro-nutrients which are nitrogen, phosphorus, and potassium is a major constraint which leads to low yields.

2.3 Fertilizer requirements of Maize

It is very important to have knowledge and understanding of the essential nutrients that are required by maize during its growth and production. Soil fertility is a very important factor in agricultural production as it influences crop growth and yield. Fertilizers are very important as they are applied to add soil nutrients. Most of the farmers in maize production commonly use inorganic fertilizers, such as compound D, ammonium nitrate and urea (N) due to their high nutrient concentration and ease to apply.

Compound D is a common basal applied fertilizer in maize and it generally comprehends the macro-nutrients, nitrogen, phosphorus and potassium (NPK). Ammonium nitrate fertilizer is commonly used as topping nitrogen-based fertilizer in maize production with higher amounts of nitrogen concentration. According to Hatungimana, *et.al*, 2021, nitrogen, phosphorous and potassium are crucial for maize normal growth. On the other hand, ammonium nitrate fertilizer is a nitrogen-based fertilizer with a high nitrogen concentration. There are factors which determine the efficacy of fertilizer use in maize production which are, the application timing, method, and soil conditions.

As a vital macronutrient, nitrogen is necessary for the growth and development of living organisms. It is an essential nutrient especially during the early and mid-growth phases. Nitrogen is the most widely applied macronutrient in agriculture, with its fertilizers playing a vital role in producing over 50% of the world's food (Abebe *et.al*, 2022). According to Gotosa, J *et.al*, 2019, Nitrogen is the most limiting nutrient to maize production in Zimbabwe. Plants take up nitrogen in the form of ammonia (NH_3) or nitrogen oxides in the form nitrates and nitrites.

Phosphorus is an essential macronutrient required in substantial quantities for healthy plant development (Abebe *et.al*, 2022). It is very crucial for root growth, facilitating water and nutrient uptake therefore it is a significant limiting nutrient in maize production. Phosphorus deficiency in maize plants lead to reduced photosynthetic rates, chlorophyll content, and biomass production, these can be seen through stunted growth, and reddish-purple leaf tips and margin coloration (Mashingaidze *et.al*., 2017).

Potassium is a vital nutrient responsible for cell wall turgidity, osmotic adjustment as it helps regulates water balance within the plant and also facilitates in the nutrient uptake. Plants absorb potassium in the form of K+ ions, which can be sourced from soil or supplemented through fertilizers like potassium chloride, nitrate, sulfate, and carbonate (Abebe *et.al*, 2022).

Traditional soil-applied fertilizers are prone to leaching (especially nitrates), volatilization (ammonia), and fixation (phosphorus) leading to potential nutrient loss . These inefficiencies necessitate alternative approaches, such as foliar fertilization, which delivers nutrients directly to plant leaves, reducing losses.

2.4 Foliar Fertilizers: Mechanism, Merits, and Empirical Insights

Foliar fertilization is an alternative nutrient supplementary method where essential nutrients are applied directly onto the plant leaves in liquid form. Like soil applied fertilizers, foliar fertilizers typically contain essential macronutrients such as nitrogen, phosphorus, and potassium (Chakanyuka *et.al*, 2019). Foliar fertilizers can supplement soil fertilization by addressing nutrient deficiencies during critical growth stages.

Given its advantages, foliar fertilization could be a viable alternative in maize production, offering greater efficiency than soil fertilization by delivering precise amounts of nutrients at specific growth stages (Niu, J *et.al*, 2020). The crops can replenish needed nutrients at a faster rate and efficiently as compared to soil fertilization because of direct absorption through leaves. Research by Nirere *et.al.* 2019) found that foliar fertilization significantly enhanced plant growth parameters, including height, leaf area, and dry matter production. Additionally, studies by Niu *et.al.*(2020) suggest that foliar fertilizers may synergize with soil-applied fertilizers, promoting nutrient uptake and reducing soil salt buildup.

However, despite the potential of foliar fertilization, Boscaro *et.al*, 2023 argued that presently, foliar fertilization has been a little explored in maize, regularly focusing on low input management systems in developing countries. Their effectiveness depends on factors such as leaf permeability, environmental conditions and nutrient formulation. Niu *et.al*, 2020, suggested that to maximize the effectiveness of foliar nutrition, careful consideration of timing and formulation concentration is crucial, taking into account the specific characteristics of the plants and soil fertility levels.

2.5 Integrating Soil and Foliar Fertilizers: Synergy or Redundancy?

The question of whether foliar fertilizers supplement or substitute soil fertilizers is central to the ongoing discourse on integrated nutrient management (INM). INM posits that combining organic, inorganic, and foliar nutrient sources enhances sustainability, efficiency, and resilience (Roy et al., 2006). The underlying logic is that while soil fertilizers establish foundational nutrient levels, foliar applications fine-tune delivery in response to crop demand or stress.

Otieno *et al*. (2021) found that maize plots treated with a combination of basal fertilizer, top-dressed AN, and foliar spray yielded 30–50% more than those with soil only fertilizer in Kenya's Rift Valley. These synergistic effects were attributed to improved nutrient synchronization aligning supply with physiological demand particularly during flowering and grain development.

Such findings highlight the need to move beyond dichotomous thinking (soil vs. foliar) towards a continuum approach, where foliar feeding complements soil fertilization under specific conditions. For peri-urban Zimbabwean farmers who often operate on resource-constrained plots, combining A.N and foliar sprays like Pflanzen Booster may offer a pathway to higher productivity without proportional cost increases.

2.6 Combination effects of foliar fertilizers with conventional inorganic fertilizers

The combination of foliar fertilizers and conventional inorganic fertilizers is another emerging subject in literature as they have the potential to synergistic effects on maize growth. Studies have suggested that the combination of both fertilizers improves the yield. The previous study by Kaur *et.al*. (2018) suggest that fertilizers applied through the soil provide a background of nutrients while foliar fertilizers supplement those nutrients during critical growth periods. Therefore, the combination of the two fertilizer regimes reduces the limitations of soil applied fertilizers and ensures a sustained nutrient supply mainly in the areas prone to soil infertility.

Reducing the amount of conventional inorganic fertilizers and promoting foliar fertilizers is an added advantage to poor farmers with limited resources. Foliar fertilizers are economically considered cost-effective as they are cheaper than conventional inorganic fertilizers. Thus foliar fertilizers can be a better alternative especially to smallholder farmers who are economically less advantaged and therefore reducing the demands high required amounts of high cost inorganic fertilizers at the same time increasing yields.

2.7 Problems associated with foliar fertilization

The efficacy of foliar fertilizers is influenced by various factors, including plant species, growth stage, formulation, and chemical properties of the fertilizer. Environmental factors such as temperature, rainfall, and humidity also play a significant role. According to Niu *et.al.* (2020), there are two primary challenges associated with foliar applications: nutrient absorption from leaves and translocation to other plant organs.

Research by Hu *et.al.* (2008) and Niu et al. (2020) suggests that under short-term drought or salt stress, foliar fertilizer application may not be effective in promoting plant growth. This is likely due to decreased transpiration, which reduces the uptake of macronutrients. Furthermore, the brief contact time between the foliar solution and the leaf surface, as well as rapid drying, can limit nutrient absorption (Niu et al., 2020).

The mobility of foliar-applied nutrients is another critical factor determining the efficiency of foliar fertilizers. Some nutrients, such as Boron (B), are immobile in the phloem, making it challenging for crops to re-translocate them from the leaf surface to sink structures. This can be attributed to factors like high pH in the phloem, decreased transpiration rate, and the formation of stable complexes that immobilize the nutrients (Niu et al., 2020).

2.8 Soil health and Environmental impact

As agriculture has grown more industrialized, concerns about its environmental impacts have increased (Williams, H, 2024). Farming can lead to soil degradation thus SDGs push for sustainable agriculture, which its aim is to promote the balance of food production with environmental stewardship. The continued use of conventional inorganic fertilizers although have been effective in increasing yields possess the risks of environmental degradation. The inorganic fertilizers have been associated with soil acidification, over-use of nutrients thus leading to long term soil infertility and also altering of microbial communities.

Foliar fertilizer application minimizes the above mentioned environmental risks. There is targeted delivery of nutrients directly on leaves. Foliar fertilization help reduce the soil ecosystem stresses imposed by the soil-applied fertilizers. According to Syers *et.al*. (2002), foliar fertilizers when used in conjunction with soil fertilizers can decrease the levels of remaining nutrients in the soil, thereby lowering the risk of leaching into adjacent ecosystems.

However, the use of foliar fertilizers is not a complete solution for soil health. Foliar fertilizers lack the ability to contribute to organic matter and improve soil structure. These are critical for supporting microbial activity and water-holding capacity. Too much reliance on foliar fertilizers also neglect essential soil fertility issues thus leading to the depletion of nutrients over time.

