BINDURA UNIVERSITY OF SCIENCE EDUCATION

DEPARTMENT OF CROP SCIENCE

Evaluating the effect of foliar fertilizer type and concentration on sugarcane performance and yield *(Saccharum officinarum L.).*



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B230716A

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF THE BACHELOR OF AGRICULTURAL SCIENCE HONOURS DEGREE

(CROP SCIENCE)

JUNE 2026

DECLARATION

I, **Mesi Clive** do hereby declare that this research project herein is my original work and has not been copied from any source without acknowledgement of the source. It has not been submitted before for any degree or examination at any other University.

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I have supervised the research project of the above-mentioned student and I am convinced that the research project:

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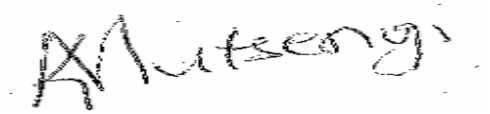
Project Supervisor: Mr. K Mutsengi Signature: 

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ABSTRACT

Sugarcane production is an important component of Zimbabwe's agricultural sector, contributing significantly to national sugar production, employment creation, and economic development. However, declining soil fertility, increasing fertilizer costs, and climate variability have necessitated the exploration of sustainable nutrient management strategies that enhance crop productivity while minimizing environmental impacts. Foliar fertilization has emerged as a promising approach for improving nutrient uptake efficiency and crop performance. This study evaluated the effects of different concentrations of OEMFF and ROOT on the growth, and yield of sugarcane under Zimbabwe Lowveld conditions. Field experiments were conducted at Hippo Valley Estate and Triangle Estate during the 2025/2026 growing season using a 2-way factorial design with Factor 1 fertilizer type Root and Oemff while factor 2 was concentration at 600ml, 900ml and 1500mls and a control with three replications. Data collected included plant height, stalk population, stalk diameter and cane yield. Analysis of variance (ANOVA) showed that fertilizer type had a significant effect on cane height at harvest at both Hippo Valley Estate ($P = 0.0118$) and Triangle Estate ($P = 0.0109$). At Triangle Estate, the interaction between fertilizer type and concentration was also highly significant ($P = 0.0078$), indicating that the response of cane height depended on the combination of fertilizer source and application concentration. The study concluded that Foliar fertilizers can be an effective supplementary nutrient management tool for sugarcane production in the Zimbabwe Lowveld. Adoption of appropriate Foliar fertilizer application rates could improve sugarcane productivity and profitability while supporting more sustainable crop production systems. Foliar fertilizers should be timed to coincide with periods of active crop growth when nutrient demand is highest in order to maximize nutrient uptake and crop response. Growers should continue to monitor soil fertility status and avoid relying solely on foliar fertilization, as sugarcane remains a high nutrient-demanding crop that requires balanced soil nutrition.

Keywords: Sugarcane, foliar fertilization, OEMFF, growth, yield, Zimbabwe Lowveld, sustainable nutrient management.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to all the individuals and institutions whose support, guidance, and encouragement contributed to the successful completion of this research study.

My heartfelt appreciation goes to my supervisor, Mr. Mutsengi, for his invaluable guidance, constructive criticism, patience, and continuous support throughout the research process. His expertise, encouragement, and willingness to provide direction at every stage of this study greatly contributed to the quality of this work.

I am deeply grateful to Dr. T.P. Chibarabada, Senior Research Agronomist for her academic guidance, professional advice, and insightful contributions. Her knowledge and encouragement played a significant role in shaping this research and enhancing my understanding of scientific research methodologies.

Special appreciation is extended to Zimbabwe Sugar Association Experiment Station (ZSAES**)** for providing the resources, facilities, technical support, and conducive environment necessary for conducting this study. Without their assistance, the successful implementation of this research would not have been possible.

I would also like to sincerely thank Mr. Shayanewako, the ZSAES Research Services Manager, for his support, coordination, and commitment to facilitating the smooth execution of the project. His assistance and willingness to accommodate the research activities are greatly appreciated.

My gratitude is further extended to the technical staff and field personnel at ZSAES, Hippo Valley Estate, and Triangle Estate who assisted with field operations, data collection, and general logistical support throughout the study period. Their dedication and cooperation were invaluable.

I would also like to acknowledge the lecturers and staff of the Department of Crop Science at Bindura University of Science Education for providing the academic foundation and knowledge that enabled me to undertake this research successfully.

Finally, I extend my deepest appreciation to my family, friends, and fellow students for their unwavering support, encouragement, understanding, and motivation throughout my academic journey. Their belief in my abilities gave me the strength and determination to complete this study.

To all those who contributed directly or indirectly to the success of this research, I am sincerely grateful.

DEDICATIONS

This thesis is dedicated to my beloved family, whose unwavering love, encouragement, sacrifices, and support have been the foundation of my academic journey. Their constant belief in my abilities, even during challenging times, provided me with the strength, motivation, and determination to persevere and achieve this milestone.

I also dedicate this work to my parents and guardians for their guidance, wisdom, and commitment to my education. Their sacrifices and encouragement have inspired me to strive for excellence and to pursue my goals with dedication and integrity.

To my friends, mentors, and all those who have supported and encouraged me throughout my studies, this achievement is a reflection of your positive influence and faith in my potential.
Finally, I dedicate this thesis to all aspiring agricultural scientists and researchers whose efforts contribute towards improving agricultural productivity, food security, and sustainable development. May this work serve as a small contribution to the advancement of knowledge in Crop Science and the continued growth of Zimbabwe's agricultural sector.

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LIST OF ABBREVIATIONS

ANOVA – Analysis of Variance

LSD – Least Significance Difference

pH – Potential of Hydrogen

ZSAES – Zimbabwe Sugar Association Experiment Station.

CHAPTER 1

1.0 INTRODUCTION

1.1 Background of the Study

Sugarcane *(Saccharum officinarum L.)* is one of the most profitable crops of the grass family. It is globally cultivated and produced in the tropical and subtropical regions, and it plays a significant role of approximately 80% of the worldwide sugar production and producing by products which are of more use including energy and feed for animals (Moore & Botha, 2014).

Sugarcane is adapted to dry environments but it requires a lot of water in its growth 1800-2500mm of water are required for its growth., The crop shows great biomass buildup of 150-350tons /ha fresh biomass yield, 30-7-tons/ha dry biomass yield and greater radiation-use effectiveness because it is a C4 plant with an optimized architecture. The crop requires large quantities of macro nutrients such as nitrogen (120kgs), phosphorus (60kg), potassium (150kg), calcium, magnesium, sulphur and more trace elements as to complete its growing cycle (Sage & Zhu, 2011). Proper management of nutrients is of paramount importance to supporting sugarcane yields and the final quality of juice. (Kingston, 2014) Stated that, sugarcane development of stalks through elongation and sucrose buildup, heavily relies on the available nutrients in the times of imposing growing phases.

In Zimbabwe, sugarcane production is mainly practiced in the Southeastern Lowveld in natural Region V, mainly in the areas of Chiredzi, Triangle the commercial estates and Mkwasine. The crop is grown under irrigation since this area is dry in most times of the year and however; the areas have inherently fertile and deep soils which are very supportive of plant growth. According to (Mugandani., *et al.,* 2012) the Natural Region V occupies around 126, 829 km^2 which is equivalent to about 32.5% of Zimbabwe characterized by semi-arid climatic conditions, with mean annual temperature ranging from 21-25 ºC in winter while mean maximum temperature range of 26-35 ºC in summer, and low annual rainfall (<450 mm), leading to the need of supplementary irrigation.

Soils in the Lowveld are mainly sandy clay to sandy loam prevailing in the areas where the crop is being grown characterized with low soil fertility (Chikowo *et al*., 2012). These soils are

susceptible to nutrient leaching, particularly nitrogen, which decreases fertilizer use effectiveness.