2.9 Gaps in the previous and current research and future research advices on foliar fertilization

Foliar fertilization has been under study for years now but still several gaps remain in the literature of the innovative fertilizer. Further long term researches are critical as most of the researches are focused on seasonal experiments. There is need for fully assessment on the nutrient cycling and crop yield stability over multiple seasons. This can help highlight the potential hidden consequences of continual foliar applications. Also the current literature was obtained from the specific agroecosystems thus limiting the generalization of the results. There is need for comparative studies that span a wider variety of environmental conditions from humid tropics to arid regions to better understand the interactions between foliar fertilizers, maize physiology and local soil types (Kaur *et.al*, 2018).

According to Fernandez and Brown (2013), current research is also exploring the development of novel foliar fertilizer formulations that incorporate nanoparticles, plant growth regulators and microbial inoculants. Through these innovations, there may be a breakthrough in further improvement of nutrient uptake, stress responses mitigation and improvement on disease resistance in maize production. Still there is need for further investigative studies on those innovations for implications on both human and environmental health.

The incorporation of new precision agriculture techniques with foliar fertilization is also important. The use of remote sensing and GPS spraying systems is important in improving foliar fertilizer application to a greater extent. These innovative technologies can help in accurate nutrient application at critical growth stages thus increasing efficacy. While a considerable body of work exists on nitrogen management in maize production, most research has been conducted in commercial or rural settings, often under ideal conditions with high input availability. There is limited empirical understanding of how integrated fertilization strategies perform in Zimbabwe's urban and peri-urban environments, where land sizes are small, resources are scarce, and microclimatic conditions vary.

More critically, studies rarely examine commercial foliar fertilizers like Pflanzen Booster in relation to conventional inputs like ammonium nitrate. The interaction effects, yield response patterns, and potential cost-efficiencies remain largely unquantified. The current study therefore seeks to generate context-specific evidence on how combined fertilization affects maize performance in Mufakose, ultimately informing adaptive fertilizer recommendations for similar agro-ecological zones.

2.10 Conceptual Framework

This study is informed by Plant Nutrition Theory, which asserts that optimal crop growth requires balanced nutrient availability in forms and quantities that match plant uptake capacity. It also draws on Liebig's Law of the Minimum, which highlights that crop performance is constrained through the most limiting nutrient. Integrating ammonium nitrate and foliar fertilizer is conceptualized as a means of addressing both macro- and micronutrient limitations in a spatially and temporally synchronized manner.

The framework also incorporates Nitrogen Use Efficiency (NUE) as a guiding principle, evaluating how different fertilization regimes affect biomass production, nutrient uptake and grain return for each unit of nitrogen applied. This dual emphasis on agronomic efficiency and ecological sustainability provides a holistic lens for evaluating the intervention.

CHAPTER 3

Materials and Methods

3.1 Study Site Description

The field experiment was conducted in Mufakose, a high-density urban suburb situated in Harare Metropolitan Province, Zimbabwe. The geographic coordinates of the site are 17.87152^0 S latitude and 30.92207^0 E longitude. Mufakose falls within Agro-Ecological Region II, which is characterized by moderate to high rainfall, making it suitable for maize production.

The region receives a mean annual rainfall ranging from 750 mm - 1050 mm, concentrated between October and March, coinciding with the country’s main cropping season. The climatic regime features mean daily summer temperatures of 20^{0}C to 28^{0}C and winter temperatures ranging from 5^{0}C to 19^{0}C. Soils in the area are predominantly black clay loam, known for their high moisture retention, nutrient-holding capacity, and suitability for intensive cropping systems, especially maize.

The choice of site was informed by its accessibility, representativeness of smallholder urban farming systems, and logistical feasibility for close monitoring of treatment effects.

3.2 Experimental Design and Layout

3.2.1 Design Framework

The experiment employed a Randomized Complete Block Design (RCBD) with four treatments replicated three times to account for spatial heterogeneity and to increase the accuracy of treatment effect estimations. The RCBD was chosen due to its effectiveness in controlling experimental error arising from field variability, particularly in agronomic researches.

3.2.2 Treatment Description

The four treatments are summarized in Table 3.1 below. Each treatment was designed to test the individual and combined effects of Ammonium Nitrate (AN) and Pflanzen Booster, a foliar fertilizer, on maize growth and yield.

Treatment number	Description
T1- Control	Zero application (No fertilizer applied)
T2	150 kg/ha AN
T3	2.5 kg/ha Pflanzen Booster (foliar application equivalent to 0.25 g/m^2)
T4	2.5 kg/ha Pflanzen Booster + 150 kg/ha AN

Figure 0:1 Description of fertilizer treatments

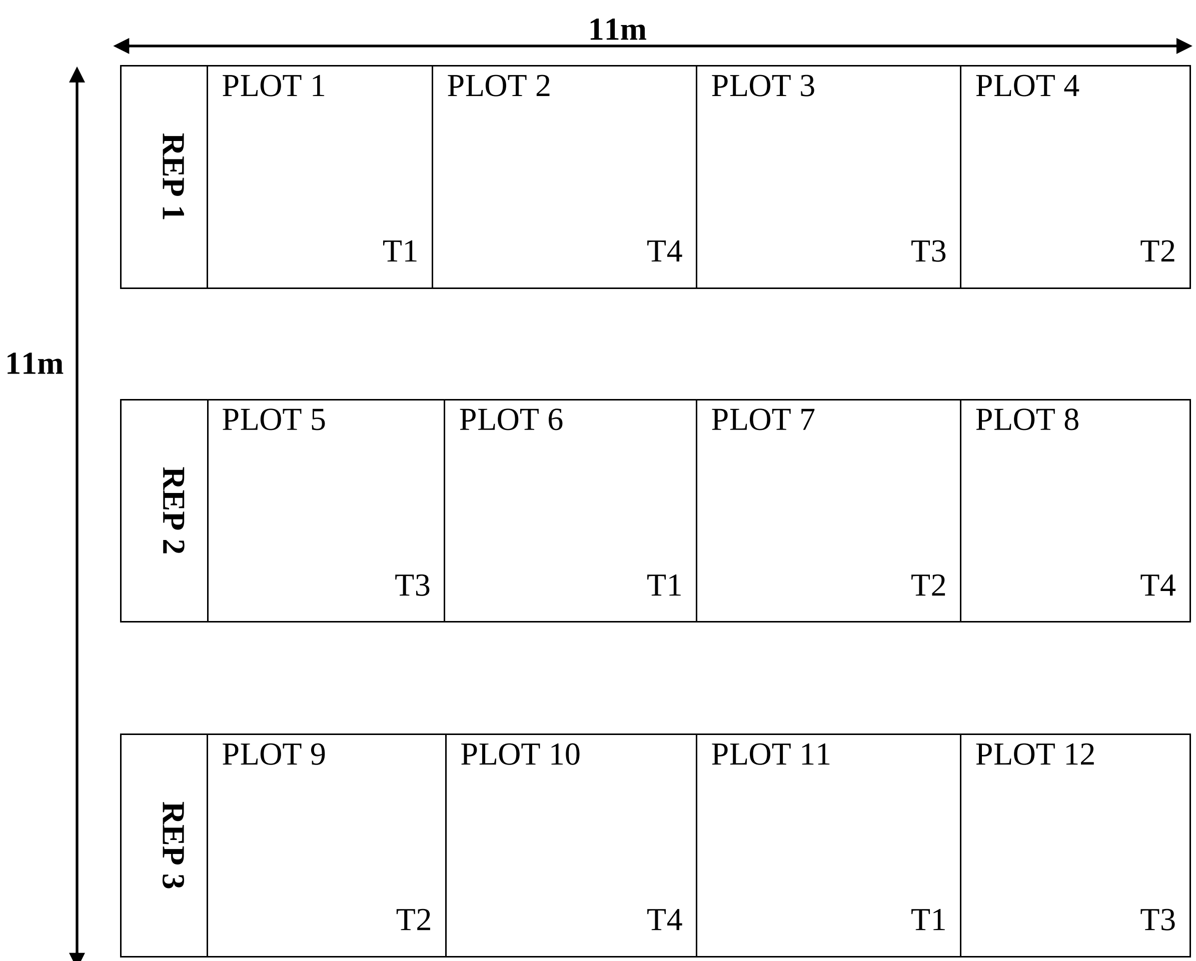

Figure 0:2 showing the field plan

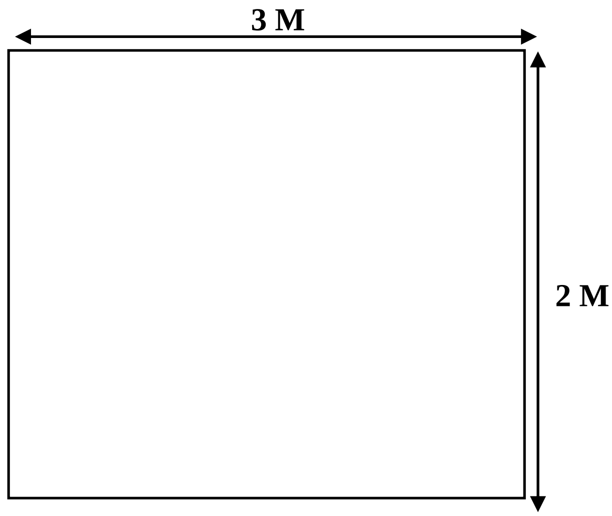

Figure 0:3 showing the plot size

Figure 0:4showing the researcher establishing plots

Each plot measured 3 m × 2 m (6 m²) and was separated from adjacent plots by 1 m buffer paths. Replicates were separated by 1 m alleyways to minimize nutrient and water transfer between blocks. The total field measured 11m in length and 11m in width, covering an area of 121 m².

Plot layout was established using the 3:4:5 triangle method to ensure perpendicular corners and uniform row alignment. Layout marking was done using wooden pegs, string lines, and a 90^0 corner template for accuracy. Treatment allocation within each replicate was determined using simple randomization, executed by drawing labelled papers from a hat to avoid systematic bias.

3.3 Agronomic and Cultural Practices

3.3.1 Crop Variety and Planting

The maize variety used was SC 437, an early-maturing hybrid cultivar developed by Seed Co Zimbabwe, known for its adaptability and drought tolerance. Planting was done manually in the early morning hours using the drill method, with seeds planted directly into prepared planting stations. Each station was spaced 75cm between rows and 25cm within rows.

3.3.2 Fertilizer Management

- Compound D Basal fertilizer: Applied during planting at a rate of 300 kg/ha directly into the planting holes and lightly covered with soil to prevent volatilization and seed contact.
- Top Dressing: For treatments involving AN, 150 kg/ha was applied 40 days after planting (DAP).
- Foliar Application: Pflanzen Booster was mixed at the recommended dosage of 2.5kg per 500 litres of water per hectare and applied using a hand-held pressure sprayer during the early vegetative phase. The plots measured $6m^2$ therefore amount of applied foliar fertilizer was as follows:

  $2\ 500g = 10\ 000m^2$

  $? = 6m^2$

  6/10 000 * 2 500 = 1.5g

  Thus 2 500g = 500 litre

  1.5/2 500 * 500 = 0.3 litres which was <u>300 ml/plot</u>

  The applied Application was done in the morning to avoid scorching and maximize leaf uptake.

3.3.3 Weed and Pest Control

- Weed Control: Weed pressure was managed through mechanical weeding using hand hoes and supplementary hand pulling. Weeding occurred one week after germination, followed by a second round two weeks later.

- Pest Management: The major pest identified was the fall armyworm (Spodoptera frugiperda). Control measures involved the application of Lambda Cyhalothrin 5 EC, a pyrethroid insecticide, at a rate of 200 ml/ha upon observation of larval damage. Pest scouting was conducted weekly.

3.4 Data Collection Procedures

Systematic data collection was conducted at biweekly intervals beginning from two weeks after top dressing (2 WATD) and continued fortnightly afterwards until there was no more vegetative growth. Measurements focused on plant biometric parameters and final yield outcomes. Random sampling was used to select four plants per plot, which were then permanently tagged for consistent monitoring.

3.4.1 Plant Height

The height of the plants was determined by measuring from the soil surface to the apex of the tallest leaf using a string which was transferred on a tape measure to obtain actual values. Values were recorded in centimetres (cm) and averaged per plot. Data collection was conducted at biweekly intervals beginning from 2 WATD AND continued at every fortnight afterwards until the plants showed no more vegetative growth.

3.4.2 Leaf Length

Measured from the leaf base to the tip on the third fully expanded leaf, ensuring uniformity across samples. A string was used on the leaf plant and was transferred measuring tape to obtain actual values which were recorded in cm. Data collection was conducted as the same as in plant height.

3.4.3 Number of days taken to reach 50% flowering

For each plot, the number of days from planting to 50% flowering was recorded, starting from the day after planting.

3.4.4 Cob Length

Following tasseling and pollination, cob development was monitored. Cob length was measured every two weeks from initial formation until harvest, which were the R1, R2 and R3 development stages, using a string on the cob, transferring the measurements to a ruler, and values were recorded in cm.

3.4.5 Grain Yield

At physiological maturity, maize cobs from each plot were harvested, manually dehusked, shelled, and sun-dried to standard moisture content (13%). Grain weight was recorded using a digital electronic scale. Yield per hectare was calculated using the formula:

Yield (kg/ha) = (Grain weight per plot (kg) × 10,000 m^2/ha) / Plot size (m^2)

3.5 Data Analysis

The following data analysis model was used:

$Y_{ijk} = \mu + B_i + T_j + E_{jk}$

Where Y_{ijk} = Variable measured (as per objectives)

μ = General mean

B_i = Block effect

T_j = Treatment effect

E_{jk} = Error

ANOVA was performed on the quantitative data using GenStat statistical software (17th Edition).The statistical model considered treatments as fixed effects and blocks as random effects. The following steps were followed:

1. Main Effects: Where ANOVA indicated significant differences ($p < 0.05$), treatment means were separated using the Least Significant Difference (LSD) test to identify statistically distinct groups.
2. Graphical Analysis: Graphs were generated to visually illustrate treatment effects on each agronomic parameter using bar charts and line graphs.

The analytical approach aimed to ensure rigor, reproducibility, and scientific validity of the findings. Interpretation of results considered both statistical significance and practical agronomic implications.

CHAPTER 4

RESULTS

4.1 Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on leaf length at 2 WATD

At 2 WATD, the effects of different fertilizer regime treatments on leaf length was statistically significant ($p < 0.027$). Maize plants treated with Pflanzen Booster exhibited the longest leaf lengths, followed closely by those treated with Ammonium Nitrate. The differences between these two treatments were not statistically significant, indicating comparable performance at this early vegetative stage. In contrast, the Control treatment (no fertilizer) recorded the shortest leaf length, which was statistically similar to the combined treatment (Pflanzen Booster + Ammonium Nitrate). This suggests potential antagonistic interactions or suboptimal nutrient uptake when both fertilizers are applied together at this stage.

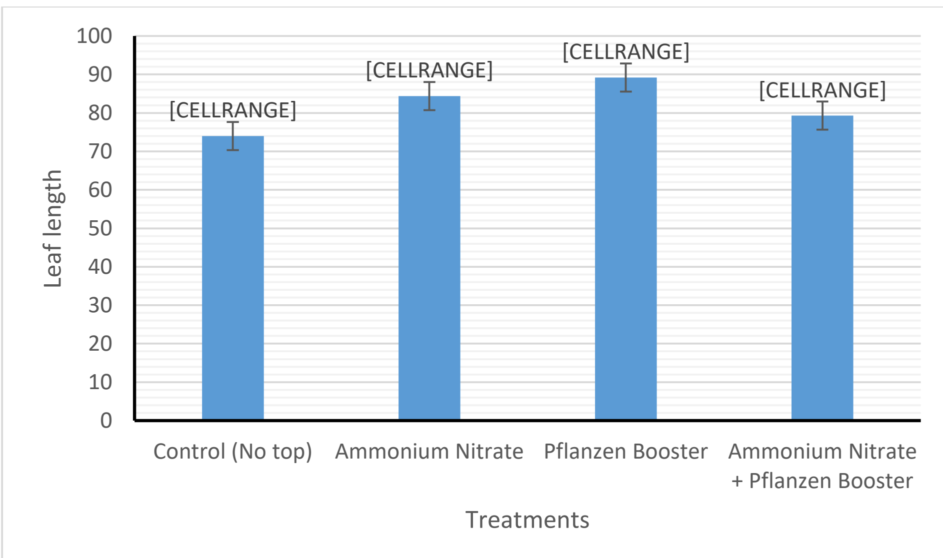

Fig 4.1: Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on leaf length at 2 WATD.

4.2 Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on plant height at 2 WATD

Significant differences in plant height were observed among the fertilizer treatments at 2 WATD ($p < 0.001$). The tallest plants were recorded in plots treated with Pflanzen Booster, although the difference was not statistically distinct from those treated with Ammonium Nitrate. The Control group exhibited the shortest plants, indicating the critical role of nutrient supplementation during early growth stages. The similarity in performance between foliar and conventional nitrogen sources suggests that foliar application can be as effective as soil-applied fertilizer during early vegetative development.