Application of fertilizers directly to the soil, is the only practice in the Zimbabwe's Sugarcane Industry. As a result, leaching, volatilization, and denitrification lead to nutrient losses (Fageria et al., 2009). The use of furrow irrigation systems in the soils characterized with low water holding capacity, leads to financial losses due to high cost of production, such as a 50kg bag of fertilizer costing US$32.50 in 2025 rising to US$45.00 in year 2026 and the application of more soil-based fertilizers with declining cane yields from 150tons Pre-2010 and now ranging to 90tons/ha (ZSAES, Sugarcane Production, 2020).

With the availability of new products in the agriculture market especially, supplementary foliar fertilizers suggest to correct and address the challenges caused by soil-based fertilizers. Foliar fertilizers use involves direct application to the leaves, makes it easy to be absorbed through the cuticles and through the stomatal pathways enhancing metabolic processes fast as compared to the soil-based nutrients (Fernandez & Eichert, 2009).

Research carried out in different crops using foliar fertilizers as supplements led to positive effect on vegetative growth stages, tiller production and contributing to high yields if applied at the correct concentration and at the right time (Fageria *et al*., 2009; El-Tilib *et al*., 2004). Correct application rates have to be used when using foliar fertilizers, if over applied they lead to leaf burns and sometimes nutrient inequity (Fernandez & Brown, 2013).

1.2 Problem Statement

Different foliar fertilizer types are on the market, as to supplement soil-based fertilizers, however, little is known on how these different foliar fertilizer types affect sugarcane field performance. Unfortunately, farmers are hesitating to go for foliar fertilizers due to lack of adequate information about the use of foliar fertilizers especially application rates in addition, the best application rates and foliar fertilizer types are still unknown.

1.3 Justification of the Study

Different foliar fertilizer types promised to be an alternative supplements for soil-based fertilizers which most farmers are heavily relying on and not applying correctly. There is need to furnish farmers with correct information on the use of foliar fertilizers available in the market. This research aims to evaluate the effectiveness of different application rates of different foliar fertilizer types used solely on sugarcane production. The results will help farmers to be very sure of benefits of different foliar fertilizer types and providing farmers with exact application rate when using foliar fertilizers on sugarcane production.

1.4 Study Objectives

1.4.1 General Objective

To evaluate the effect of different foliar fertilizer concentrations on sugarcane performance in the Zimbabwe's Lowveld.

1.4.2 Specific Objectives

- ✓ To determine the effect of foliar fertilizer type and concentrations on sugarcane vegetative growth.
- ✓ To evaluate the effect of foliar fertilizer type and concentrations on total cane yield.

1.5 Research Hypotheses

Different foliar fertilizer and concentrations have no significant effect on sugarcane vegetative growth.

Different foliar fertilizers types and concentrations have no significant effect on sugarcane yield.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Importance of sugarcane

Sugarcane *(Saccharum officinarum L.)* is a perennial crop from the grass family (*Poaceae*) (Moore & Botha, 2014; Sage & Zhu, 2011). It is one of the crops which requires macronutrients in large quantities consisting of Nitrogen for vegetative growth, increasing tillering, leaf area index and leaf longevity. Phosphorus is crucial for early root development and energy transfer (ATP) within the plant and thereby playing a key role in photosynthesis and stalk elongation. With potassium playing a vital role in determining yield and quality and being responsible for transporting carbohydrates from the leaves to the stalks. It also aids in enzyme activation, stomatal regulation, and improves water tolerance (ZSAES, Zimbabwe Sugarcane Production Manual, 2024).

In Zimbabwe, the production of sugarcane is mainly concentrated in the Southeastern Lowveld with mainly relying with irrigation systems (Chikowo *et al*., 2012). Out grower farmers are now receiving average yields ranging from 75-90t/ha which is becoming a decline in yield whereas, Commercial estates are producing better as compared to small out grower farmers. The yield varies significantly depending on the agronomic practises, soil fertility, and the resources availability (ZSAES, Sugarcane Production, 2020). Therefore, it is ideal to manage soil fertility status in the sugarcane production in the Lowveld.

2.2 Fertilizer application in Sugarcane in Zimbabwe

Fertilizer is important in sugarcane production covering 30% of the variable costs. Because of this significant contribution to production cost, it is important that fertilizers be managed properly. The use of fertilizers plays a vital role in increasing yields, whilst nutrients under threshold value will generally result in low yields (Fernandez & Eichert, 2009).

Continued growing of sugarcane crop without sufficient nutrient replacement, has a negative effect leading exhaustion of available nutrients in the soil. With the use irrigation systems in sugarcane production in Zimbabwe's sugar industry, nitrogen the major component is lost through leaching below the root zone by water and volatilization, involving the transformation of

nitrogen fertilizers into ammonia gas, which escapes into the atmosphere and leading to the unavailability of nutrients to the crop. High irrigation, sandy soils, high fertilizer application, and groundwater contamination are therefore leading reduced nutrient availability, causing stunted growth and lower yields (ZSAES, Sugarcane Production, 2020).

Surface application through broadcasting urea or ammonium nitrate onto the soil surface, rather than incorporating it, high temperature and alkaline pH, all enhance the conversion of ammonium to ammonia gas, green cane trash blanketing as leaving residues on the surface can increase volatilization (30-70% of applied N can be lost) because urease enzymes in the trash breaks down urea leading to high ammonium levels that convert to gas and all leads to nitrogen volatilization (Robinson *et al*., 2011; Thorburn *et al*., 2017).

However, productivity in the Lowveld is increasingly being constrained by declining soil fertility, nutrient imbalances, salinity problems, and the rising cost of conventional soil-applied fertilizers. Researchers have reported that continuous monocropping of sugarcane often leads to nutrient depletion and reduced soil productivity, thereby affecting cane growth, sucrose accumulation, and overall yield.

In recent years, foliar fertilization has emerged as a promising supplementary nutrient management strategy in sugarcane production. This approach is particularly relevant in the Zimbabwe Lowveld where high temperatures, erratic rainfall patterns, and alkaline or saline-sodic soils may reduce the effectiveness of soil-applied fertilizers. Several studies have demonstrated the positive effects of foliar fertilizers on sugarcane growth and productivity (Chibarabada, T.P & Murahwa, G.T, 2025).

Research conducted by Agronomy researchers in Brazil observed that foliar application of micronutrients and bio stimulants significantly improved stalk mass, sucrose content, and total recoverable sugar in ratoon sugarcane. The study further highlighted that the timing and concentration of foliar fertilizer application play a critical role in determining crop response. Treatments involving combinations of micronutrients and bio stimulants resulted in notable increases in cane productivity compared to untreated controls (Junior *et al.,* 2013).

In Zimbabwe, research on sugarcane nutrition has largely focused on nitrogen management, residue recycling, irrigation management, and soil fertility restoration rather than foliar fertilizer concentration effects. For example, studies conducted in the Southeastern Lowveld demonstrated that integrating legumes such as soybean into sugarcane production systems could reduce nitrogen fertilizer requirements while improving soil fertility and sustaining cane yields. Other studies in the Lowveld have emphasized that fertilizer requirements vary among sugarcane varieties due to differences in nutrient uptake and biomass accumulation (Nzvenga, P., Nzima, M., Chinorumba, S., & Mutatu, W., 2024).

Furthermore, salinity and sodicity remain major challenges affecting sugarcane production in the Zimbabwean Lowveld. Soil salinity reduces nutrient availability and impairs root function, resulting in stunted growth and lower yields. Recent studies evaluating bio stimulants under saline-sodic conditions in Zimbabwe reported improvements in physiological performance, plant height, and estimated recoverable crystal percentage following foliar applications, although yield responses varied across environments. These findings suggest that foliar nutrient management may help mitigate environmental stress effects and improve crop performance under marginal conditions (Chibarabada, T.P & Murahwa, G.T, 2025).

Despite the growing global interest in foliar fertilization, there remains limited information on the optimum foliar fertilizer concentrations suitable for sugarcane production under Zimbabwean Lowveld conditions. Most available studies have been conducted under different climatic, soil, and management conditions outside Zimbabwe, making it difficult to directly apply their recommendations to local production systems. Additionally, the interaction between foliar fertilizer concentration, sugarcane growth, yield components, and juice quality characteristics under Lowveld conditions is still inadequately understood.