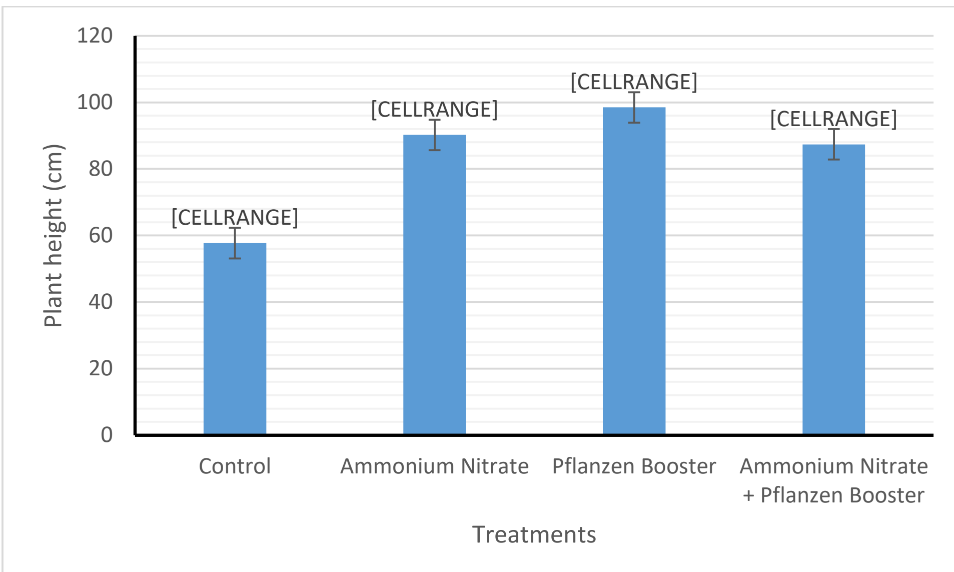

Fig 4.2: Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on plant height at 2 WATD.

4.3 Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on leaf length at 4 WATD

At 4 WATD, fertilizer treatments had a statistically significant effect on leaf length ($p < 0.009$). The longest leaves were observed in the Pflanzen Booster treatment, indicating continued vegetative growth stimulation from the foliar fertilizer. Ammonium Nitrate treatments produced slightly shorter leaves, although not statistically different from Pflanzen Booster, suggesting comparable efficacy during this stage. The Control group again had the shortest leaf length, while the combined treatment (Pflanzen Booster + Ammonium Nitrate) showed reduced performance, statistically similar to the control. This pattern supports the hypothesis that excessive or unbalanced nutrient supply may compromise foliar absorption or induce mild nutrient stress.

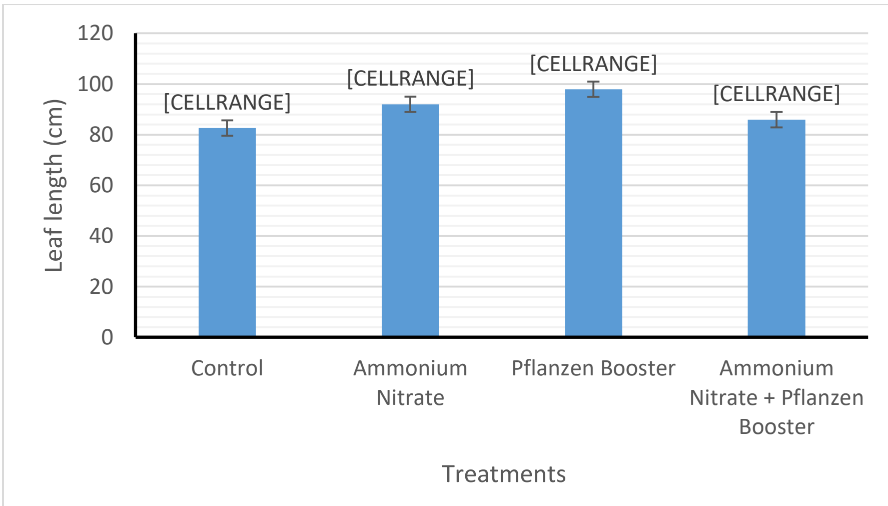

Fig 4.3: Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on leaf length at 4 WATD

4.4 Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on plant height at 4 WATD

Plant height differences remained statistically significant at 4 WATD ($p < 0.002$). The tallest maize plants were observed in the Pflanzen Booster treatment, followed by Ammonium Nitrate and the combined treatment. The Control treatment produced the shortest plants. Notably, the combination treatment did not show additive effects; its plant height was statistically similar to Ammonium Nitrate but still inferior to foliar-only treatment. These results reinforce the observation that foliar application promotes rapid early growth and may bypass soil-related nutrient losses, while the combined treatment may be hindered by nutrient competition or over-application effects.

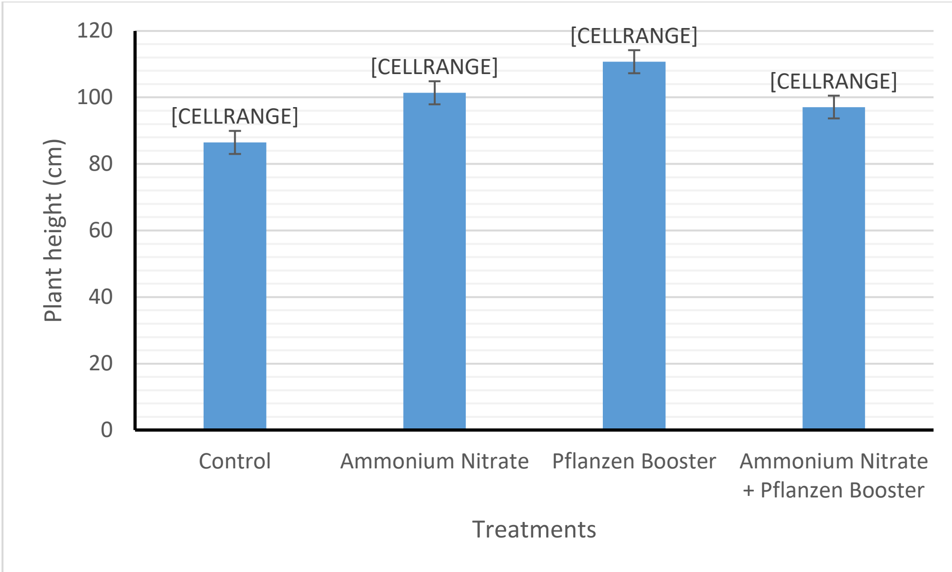

Fig 4.4: Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on plant height at 4 WATD

4.5 Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on leaf length at 6 WATD

At 6 WATD, the treatments continued to show a statistically significant impact on leaf length ($p < 0.002$). Pflanzen Booster maintained its lead, producing the longest leaves among all treatments. Interestingly, the combined treatment (Pflanzen Booster + Ammonium Nitrate) did not outperform the Control group, and both were statistically similar. This suggests a possible inhibitory interaction or diminished uptake efficiency when both fertilizers are applied concurrently. The trend reinforces concerns over potential nutrient antagonism or osmotic stress caused by excessive or imbalanced nutrient application.

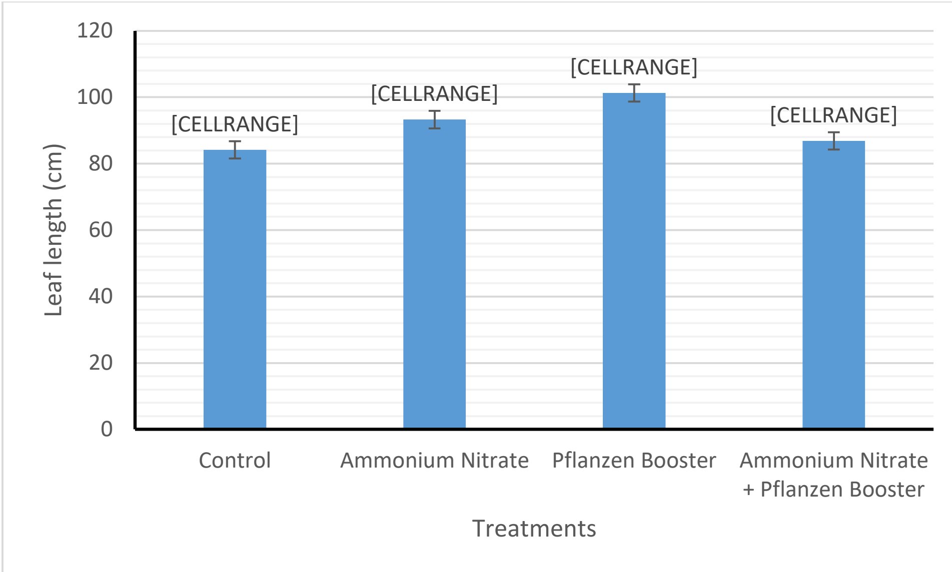

Fig 4.5: Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on leaf length at 6 WATD

4.6 Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on plant height at 6 WATD

Significant variation in plant height was observed at 6 WATD among the treatments ($p < 0.001$). Pflanzen Booster resulted in the tallest plants, followed by Ammonium Nitrate, and then the combined treatment, with the Control recording the shortest stature. Unlike earlier stages, all four treatments differed significantly from one another, indicating diverging responses to nutrient availability as the crop entered advanced vegetative growth. The relatively poor performance of the combined treatment suggests that excess fertilization may have started to suppress growth through physiological or biochemical stress mechanisms.