Table 1: Application ranges of ammonium nitrate and urea on different soil types (ZSAES, Zimbabwe Sugarcane Production Manual, 2024).

SOIL CLASS	CROP	N (kg/ha)	AN (kg/ha)	AN (*Bags/ha)	UREA (kg/ha)	UREA (*Bags/ha)
Sandy Loam (SaL)	Plant	120-160	350-	7-9	261-	5-7

			465		348	
			405-		304-	
	Ratoon	140-170	495	8-10	370	6-8
Sand Clay Loam			320-		239-	
(SaCL)	Plant	110-140	405	6-8	304	5-6
			375-		283-	
	Ratoon	130-160	465	8-9	348	6-7
			345-		261-	
Basalt Clay	Plant	120-160	465	7-9	348	5-7
			405-		304-	
	Ratoon	140-180	525	8-11	391	6-8

2.3 Micronutrient in sugarcane production

Micronutrients such as zinc (Zn), iron (Fe), and boron (B) are very important for enzyme activation and carbohydrate metabolism. Unavailability in these nutrients can hinder stalk elongation and sucrose synthesis (Kingston, 2014). Sandy soils common in the Lowveld are particularly prone to micronutrient deficiencies due to low cation exchange capacity and organic matter content (Chikowo *et al.*, 2012).

Micronutrients shortage is one of the restraining aspects in sugarcane productivity due to various aspects, such as soil alkalinity, the usage of fertilizers with low micronutrients levels, increased agricultural productivity, decreased level of soil organic matter, and concentrated farming in low-fertility areas (Fageria, 2002).

There is evidence that boron promotes RG II (rhamnogalacturonan II) cross-links in the cell wall and drives cell elongation and plant hormonal responses (Taiz *et al*., 2017). Copper is associated with enzymes such as plastocyanin, which is involved in electron transfer during light-dependent reactions in plants (Taiz *et al*., 2017).

Iron is one of the crucial micronutrient components for plant growth and helps in the primary process of photosynthesis. Manganese is the utmost extracted micronutrient from the soil by

sugarcane plants and, when provided at adequate levels, can contribute to productivity (BENETT *et al*., 2016). According to (Taiz et al., 2017), decarboxylases and dehydrogenases, which are involved in the citric acid cycle (Krebs cycle) are specially activated by manganese.

Zinc is needed for chlorophyll biosynthesis in other plants, and its deficit is characterized by decreased internode growth, with plants showing a rosette growth habit (Taiz *et al*., 2017). In sugarcane, it possibly increases productivity and tillering when brought in low fertility soils.

2.3 Foliar application of fertilizers

It is the direct application of nutrients directly onto plant leaves to supplement soil-applied fertilizers (Fernandez & Eichert, 2009).The use of foliar fertilizers has great impact and added advantage in circumstances where soil conditions are a contributing factor to the unavailability of nutrients to the crop. (Fageria *et al*., 2009). Foliar fertilization can enhance nutrient use effectiveness by bypassing soil fixation and decreasing nutrient losses. In circumstances where root uptake is constrained such as during drought stress or in sandy soils, foliar applications can provide direct nutrient correction.

Recent studies show that the application of foliar fertilizers consisting of nitrogen, can increase apparent nitrogen recovery compared to soil-only treatments, mostly when applied during active vegetative growth stages (Otto *et al*., 2016). Nevertheless, application rate is critical; extreme applications may cause osmotic stress and leaf scorch (Fernandez & Brown, 2013).

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

The study was conducted during the 2025/26 cropping season at two commercial sugarcane estates in the Southeastern Lowveld of Zimbabwe, namely Hippo Valley Estate (Section 8, Field 4) and Triangle Sugar Estate (Section 10, Field 2). Hippo Valley Estate is located at approximately 20°12′S, 31°00′E, while Triangle Sugar Estate lies at approximately 20°04′S, 31°01′E. Sandy clay loam are the soils within the Triangle sites which are predominantly light-textured derived from granitic parent material, which are typically low in organic matter, nitrogen, and water-holding capacity, whilst Hippo Valley had sandy loam , reddish brown color derived from granitic parent material (Nyamapfene, 1991; Mugandani *et al*., 2012).

Mean maximum temperatures are generally high, often exceeding 30 °C during the summer months, while winter temperatures remain relatively warm compared to higher-altitude regions of Zimbabwe (Unganai, 1996). High potential evapotranspiration relative to precipitation results in a pronounced moisture deficit, rendering rain-fed crop production unreliable and reinforcing the necessity for irrigation-based agriculture in the southern Lowveld (Mugandani *et al*., 2012; Kupika *et al.*, 2019).

The climate of Agro-ecological Region V is characterized by low, erratic, and highly variable rainfall, typically below 450 mm per annum, with frequent mid-season dry spells and recurrent droughts (Unganai and Murwira, 2010; Kupika *et al*., 2019).

3.2 Experimental design

The trial was a 2-factor laid in Randomized Complete Block Design (RCBD) with a factorial arrangement. Factors being concentration rate (2%=600ml, 3%=900ml and 5%=1500ml) and Fertilizer type (Oemff and Root products), with a control. The trial was replicated 3 times. Slope was used as the blocking factor to account for variation in soil moisture and fertility across the site.

Model of the experimental design

The statistical model used was: $Yijk=\mu+Bi+Fj+Ck+(FC)jk+eijk$

Where:

$Yijk$ = observed value

μ = overall mean

Bi= block effect

Fj= foliar fertilizer type

Ck = concentration effect

$FCjk$= interaction effect

$eijk$ = random error

Table 2: Treatment structure

Treatment code	Foliar fertilizer	Concentration
T1	Root	2% (600ml)
T2	Root	3% (900ml)
T3	Root	5% (1500ml)
CONTROL	Control	0%
T5	OEMFF	2% (600ml)
T6	OEMFF	3% (900ml)
T7	OEMFF	5% (1500ml)

3.4 General Management

Two commercial foliar fertilizers were evaluated strictly as supplementary inputs to soil-based fertilization using Single Super Phosphate at 60kg/Ha, Nitrogen at 120kg/Ha and Potassium at 150kg/Ha.

Soil fertilization program (Basal and Top Dressing) was applied uniformly across all plots. Single Super Phosphate (SSP) at 60kg/Ha was applied as basal fertilizer immediately after cane harvest, based on soil analysis results from the ZSAES laboratory. Nitrogen at 120kg/Ha fertilizer and Potassium at 150kg/Ha were applied in two split applications at 4 weeks and 8 weeks after ratoon emergence, following ZSAES fertilizer recommendations.

Foliar fertilizers were applied using a DJI Agras T40 drone, operated by trained personnel from ZSAES. Applications were conducted on 20 August 2025 at Hippo Valley Estate, and on 21 August 2025 at Triangle Estate. Spraying was done during calm morning conditions to minimize drift and ensure uniform canopy coverage.

Table 3: Nutrient composition of foliar fertilizers used

Nutrient	Root (g kg^{-1})	OEMFF (g kg^{-1})
Nitrogen (N)	56	90
Phosphorus (P)	36	56
Potassium (K)	16	87
Magnesium (Mg)	9.6	22
Sulphur (S)	11	30
Micronutrient	Root (mg kg^{-1})	OEMFF (mg kg^{-1})
Iron (Fe)	–	3550
Manganese (Mn)	–	1130
Zinc (Zn)	9576	1900
Copper (Cu)	2394	690
Boron (B)	758	730
Molybdenum (Mo)	158	120

3.4 Data Collection

3.4.1 Tillers and Stalks per Meter

The number of tillers and stalks was assessed using a permanently marked 1 m quadrat placed at a fixed sampling point within each plot. The quadrat location was established at the beginning of the experiment to ensure repeated measurements were taken from the same area throughout the study period. At each two-week interval, all tillers and stalks emerging within the quadrat were

counted and recorded. This approach allowed for continuous monitoring of crop establishment and early growth dynamics.

3.4.2 Plant height

It was measured using a height stick from ground surface to the top visible dewlap. The five tagged plants per plot were measured repeatedly from the same area throughout the study period.

3.4.3 Leaf Chlorophyll Content

Leaf chlorophyll content was measured using a SPAD-502 chlorophyll meter. Readings were taken from the middle part of youngest fully expanded leaf on the same tagged plants.

3.5 Ethical and Operational Considerations

All field operations complied with estate safety regulations and ZSAES research protocols. No environmental or ethical risks were associated with the study.

3.6 Data analysis

Data were subjected to Analysis of Variance (ANOVA) using R studio. Mean separation was performed using Least Significant Difference (LSD) at 5% probability level performing using Tukey.

CHAPTER 4

4.0 RESULTS

4.1 Crop growth yield response to foliar fertilization treatments

4.1.1 Effects of foliar fertilizer treatments on Plant height

Plant height increased progressively with crop age across all treatments at both sites. Foliar fertilizer treatments significantly affected plant height at later growth stages ($p < 0.05$).

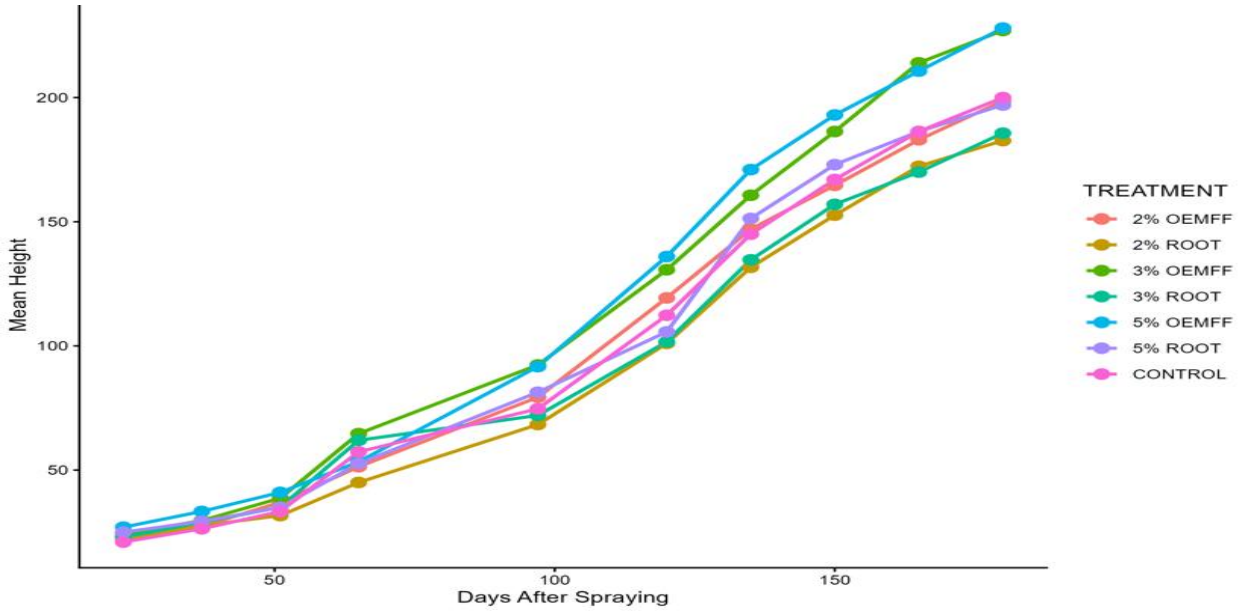

Figure 4.1: Effects of Foliar fertilizer treatments on sugarcane height at Hippo Valley Estates.

Figure 4.1 showed seven treatments at Hippo Valley. Among them, 3% and 5% OEMFF treatments showed significantly greater plant height compared to the control ($p < 0.05$), and 5% Root, with 2% and 3% Root the lowest. 5% and 3% Oemff showed highest height LSD grouping with 118.5 and 116.8 respectively followed by 5% Root (103.6), 2% Oemff (103.1), Control (102.3), 3% Root (97.0) and the lowest being 2% Root (93.4).

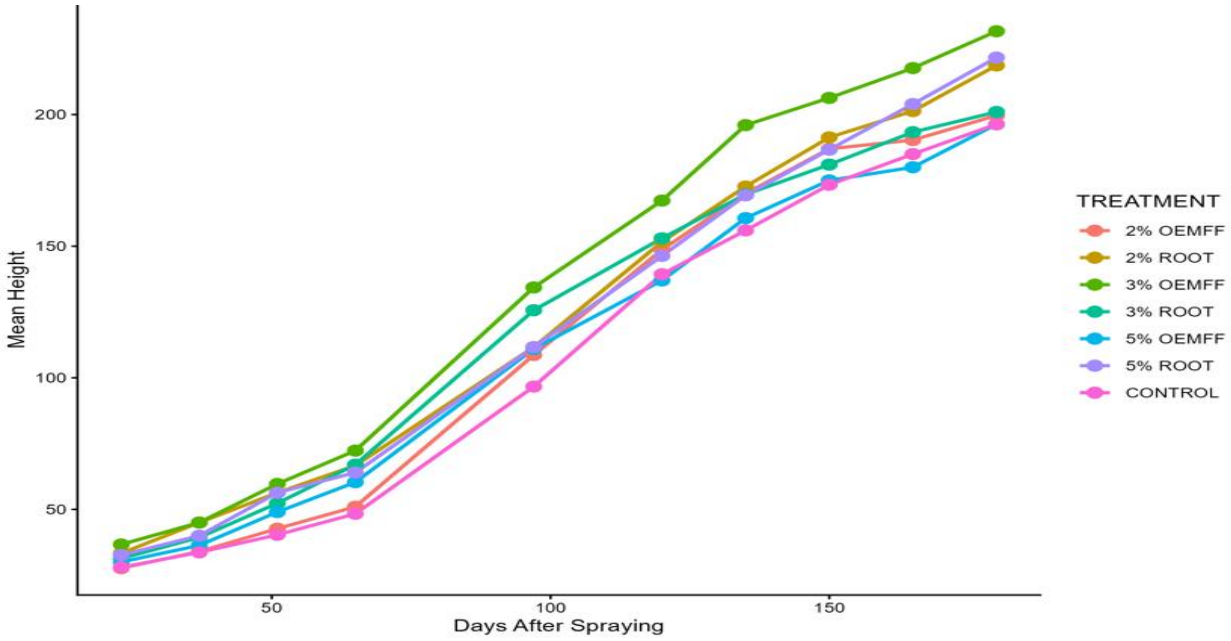

Figure 4.2: Effects of Foliar fertilizer treatments on sugarcane height at Triangle Estates.

Figure 4.2 showed trend patterns at Triangle, medium and high fertilization treatments significantly increased plant height compared to the control ($p < 0.05$), but no significant differences were observed among the top-performing treatments. LSD grouping for height showed that 3% Oemff (136.7) showed the highest compared to 2% Root (124.8), 5% Root (123.2), 3% Root (121.3), 2% Oemff (115.9), 5% Oemff (113.5) and the least being the Control (109.7).

4.1.2 Tiller population

Tiller production was significantly influenced by fertilization treatments ($p < 0.05$) at both sites (Figure 4.3). Treatments supplied with foliar fertilizers produced higher tiller populations than the control treatment, although the response varied depending on fertilizer type and concentration.