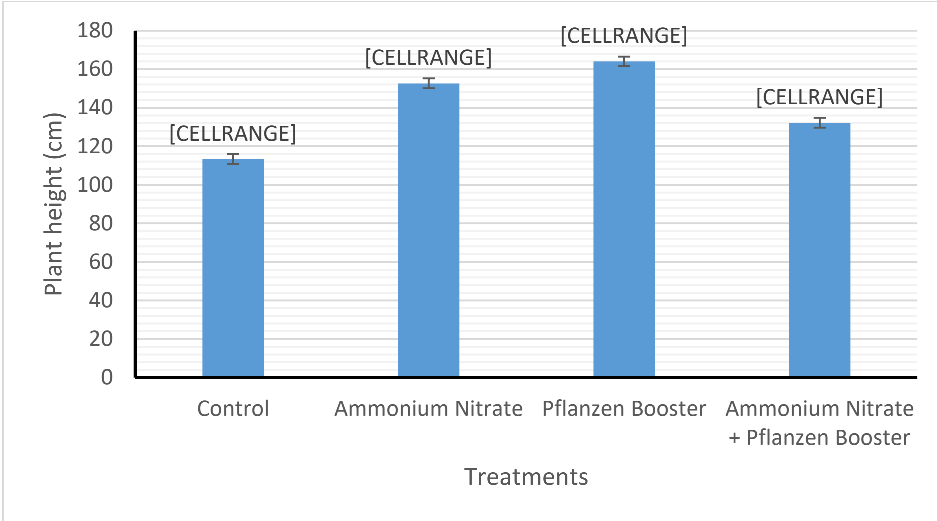

Fig 4.6: Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on plant height at 6 WATD

4.7 Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on leaf length at 8 WATD

By 8 WATD, statistically significant differences in leaf length persisted among the fertilizer treatments ($p < 0.002$). Pflanzen Booster maintained its superiority, consistently producing the longest leaves across all growth intervals. The Control treatment again had the shortest leaves, which were statistically similar to the combined treatment (Pflanzen Booster + Ammonium Nitrate). This continued trend suggests that foliar application alone supports extended leaf expansion into later vegetative stages, while the combined application may suffer from nutrient absorption inefficiencies or mild toxicity due to over-fertilization.

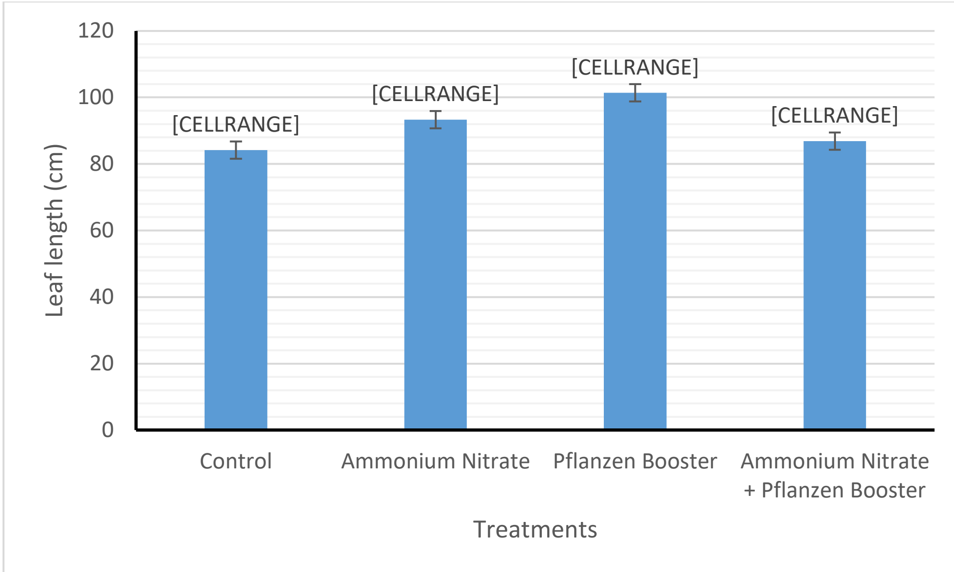

Figure 4.7: Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on leaf length at 8 WATD

4.8 Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on plant height at 8 WATD

Significant differences in plant height were also evident at 8 WATD ($p < 0.001$). Pflanzen Booster outperformed all other treatments, producing the tallest plants with a statistically significant advantage. Ammonium Nitrate and the combined treatment recorded shorter plant heights, with no significant difference between them. The Control treatment produced the shortest plants overall. These findings suggest that foliar fertilization provided a more efficient and sustained nutrient supply throughout the vegetative growth period, while combined treatments may have resulted in nutrient imbalances that constrained vertical growth.

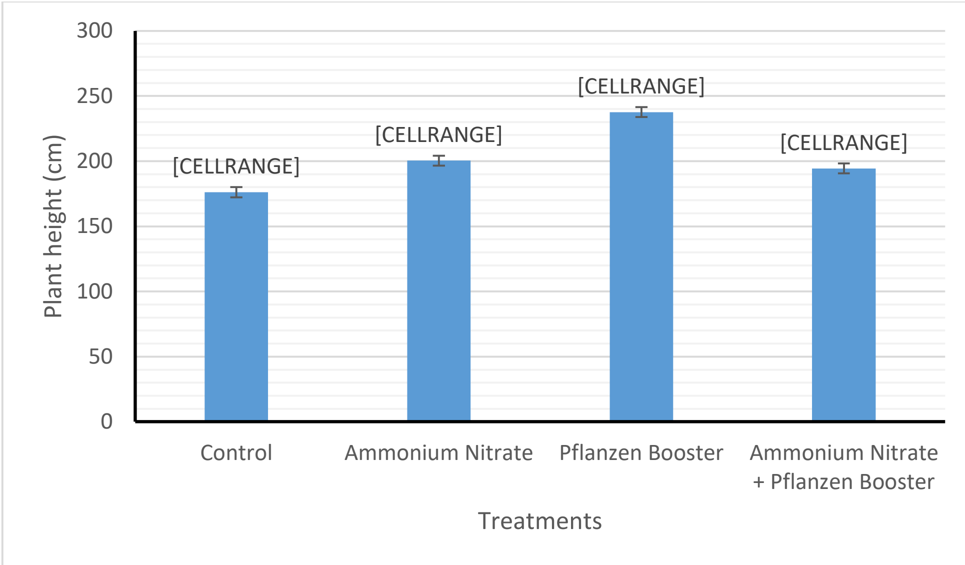

Figure 4.8: Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on plant height at 8 WATD

4.9 Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on cob length at R1 development stage

At the R1 developmental stage, a statistically significant difference in cob length was observed among the treatments ($p < 0.019$). The Pflanzen Booster treatment produced the longest cobs, followed closely by Ammonium Nitrate and the combined treatment. These three were statistically similar, suggesting that by the onset of reproductive growth, all three fertilized treatments contributed comparably to early cob formation. However, the Control treatment recorded significantly shorter cobs, confirming the necessity of nutrient supplementation for effective reproductive development.

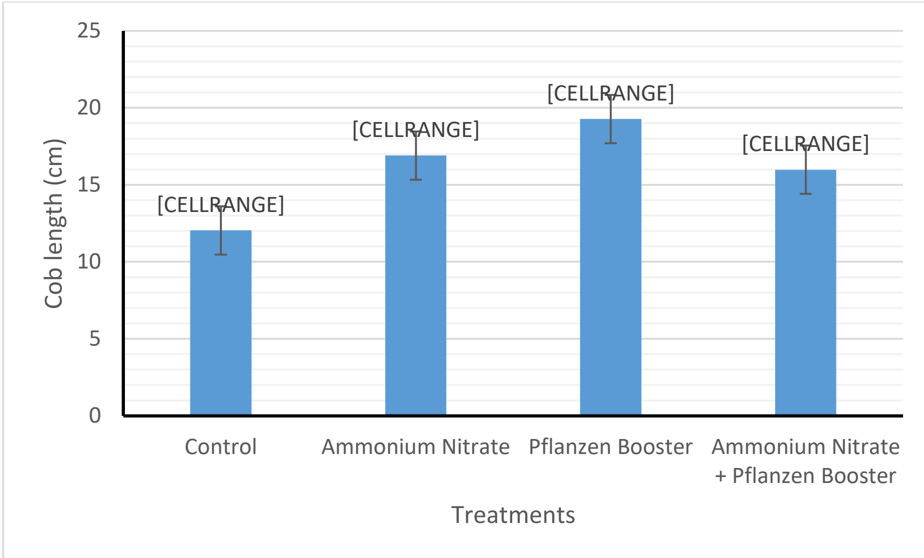

Figure 4.9: Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on cob length at R1 development stage

4.10 Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on cob length at R2 development stage

By the R2 stage, treatment effects on cob length became more pronounced and statistically significant ($p < 0.001$). Ammonium Nitrate yielded the longest cobs, followed closely by Pflanzen Booster; however, the difference between the two was not statistically significant. This suggests that soil-applied nitrogen may have a stronger residual effect during mid-reproductive development. The Control treatment again produced the shortest cobs, reinforcing the role of fertilizers in sustaining cob elongation during grain fill initiation.