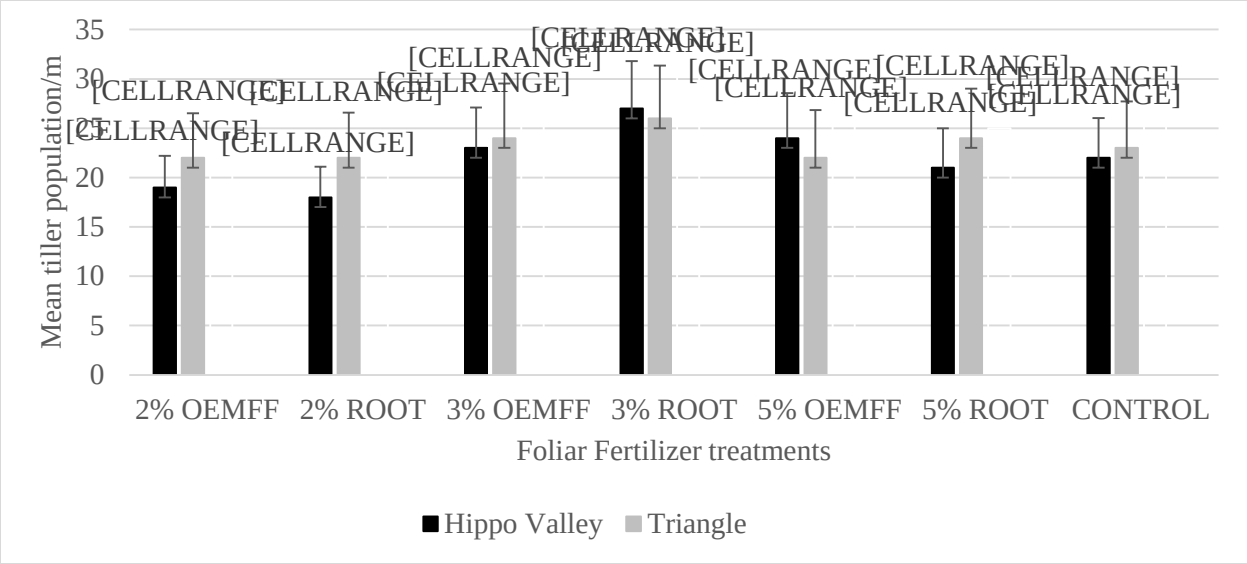

Figure 4.3: Effects of foliar treatments on sugarcane tillering population at Hippo Valley and Triangle.

Figure 4.3 showed that at Hippo Valley, the 3% ROOT treatment recorded the highest tiller population, averaging approximately 27 tillers m^{-1} compared to the Control with average of $22m^{-1}$. This treatment performed significantly better than the lower concentration treatments, particularly 2% OEMFF and 2% ROOT. The 3% OEMFF and 5% OEMFF treatments also produced relatively high tiller populations. In contrast, the lowest tiller populations at HVE were observed under the 2% OEMFF and 2% ROOT treatments.

A similar trend was observed at Triangle, where the 3% ROOT treatment again produced one of the highest tiller populations ($26m^{-1}$), followed closely by the 3% OEMFF and 5% ROOT treatments. The control treatment produced moderate tiller numbers at both sites, indicating that although sugarcane plants were able to tiller under normal field conditions, foliar fertilizer application improved crop establishment and stand density.

4.1.3 Chlorophyll concentration (SPAD)

Table 4: Effects of foliar treatments on sugarcane nitrogen levels at HVE and TRI as at 120 days after spraying.

TREATMENT	HIPPO VALLEY	TRIANGLE
2% OEMFF	43[a]	38[bc]
CONTROL	42[ab]	38[bc]
5% OEMFF	42[ab]	39[ab]
3% OEMFF	42[b]	38[c]
5% ROOT	42[b]	40[a]
2% ROOT	41[b]	39[ab]
3% ROOT	41[b]	39[b]

At Hippo Valley treatment was significant and there were differences among treatment means with $p<0.05$, the highest chlorophyll level was recorded under the 2% OEMFF treatment, with SPAD values exceeding 43 units. This treatment differed significantly from several other treatments, indicating a stronger influence on chlorophyll accumulation and leaf nitrogen content. The 5% OEMFF treatment also produced relatively high SPAD readings, while the 2% ROOT, 3% OEMFF, and 3% ROOT treatments recorded intermediate values. The control treatment maintained moderate nitrogen levels, suggesting that although the crop was able to access nutrients from the soil, foliar fertilization improved leaf nutrient status.

At Triangle, treatment was highly significant and there were differences among treatment means with $p<0.001$. The highest SPAD reading was observed under the 5% ROOT treatment, with value to 40 SPAD units. The 2% and 3% ROOT and 5% OEMFF treatments also recorded comparatively high chlorophyll levels of 39 units, while the 2% and 3% OEMFF treatment produced the lowest SPAD values of 38 the same as Control.

The statistical groupings indicated by the letter annotations show significant differences among treatments ($P \leq 0.05$). Treatments sharing similar letters were not significantly different, whereas treatments with different letters differed significantly in their effects on nitrogen levels.

4.1.4 Stalk population

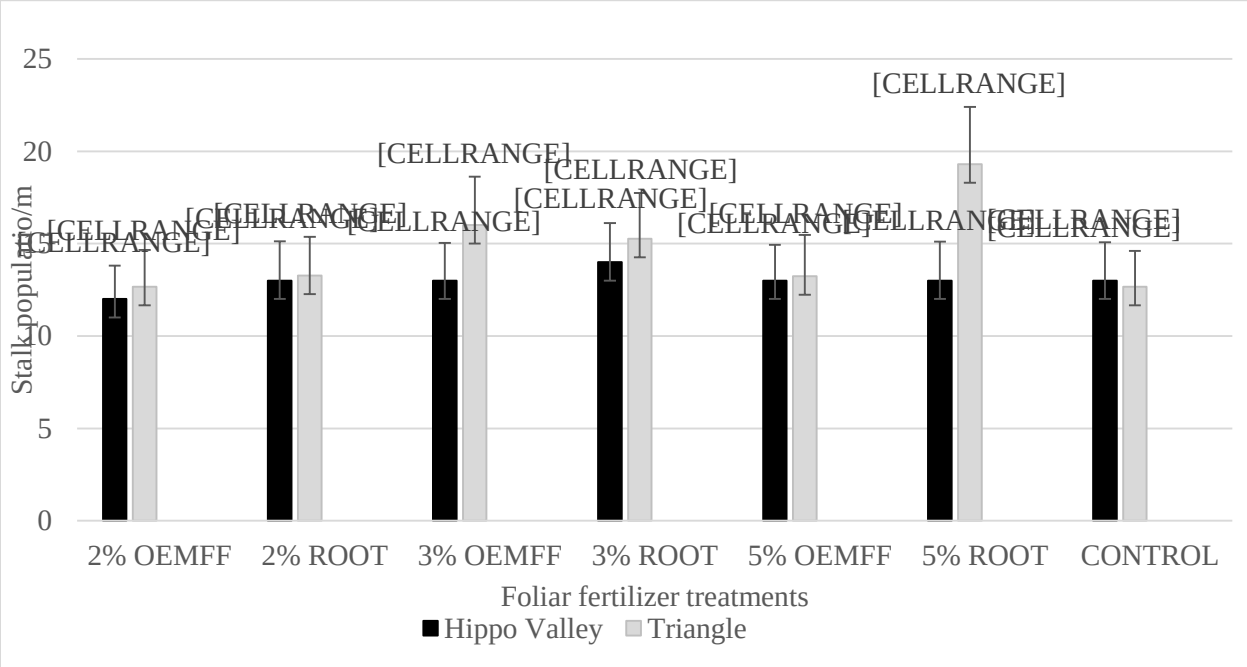

Figure 4.4: Effects of foliar fertilizer treatments on stalk development at Hippo Valley and Triangle as at 120 Days after spraying.

The results in Figure 4.4 show the effect of different foliar fertilizer treatments on stalk population (stalks m^{-1}) at the two trial sites, Hippo Valley Estate and Triangle Estate.

At Hippo Valley, treatments were not significant. The highest mean at HVE was observed under the 3% ROOT treatment (approximately 14 stalks m^{-1}), while the lowest was under 2% OEMFF (approximately 12 stalks m^{-1}). However, the variation among treatments was small, indicating that site conditions may have moderated treatment effects.

At Triangle, treatment was highly significant with $p<0.001$. The 5% ROOT treatment produced the highest stalk population, significantly exceeding most other treatments, with nearly 19–20 stalks m^{-1}. In contrast, the control and 2% OEMFF treatments recorded comparatively lower values, demonstrating reduced stalk proliferation where no fertilizer or lower concentrations were applied.

4.2 Yield results

4.2.1 Effects of Foliar Fertilizer Treatments on Sugarcane Yield

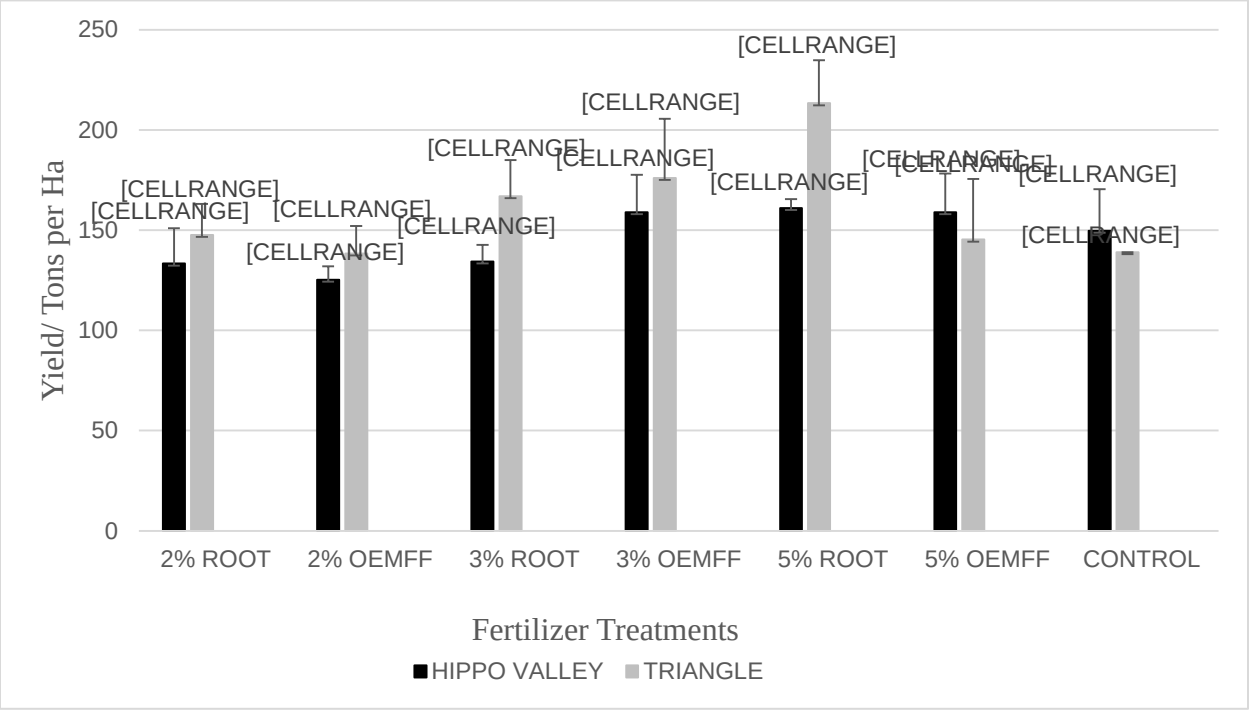

Figure 4.5: Effects of foliar treatments on Sugarcane yield

Fertilizer treatments were not significantly different from each other, while there was no significance difference at both sites with $p>0.05$. At Hippo Valley Estate, the highest yield was recorded under the 5% ROOT treatment, which produced approximately 160 tons ha^{-1}, followed closely by 3% OEMFF (159tons ha^{-1}) and 5% OEMFF (159tons ha^{-1}) treatments. The lowest yield was observed under the 2% OEMFF treatment, with yields slightly above 120 tons ha^{-1} and the Control had (150tons ha^{-1}).

At Triangle Estate, the 5% ROOT treatment produced the greatest yield response of approximately 210 tons ha^{-1}, which was substantially higher than all other treatments. The control treatment at Triangle Estate recorded (139tons/Ha) comparatively lower yields than most fertilized treatments. The results suggest that increasing foliar fertilizer concentration generally improved cane yield, particularly with the ROOT formulations.

4.2.2 Plant height at harvest

Table 5: Effects of foliar fertilizer treatments on sugarcane plant height at harvest at Hippo Valley and Triangle.

Plant Height	Hippo Valley	Triangle
Oemff.900ml	243[a]	238[a]
Oemff.1500ml	242[a]	220[bc]
Oemff.600ml	227[ab]	218[c]
Root.1500ml	225[ab]	237[a]
Control.0	217[b]	213[c]
Root.900ml	217[b]	225[abc]
Root.600ml	208[b]	233[ab]
Grand Mean	**225.47**	**226.4**
LSD	**22.8**	**13.4**
P-value	**0.01**	**0.01**

The results demonstrate that foliar fertilizer concentration and source affected sugarcane growth differently depending on the site ($p<0.05$). At Hippo Valley, 3% OEMFF of 243cm produced the tallest plants and was statistically similar to 5% OEMFF 242cm, 2% OEMFF with 227cm, 5% ROOT with 225cm, 3% Root being the same with Control at 217 and the least being 2% ROOT with 208cm.

At Triangle $p<0.01$, 3% OEMFF (238cm) and 5% ROOT (237cm) had the highest means and were significantly superior to the Control (213). 2% ROOT had 233cm, 3% Root had 225cm, 5% OEMFF had 220cm while 2% OEMFF had 218cm being the second lowest from the Control.

The 3% OEMFF treatment gave superior plant height across both sites. This treatment consistently produced taller plants than lower concentrations, suggesting that moderate foliar nutrient concentration was optimal for promoting vegetative growth.

The 5% OEMFF treatment performed well at Hippo Valley but less effectively at Triangle, indicating possible environmental limitation at the latter site. ROOT fertilizer showed improved performance at Triangle, especially at 5%, suggesting differential adaptation to local conditions.

CHAPTER 5

5.0 DISCUSSION OF RESULTS

5.1 Effect of Foliar Fertilizer Levels on Sugarcane Growth Parameters

The results of this study showed that foliar fertilizer application had a positive influence on sugarcane growth, particularly on plant height, stalk population and stalk diameter. Across both experimental sites, treatments receiving higher concentrations of foliar fertilizer generally produced better growth than the lower concentrations and the control treatment. This indicates that foliar nutrient supplementation improved the nutritional status of the crop and promoted more vigorous vegetative development (Singh *et al*., 2013).

Treatment was highly significant on both sites with $p < 0.001$ whilst Mean separation using Tukey and LSD grouping, showed that 5% Oemff had the highest height of 118.5cm followed by 3% Oemff with 116.8cm while the Control had 102.3cm, with the least being 2% Root at 93.46cm at Hippo Valley. At Triangle, 3% Oemff had the highest plant height of 136.7cm followed by 2% Root with 124.86cm and 5% Root with 123.26cm. 5% Oemff had the least height of 113.56cm and only above the Control which had 109.7cm.

Plant height is an important indicator of crop vigor because it reflects the plant's ability to capture sunlight and accumulate biomass. The taller plants observed under higher foliar fertilizer concentrations may be attributed to improved nutrient availability, which enhanced cell division, cell elongation and photosynthetic activity (Fernández & Brown,, 2013) . Foliar fertilizers provide nutrients directly through the leaves, allowing rapid absorption and utilization by the plant. According to Fernández and Brown (2013), foliar-applied nutrients can improve plant metabolism, nutrient-use efficiency and crop growth by supplying nutrients directly to physiologically active tissues. These findings support the positive response in plant height observed in the present study.

The increase in stalk population with increasing fertilizer concentration suggests that foliar feeding promoted tiller emergence and survival. In sugarcane production, stalk population is one of the most important yield-determining components because it directly influences the number of millable canes harvested at the end of the season. Improved nutrient availability may have

enhanced bud activation and tiller establishment, resulting in a denser crop stand. Similar observations have been reported in sugarcane production systems where improved plant nutrition increased tillering capacity and overall crop vigor (Castro *et al*., 2023).