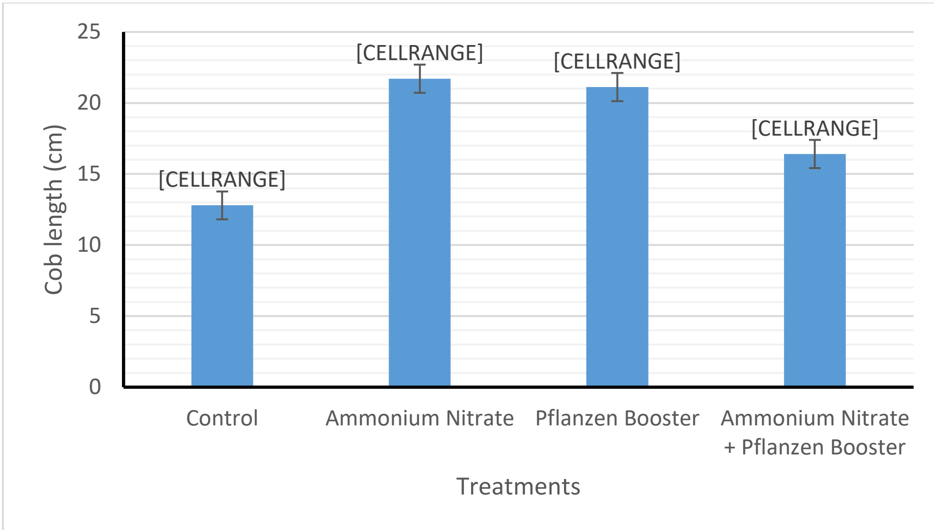

Figure 4.10: Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on cob length at R2 development stage

4.11 Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on cob length at R3 development stage

At the R3 stage, cob length differences remained statistically significant ($p < 0.002$). Ammonium Nitrate led to the longest cobs, followed by Pflanzen Booster, with both treatments statistically similar. The combined treatment came third, while the Control had the shortest cobs, though there was no significant difference between these two. These results suggest that while both Ammonium Nitrate and foliar fertilization support late-stage cob development, excessive or combined applications may have limited additional benefit or even hindered performance.

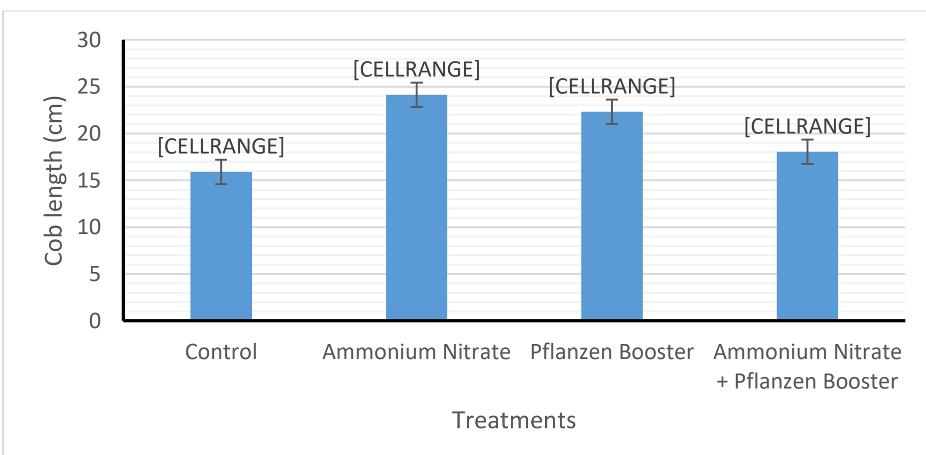

Figure 4.11: Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on cob length at R3 development stage

4.12 Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on number of days taken to reach 50% flowering

Significant differences were observed in the number of days to 50% flowering across treatments ($p < 0.052$). Pflanzen Booster led to the earliest flowering, followed closely by Ammonium Nitrate; however, the two treatments were statistically similar. The Control treatment required the longest time to reach 50% flowering, indicating delayed crop development due to nutrient deficiency. Interestingly, the combined treatment did not accelerate flowering as expected and was statistically similar to the Control, suggesting that the simultaneous application of foliar and conventional fertilizers may have caused physiological delays possibly due to stress from nutrient imbalance.

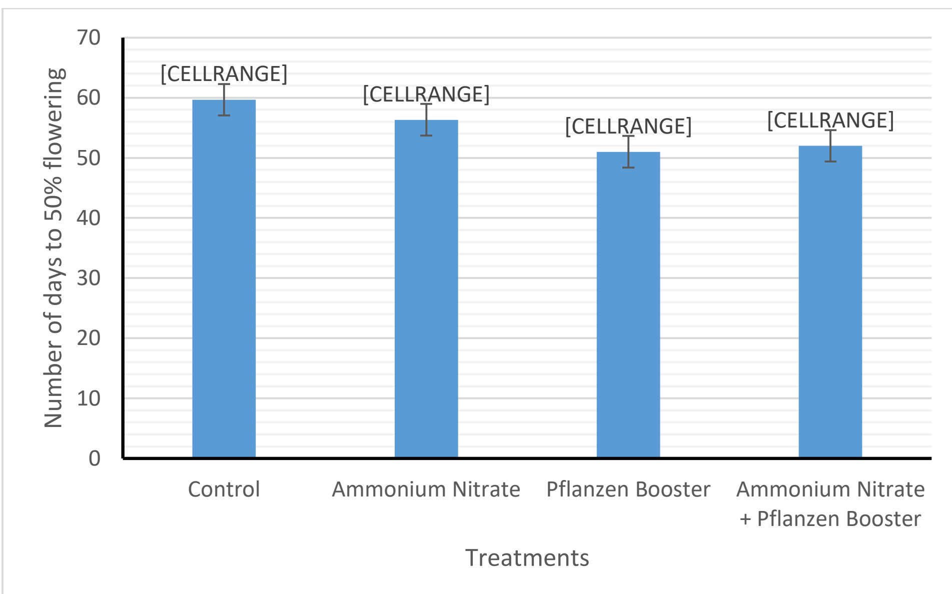

Fig 4.12: Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on number of days taken to reach 50% flowering

4.13 Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on the final grain yield (tonnes/ha)

There was a statistically significant difference in final grain yield among the treatments ($p < 0.001$). Pflanzen Booster produced the highest yield, followed closely by Ammonium Nitrate with no significant difference between the two. This parity underscores the effectiveness of foliar fertilization as a viable alternative to conventional soil fertilization in enhancing maize productivity. The combined treatment recorded the third highest yield but was statistically similar to the Control, which had the lowest yield overall. The underperformance of the combined treatment suggests a possible case of diminishing returns or nutrient antagonism when both fertilizers are applied simultaneously at full rates.

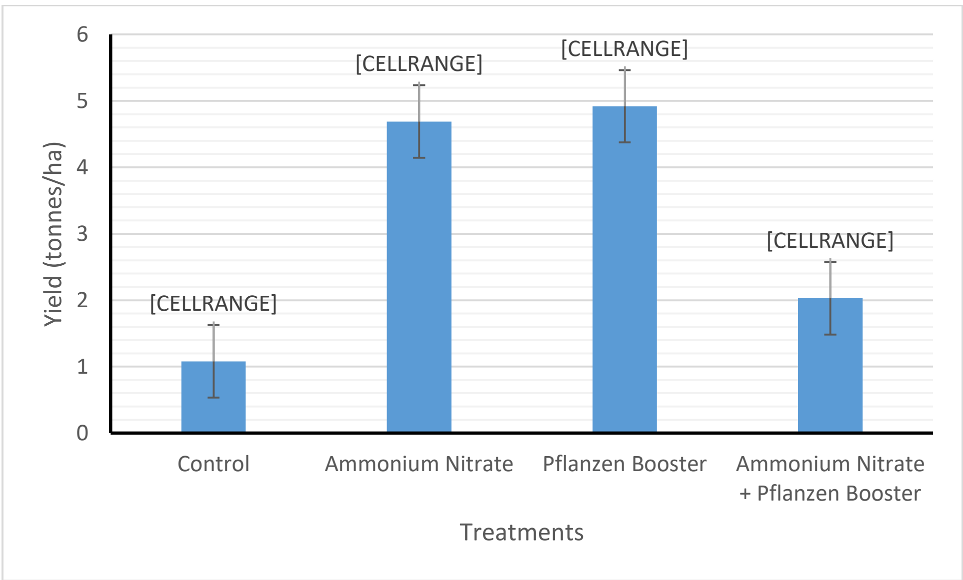

Figure 4.13: Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on the final grain yield (tonnes/ha).