Stalk diameter also increased under higher foliar fertilizer treatments. Thick stalks are generally associated with greater biomass accumulation and improved yield potential because they provide larger storage capacity for assimilates and sucrose. The increase in stalk diameter may have resulted from enhanced photosynthesis and more efficient translocation of carbohydrates to developing stalk tissues. These findings indicate that foliar nutrition contributed not only to increased vegetative growth but also to structural development of the cane crop.

Foliar fertilizer treatments were significant at Hippo Valley ($p < 005$) whereas highly significant at Triangle ($p < 0.001$) on nitrogen levels. At Hippo Valley, the highest nitrogen level was recorded under the 2% OEMFF treatment, with SPAD values 42.9 units. This treatment differed significantly from several other treatments, indicating a stronger influence on chlorophyll accumulation and leaf nitrogen content. The 5% OEMFF treatment also produced relatively high SPAD readings, while the 2% ROOT, 3% OEMFF, and 3% ROOT treatments recorded intermediate values. The control treatment maintained moderate nitrogen levels, suggesting that although the crop was able to access nutrients from the soil, foliar fertilization improved leaf nutrient status.

At Triangle, the highest SPAD reading was observed under the 5% ROOT treatment, with values close to 40 SPAD units. The 2% ROOT and 3% OEMFF treatments also recorded comparatively high chlorophyll levels, while the 5% OEMFF treatment produced the lowest SPAD values among all treatments at this site. These results suggest that sugarcane response to foliar fertilizers differed between the two locations, possibly due to variations in soil fertility, climatic conditions, and nutrient availability.

The statistical groupings indicated by the letter annotations show significant differences among treatments ($P \leq 0.05$). Treatments sharing similar letters were not significantly different, whereas treatments with different letters differed significantly in their effects on nitrogen levels. The

generally higher SPAD values observed under several foliar fertilizer treatments indicate that foliar nutrient application enhanced nitrogen uptake and chlorophyll synthesis.

SPAD chlorophyll readings are closely associated with plant nitrogen content because nitrogen is a major component of chlorophyll molecules. According to Marschner (2012), adequate nitrogen supply promotes chlorophyll formation, photosynthesis, and overall vegetative growth in crops. Increased chlorophyll concentration enhances light interception and photosynthetic efficiency, which ultimately contributes to improved crop growth and productivity.

The positive response observed in this study agrees with findings by (Muchow, *et al*., 1994) who reported that nitrogen availability strongly influences sugarcane canopy development and biomass accumulation. Similarly, (Kingston, 2014), noted that foliar nutrient application can rapidly correct nutrient deficiencies and improve crop physiological performance, particularly during active vegetative growth stages.

Overall, the results demonstrate that foliar fertilizer application positively influenced sugarcane nitrogen status at both sites, although the effectiveness of treatments depended on fertilizer concentration and environmental conditions.

5.2 Effect of Foliar Fertilizer Levels on Cane Yield

Cane yield is the ultimate indicator of crop performance because it integrates the cumulative effects of growth and development throughout the season. The results demonstrated that increasing foliar fertilizer concentration generally resulted in higher cane yields. This trend corresponded closely with improvements observed in plant height, stalk population and stalk diameter (Raposo *et al*., 2013)

The yield increase is enhanced by photosynthetic effectiveness and improved nutrient availability throughout crop development. Sugarcane requires substantial amounts of nutrients to support rapid growth and biomass accumulation (Raposo *et al*., 2013). Foliar fertilization may have supplied nutrients during critical growth stages, thereby reducing temporary nutrient deficiencies

and supporting sustained growth. As a result, plants were able to produce larger stalks and greater biomass, leading to increased yield.

The findings of the present study are consistent with those reported by (Raposo *et al*., 2013), who observed yield improvements following foliar fertilizer application in sugarcane. Their study reported yield increases ranging from approximately 11% to 21% depending on the fertilizer composition and timing of application. The authors concluded that foliar nutrient supplementation improved crop productivity through enhanced physiological performance and biomass production.

Recent studies have also shown that foliar fertilization improves nutrient recovery and nutrient-use efficiency in sugarcane. For example, (Andrade et al., 2024) found that foliar nitrogen application increased nitrogen accumulation and improved fertilizer recovery efficiency, ultimately enhancing crop nutrition and productivity.

The strong positive relationship observed between vegetative growth and yield supports established sugarcane production theory, which identifies stalk population, stalk size and stalk weight as the primary determinants of cane yield. Therefore, management practices that improve these growth characteristics are likely to contribute directly to increased productivity.

The overall growth response observed in this study agrees with the concept that foliar fertilizers complement conventional soil fertilization by supplying nutrients during periods when root uptake may be restricted by soil conditions or environmental factors. Consequently, the crop is able to maintain active growth and achieve greater biomass accumulation throughout the growing season.

5.3 Trends and Spatial Differences Between Hippo Valley Estate and Triangle Estate

One of the notable observations from this study was the presence of spatial differences between Hippo Valley Estate and Triangle Estate. Although treatment rankings were generally similar at both sites, differences were observed in the magnitude of growth and yield responses. Such variations are expected because crop performance is influenced by environmental conditions, soil

characteristics and management practices that differ from one location to another (ZSAES, Sugarcane Production, 2020).

Differences in soil fertility status may have affected nutrient availability and fertilizer-use efficiency between the two sites. Soil texture, organic matter content and water-holding capacity influence nutrient retention and uptake by plants. Variations in irrigation effectiveness and microclimatic conditions may also have contributed to differences in treatment responses. Sugarcane is highly responsive to environmental conditions, and even small differences in soil moisture or nutrient availability can influence growth and productivity (ZSAES, Zimbabwe Sugarcane Production Manual, 2024).

Despite these differences, the general trend remained consistent across both sites, with higher foliar fertilizer concentrations producing superior growth and yield responses. This consistency strengthens confidence in the findings and suggests that foliar fertilization has potential for wider application throughout the Zimbabwe Lowveld. The observed spatial variation therefore does not weaken the results but rather highlights the importance of site-specific nutrient management strategies in sugarcane production (Fageria *et al*., 2009).

5.4 Relationship Between Growth Parameters and Yield

A clear relationship was observed between vegetative growth and final cane yield. Treatments that produced taller plants, larger stalk populations and greater stalk diameters consistently achieved higher yields. This finding confirms that yield improvements were primarily driven by enhanced crop growth throughout the season.

Improved canopy development increases light interception and photosynthetic capacity, enabling the crop to produce and accumulate greater quantities of carbohydrates. These assimilates are subsequently transported to developing stalks where they contribute to biomass production and yield formation. Therefore, the superior yields recorded under higher foliar fertilizer concentrations were likely a direct consequence of improved physiological activity and vegetative development.

The results demonstrate that growth parameters can serve as reliable indicators of final productivity in sugarcane and highlight the importance of maintaining adequate nutrient availability throughout the crop cycle.

CHAPTER 6

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study was conducted to evaluate the effects of different foliar fertilizer concentrations on the growth, yield of sugarcane under irrigated conditions in the Zimbabwe Lowveld. The findings demonstrated that foliar fertilization has considerable potential to improve sugarcane performance when applied at appropriate concentrations.

The results showed that foliar fertilizer application positively influenced key growth parameters, including plant height, stalk population and stalk diameter. Treatments receiving higher foliar fertilizer concentrations generally produced more vigorous crop growth than lower concentrations and the untreated control. This indicates that foliar nutrient supplementation enhanced nutrient availability during critical growth stages, thereby promoting vegetative development and improving crop establishment.

The positive response observed in growth characteristics was reflected in final cane yield. Treatments that produced taller plants, higher stalk populations and thicker stalks also recorded higher yields, highlighting the strong relationship between vegetative growth and productivity in sugarcane. The findings suggest that foliar fertilization can serve as an effective supplementary nutrient management practice capable of enhancing cane production under Lowveld conditions.