CHAPTER 5

DISCUSSION

5.1 Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on leaf length

The observed variations in leaf length as shown on figure 4.5 across treatments highlight the significant influence of nutrient source and delivery method on early vegetative growth in maize. Figure 4.7 showed that Pflanzen Booster consistently produced the longest leaves, indicating its effectiveness in promoting sustained leaf elongation. This result aligns with Ertani *et al.* (2018), who reported that seaweed-based foliar fertilizers enhance leaf expansion through cytokinin-like compounds that promote cell division and elongation.

While Ammonium Nitrate also improved leaf length in the early stages, its performance declined as shown on figure 4.7, suggesting a reduction in nitrogen availability likely due to losses via volatilization and leaching, as noted by Evans and Clarke (2019). Notably, the combined treatment (Pflanzen Booster + Ammonium Nitrate) did not result in synergistic effects. Instead, it underperformed in later stages, matching the Control in some measurements. This suggests potential antagonistic nutrient interactions or osmotic stress arising from over-application. Wierzbowska *et al.* (2022) and Zingore *et al*. (2007) similarly warn that excessive or poorly timed nitrogen application can lead to inefficient nutrient uptake and physiological stress.

Overall, the findings confirm that foliar fertilization when appropriately timed and dosed could offer superior support for leaf development and sustained vegetative growth.

5.2 Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on plant height

Plant height trends mirrored those of leaf length, with Pflanzen Booster consistently resulting in the tallest plants across all growth intervals. This underscores the efficacy of foliar-applied nutrients in bypassing soil-related inefficiencies, facilitating faster nutrient uptake, and stimulating robust shoot development. According to Fernandez and Eichert (2013), foliar feeding enables rapid nutrient assimilation through stomatal and cuticular pathways, promoting internode elongation and increased biomass.

Interestingly, Ammonium Nitrate also contributed to increased plant height, but not to the same extent as foliar feeding at later stages. This may be attributed to declining nitrogen use efficiency in soil-based applications over time, particularly under conditions prone to leaching or low soil retention.

Once again, the combined treatment did not yield additive benefits, and in some instances, performed worse than single treatments. This supports Liu and von Wiren's (2017) findings that over-supply of nitrogen can disrupt hormonal balances especially auxins and cytokinins thereby suppressing vertical growth.

The results reinforce the principle that more fertilizer does not necessarily equate to more growth, and that delivery mechanisms and timing are critical in maximizing nutrient efficacy.

5.3 Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on cob length

Cob length progression across the R1, R2, and R3 stages demonstrated that nutrient availability during reproductive development is pivotal to maize productivity. In the R1 stage, Pflanzen Booster led to early cob elongation, likely due to its role in accelerating physiological maturity through improved nutrient access.

However, by R2 and R3 stages, Ammonium Nitrate surpassed or equaled Pflanzen Booster in cob length, suggesting that its residual soil nitrogen supported extended grain fill and reproductive tissue expansion. Masood *et al*. (2023) explain this by noting that nitrate-nitrogen (NO_3^-) provides fast-acting energy while ammoniacal-nitrogen (NH_4^+) supports sustained uptake both of which are prominent in Ammonium Nitrate formulations.

The combined treatment again underperformed at later reproductive stages. This result is consistent with findings from Chen *et al.* (2020), who caution that excessive nutrient supply can create metabolic imbalances or toxicity, interfering with sink-source allocation during grain filling.

These outcomes point to the need for strategic nutrient management, ensuring that inputs support rather than hinder reproductive development.

5.4 Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on number of days taken to reach 50% flowering

Time to 50% flowering was shortest under Pflanzen Booster, suggesting accelerated crop development and early transition to the reproductive phase. This may be attributed to the immediate availability of essential nutrients such as micronutrients and cytokinin-activating compounds, which stimulate floral induction. Farooq et al. (2018) reported similar effects, with foliar feeding accelerating flowering through hormonal regulation.

Ammonium Nitrate followed closely behind, supporting the idea that adequate nitrogen facilitates reproductive readiness. Korkmaz and Karagol (2021) observed that optimal nitrogen availability enhances early flowering through improved vegetative vigor and carbon partitioning.

Conversely, the combined treatment and the Control delayed flowering, possibly due to either nutrient deficiency (Control) or nutrient overload (combined), which can interfere with photoperiodic and hormonal signalling Ruan *et al*. (2018) and Wang *et al*. (2018) both showed that excess nitrogen can suppress flowering through epigenetic downregulation of flowering genes.

The results emphasize the importance of balanced nutrition, especially at critical phenological junctures.

5.5 Effects of pflanzen booster foliar fertilizer and ammonium nitrate applications on the final grain yield (tonnes/ha)

Final grain yield serves as the most integrative indicator of fertilizer treatment efficacy. The results demonstrated that both Pflanzen Booster and Ammonium Nitrate achieved statistically similar and highest yields, confirming that foliar fertilizers can match the performance of traditional soil-based nutrients. These findings corroborate studies by Singh *et al*. (2014), Khursheed *et al.* (2018), and Sultana et al. (2018), all of whom reported significant yield improvements with foliar application in cereals.

The Control group recorded the lowest yields, as expected, while the combined treatment did not enhance yield despite increased nutrient input. This underscores the principle of diminishing returns, where over-application may lead to nutrient antagonism, root stress, or metabolic imbalances, ultimately reducing yield potential (Zingore *et al*., 2007; Tavirimirwa *et al*., 2018).

The findings suggest that efficient and timely application of a single fertilizer particularly foliar formulations can deliver optimal yield outcomes without excessive nutrient use, offering both environmental and economic advantages.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

This study set out to compare the effectiveness of Pflanzen Booster foliar fertilizer and conventional Ammonium Nitrate, both individually and in combination, on maize growth, flowering, and yield performance. The results demonstrated that Pflanzen Booster alone significantly improved vegetative growth traits (leaf length and plant height), accelerated flowering, and produced the highest final grain yield comparable to Ammonium Nitrate.

In contrast, the combined application of foliar and conventional fertilizers did not yield additive benefits. In several cases, it underperformed relative to the individual treatments, often showing similar or inferior outcomes to the unfertilized control. These findings suggest that nutrient overload or poor synchrony between soil and foliar nutrient delivery may hinder plant development.

Overall, the study rejects all null hypotheses, confirming that fertilizer type and method of application significantly affect maize growth dynamics, phenological progression, and yield. The results support the use of foliar fertilizers specifically Pflanzen Booster as a viable and potentially superior alternative to conventional inorganic fertilizers under field conditions in Zimbabwe.

6.2 Recommendations

Basing on the results of this study, the following recommendations are suggested:

1. Adoption of Foliar Fertilizers:

   Smallholder and peri-urban farmers should consider adopting Pflanzen Booster foliar fertilizer as a stand-alone top-dressing option, especially in resource-constrained or environmentally sensitive settings. Its performance was comparable and in some cases superior to conventional ammonium nitrate.

2. Cautious Use of Combined Fertilization:

   The simultaneous use of foliar and soil-applied fertilizers at full rates is not recommended without further calibration. The lack of synergistic effects observed suggests a risk of nutrient antagonism or over-application stress. Future applications should experiment with reduced dosages or staggered timing to optimize nutrient uptake.

3. Sustainable Nitrogen Management:

   Where Ammonium Nitrate remains in use, split applications should be adopted to reduce leaching and volatilization losses. This approach enhances nitrogen use efficiency while minimizing environmental risks.

4. Site-Specific Validation:

   Additional research is recommended to test these findings across different agro-ecological zones, soil types, and climatic conditions in Zimbabwe. This would help generate more generalized and scalable fertilizer recommendations.

5. Economic and Environmental Assessments:

   Future studies should incorporate cost-benefit analysis and environmental impact assessments to quantify the economic viability and ecological sustainability of foliar fertilization under varying production scales.

In summary, this research contributes to the growing body of evidence supporting climate-smart, resource-efficient maize production systems and underscores the value of innovative fertilization strategies for achieving both productivity and sustainability goals.

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APPENDIX

Analysis of variance

Variate: Leaf_Length_cm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	24.15	12.08	1.09	
REP.*Units* stratum					
Treatment	3	44.11	14.70	1.33	0.349
Residual	6	66.19	11.03		
Total	11	134.45			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Leaf_Length_cm

Grand mean 28.84

Treatment	T1	T2	T3	T4
	28.72	26.77	27.93	31.93

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	1.918

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	2.712

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	6.636

Stratum standard errors and coefficients of variation

Variate: Leaf_Length_cm

Stratum	d.f.	s.e.	cv%
REP	2	1.738	6.0
REP.*Units*	6	3.321	11.5

Analysis of variance

Variate: Plant_Height_cm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	10.910	5.455	1.13	
REP.*Units* stratum					
Treatment	3	47.838	15.946	3.32	0.099
Residual	6	28.841	4.807		
Total	11	87.589			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Plant_Height_cm

Grand mean 52.23

Treatment	T1	T2	T3	T4
	53.86	51.65	54.19	49.21

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	1.266

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	1.790

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	4.380

Stratum standard errors and coefficients of variation

Variate: Plant_Height_cm

Stratum	d.f.	s.e.	cv%
REP	2	1.168	2.2
REP.*Units*	6	2.192	4.2

Analysis of variance

Variate: Leaf_Length_cm_1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	3.46	1.73	0.09	
REP.*Units* stratum					
Treatment	3	383.85	127.95	6.40	0.027
Residual	6	120.00	20.00		
Total	11	507.31			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Leaf_Length_cm_1

Grand mean 81.7

Treatment	T1	T2	T3	T4
	74.0	84.4	89.2	79.3

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	2.58

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	3.65

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	8.93

Stratum standard errors and coefficients of variation

Variate: Leaf_Length_cm_1

Stratum	d.f.	s.e.	cv%
REP	2	0.66	0.8
REP.*Units*	6	4.47	5.5

Analysis of variance

Variate: Plant_Height_cm_1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	23.84	11.92	0.38	
REP.*Units* stratum					
Treatment	3	2846.97	948.99	30.04	<.001

Residual	6	189.53	31.59
Total	11	3060.34	

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Plant_Height_cm_1

Grand mean 83.5

Treatment	T1	T2	T3	T4
	57.7	90.2	98.5	87.4

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	3.24

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	4.59

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	11.23

Stratum standard errors and coefficients of variation

Variate: Plant_Height_cm_1

Stratum	d.f.	s.e.	cv%
REP	2	1.73	2.1

REP.*Units*	6	5.62	6.7

Analysis of variance

Variate: Leaf_Length_cm_2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	5.55	2.77	0.20	
REP.*Units* stratum					
Treatment	3	410.84	136.95	10.09	0.009
Residual	6	81.44	13.57		
Total	11	497.83			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Leaf_Length_cm_2

Grand mean 89.6

Treatment	T1	T2	T3	T4
	82.6	92.0	97.9	85.9

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	2.13

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	3.01

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	7.36

Stratum standard errors and coefficients of variation

Variate: Leaf_Length_cm_2

Stratum	d.f.	s.e.	cv%
REP	2	0.83	0.9
REP.*Units*	6	3.68	4.1

Analysis of variance

Variate: Plant_Height_cm_2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	1.35	0.68	0.04	
REP.*Units* stratum					
Treatment	3	909.23	303.08	16.96	0.002
Residual	6	107.24	17.87		
Total	11	1017.82			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Plant_Height_cm_2

Grand mean 98.9

Treatment	T1	T2	T3	T4
	86.5	101.4	110.7	97.1

Standard errors of means

Table	Treatment
rep.	3
d.f.	6

e.s.e.	2.44

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	3.45

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	8.45

Stratum standard errors and coefficients of variation

Variate: Plant_Height_cm_2

Stratum	d.f.	s.e.	cv%
REP	2	0.41	0.4
REP.*Units*	6	4.23	4.3

Analysis of variance

Variate: Leaf_Length_cm_3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	6.59	3.29	0.32	
REP.*Units* stratum					
Treatment	3	525.86	175.29	17.29	0.002
Residual	6	60.84	10.14		
Total	11	593.29			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Leaf_Length_cm_3

Grand mean 91.39

Treatment	T1	T2	T3	T4
	84.14	93.26	101.32	86.85

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	1.839

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	2.600

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	6.362

Stratum standard errors and coefficients of variation

Variate: Leaf_Length_cm_3

Stratum	d.f.	s.e.	cv%
REP	2	0.907	1.0
REP.*Units*	6	3.184	3.5

Analysis of variance

Variate: Plant_Height_cm_3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	15.582	7.791	0.82	

REP.*Units* stratum					
Treatment	3	4527.312	1509.104	158.72	<.001
Residual	6	57.047	9.508		
Total	11	4599.941			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Plant_Height_cm_3

Grand mean 140.54

Treatment	T1	T2	T3	T4
	113.31	152.62	164.04	132.20

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	1.780

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	2.518

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	6.160

Stratum standard errors and coefficients of variation

Variate: Plant_Height_cm_3

Stratum	d.f.	s.e.	cv%
REP	2	1.396	1.0
REP.*Units*	6	3.083	2.2

Analysis of variance

Variate: Leaf_Length_cm_4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	6.43	3.22	0.32	
REP.*Units* stratum					
Treatment	3	526.60	175.53	17.46	0.002
Residual	6	60.33	10.06		
Total	11	593.37			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Leaf_Length_cm_4

Grand mean 91.42

Treatment	T1	T2	T3	T4
	84.18	93.28	101.37	86.87

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	1.831

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	2.589

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	6.335

Stratum standard errors and coefficients of variation

Variate: Leaf_Length_cm_4

Stratum	d.f.	s.e.	cv%
REP	2	0.897	1.0
REP.*Units*	6	3.171	3.5

Analysis of variance

Variate: Plant_Height_cm_4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	256.52	128.26	5.78	
REP.*Units* stratum					
Treatment	3	5971.16	1990.39	89.66	<.001
Residual	6	133.19	22.20		
Total	11	6360.87			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Plant_Height_cm_4

Grand mean 202.1

Treatment	T1	T2	T3	T4
	176.2	200.4	237.6	194.4

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	2.72

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	3.85

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	9.41

Stratum standard errors and coefficients of variation

Variate: Plant_Height_cm_4

Stratum	d.f.	s.e.	cv%
REP	2	5.66	2.8
REP.*Units*	6	4.71	2.3

Analysis of variance

Variate: Cob_Length_cm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	6.145	3.073	0.84	
REP.*Units* stratum					
Treatment	3	81.446	27.149	7.39	0.019
Residual	6	22.030	3.672		
Total	11	109.621			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Cob_Length_cm

Grand mean 16.05

Treatment	T1	T2	T3	T4
	12.04	16.90	19.27	15.98

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	1.106

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	1.565

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	3.828

Stratum standard errors and coefficients of variation

Variate: Cob_Length_cm

Stratum	d.f.	s.e.	cv%
REP	2	0.876	5.5
REP.*Units*	6	1.916	11.9

Analysis of variance

Variate: Cob_Length_cm_1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	10.375	5.188	3.54	
REP.*Units* stratum					

Treatment	3	159.251	53.084	36.21	<.001
Residual	6	8.796	1.466		
Total	11	178.422			

Information summary

All terms orthogonal, none aliased.

Message: the following units have large residuals.

REP 1 *units* 2	-1.92	s.e. 0.86

Tables of means

Variate: Cob_Length_cm_1

Grand mean 18.00

Treatment	T1	T2	T3	T4
	12.79	21.71	21.11	16.41

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	0.699

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	0.989

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	2.419

Stratum standard errors and coefficients of variation

Variate: Cob_Length_cm_1

Stratum	d.f.	s.e.	cv%
REP	2	1.139	6.3
REP.*Units*	6	1.211	6.7

Analysis of variance

Variate: Cob_Length_cm_2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.333	0.167	0.07	
REP.*Units* stratum					
Treatment	3	129.526	43.175	17.01	0.002
Residual	6	15.230	2.538		
Total	11	145.090			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Cob_Length_cm_2

Grand mean 20.09

Treatment	T1	T2	T3	T4
	15.89	24.14	22.31	18.04

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	0.920

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6

s.e.d.	1.301

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	3.183

Stratum standard errors and coefficients of variation

Variate: Cob_Length_cm_2

Stratum	d.f.	s.e.	cv%
REP	2	0.204	1.0
REP.*Units*	6	1.593	7.9

Analysis of variance

Variate: Number_of_days_to_50%_flowering

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	15.50	7.75	0.75	
REP.*Units* stratum					
Treatment	3	144.92	48.31	4.69	0.052
Residual	6	61.83	10.31		
Total	11	222.25			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Number_of_days_to_50%_flowering

Grand mean 54.75

Treatment	T1	T2	T3	T4
	59.67	56.33	51.00	52.00

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	1.853

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	2.621

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	6.414

Stratum standard errors and coefficients of variation

Variate: Number_of_days_to_50%_flowering

Stratum	d.f.	s.e.	cv%
REP	2	1.392	2.5
REP.*Units*	6	3.210	5.9

Analysis of variance

Variate: Yield_tonnes_ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	1.0968	0.5484	1.23	
REP.*Units* stratum					
Treatment	3	33.1017	11.0339	24.77	<.001
Residual	6	2.6729	0.4455		
Total	11	36.8714			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Yield_tonnes_ha

Grand mean 3.18

Treatment	T1	T2	T3	T4
	1.08	4.69	4.92	2.03

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	0.385

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	0.545

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	1.333

Stratum standard errors and coefficients of variation

Variate: Yield_tonnes_ha

Stratum	d.f.	s.e.	cv%
REP	2	0.370	11.6
REP.*Units*	6	0.667	21.0