The study also revealed differences in crop performance between Hippo Valley Estate and Triangle Estate. While treatment responses followed similar patterns at both locations, variations in the magnitude of response indicate that environmental conditions, soil properties and local management factors may influence the effectiveness of foliar fertilizer applications. Nevertheless, the consistent positive response observed across both sites suggests that foliar fertilization can be successfully integrated into sugarcane production systems throughout the Zimbabwe Lowveld.

Overall, the study confirms that foliar fertilizer application can be a valuable component of sugarcane nutrient management programs. When applied at suitable concentrations, foliar

fertilizers improve crop growth and yield while maintaining acceptable quality characteristics, thereby contributing to improved productivity and potentially greater economic returns for growers.

6.2 Recommendations for Sugarcane Production

Based on the findings of this study, the following recommendations are proposed:

1. Sugarcane growers should consider incorporating foliar fertilizer applications into their nutrient management programs as a supplement to recommended soil fertilization practices.
2. The foliar fertilizer concentration that consistently produced superior growth and yield performance 1500ml ROOT at Triangle and 900ml and 1500ml at Hippo Valley should be adopted under production conditions similar to those of the Zimbabwe Lowveld.
3. Foliar fertilizer applications should be timed to coincide with periods of active crop growth when nutrient demand is highest in order to maximize nutrient uptake and crop response.
4. Growers should continue to monitor soil fertility status and avoid relying solely on foliar fertilization, as sugarcane remains a high nutrient-demanding crop that requires balanced soil nutrition.
5. Estate agronomists and extension personnel should promote awareness of foliar nutrition as part of integrated nutrient management strategies aimed at improving productivity and fertilizer-use efficiency.

6.3 Recommendations for Future Research

The results of this study have highlighted several areas requiring further investigation:

1. Similar studies should be conducted over multiple growing seasons to evaluate the consistency of responses under varying climatic conditions.
2. Research should investigate the effects of foliar fertilizer application on ratoon crops, which constitute a major component of commercial sugarcane production.
3. Future studies should include leaf tissue nutrient analysis to improve understanding of nutrient uptake, translocation and utilization following foliar application.

4. Economic analyses should be undertaken to determine the cost-effectiveness of different foliar fertilizer concentrations and identify optimum profit-maximizing application rates.
5. Additional studies should evaluate interactions between foliar fertilization, irrigation management and soil fertility status in order to develop integrated nutrient management recommendations.
6. Research should also investigate varietal differences in response to foliar fertilizer application to determine whether specific recommendations are required for different sugarcane cultivars.

6.4 Final Remark

The challenge facing modern sugarcane production is not only to increase yields but also to improve the efficiency with which resources are used. The findings of this study demonstrate that foliar fertilization can contribute to this objective by enhancing crop growth and productivity under Zimbabwe Lowveld conditions. Although further research is required to refine recommendations and evaluate long-term effects, the results provide encouraging evidence that foliar nutrient supplementation can play an important role in improving the sustainability and profitability of sugarcane production systems.

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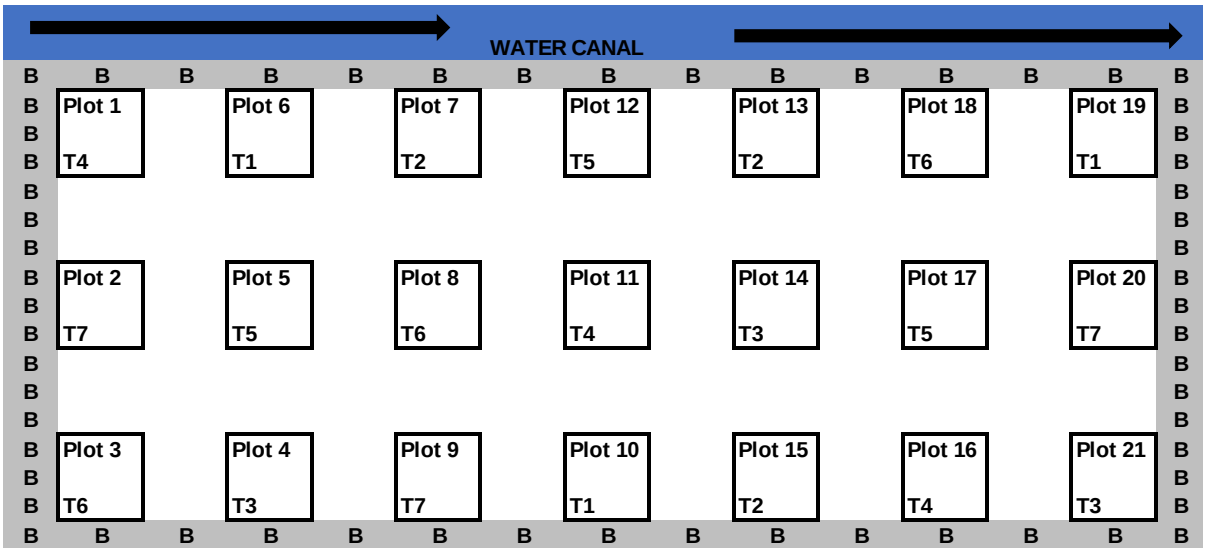
LIST OF APPENDICES

Appendix A: Field map



Appendix B: Anova Tables

HIPPO VALLEY YIELD

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
REP	2	720.4	360.19	0.6134	0.5576
FERTILIZER	2	382.1	191.06	0.3254	0.7284
CONCENTRATION	2	2926.3	1463.17	2.4918	0.1244
FERTILIZER: CONCENTRATION	2	940.1	470.06	0.8005	0.4717
Residuals	12	7046.3	587.19		

HIPPO VALLEY CANE HEIGHT AT HARVEST

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
REP	2	516.67	258.33	1.563	0.24931	
FERTILIZER	2	2173.02	1086.51	6.5738	0.01181	*
CONCENTRATION	2	836.11	418.06	2.5294	0.12117	
FERTILIZER: CONCENTRATION	2	86.11	43.06	0.2605	0.77491	
Residuals	12	1983.33	165.28			

TRIANGLE YIELD

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
REP	2	6264.7	3132.3	2.5684	0.1179
FERTILIZER	2	4745	2372.5	1.9454	0.1854
CONCENTRATION	2	3464.8	1732.4	1.4205	0.2795
FERTILIZER: CONCENTRATION	2	2628.1	1314.1	1.0775	0.3712
Residuals	12	14634.7	1219.6		

TRIANGLE CANE HEIGHT AT HARVEST

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
REP	2	50	25	0.439	0.65462	
FERTILIZER	2	768.25	384.13	6.7456	0.01088	*
CONCENTRATION	2	102.78	51.39	0.9024	0.43141	
FERTILIZER: CONCENTRATION	2	852.78	426.39	7.4878	0.00775	**
Residuals	12	683.33	56.94			

Growth Height Hippo Valley

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
REP	2	3923	1961	14.5296	1.88E-06
TREATMENT	6	15954	2659	19.6969	< 2.2e-16
DAS	9	907020	100780	746.552	< 2.2e-16
TREATMENT: DAS	54	8947	166	1.2274	0.172
Residuals	138	18629	135		

Growth Height Triangle

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
REP	2	2094	1047	8.9958	0.0002127	***
TREATMENT	6	14239	2373	20.3885	< 2.2e-16	***
DAS	9	926598	102955	884.5003	< 2.2e-16	***
TREATMENT: DAS	54	5000	93	0.7954	0.8301637	
Residuals	138	16063	116			

SPAD Hippo Valley

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
REP	2	3.92	1.962	0.4371	0.6468	
TREATMENT	6	64.63	10.771	2.3998	0.03087	*
DAS	9	636.8	70.756	15.7639	< 2e-16	***
TREATMENT: DAS	54	376.23	6.967	1.5522	0.02162	*
Residuals	138	619.41	4.488			

SPAD Triangle

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
REP	2	2.6	1.28	0.3174	0.7285345	
TREATMENT	6	108.6	18.1	4.5015	0.0003389	***
DAS	9	3262.5	362.5	90.1695	< 2.2e-16	***
TREATMENT: DAS	54	355.6	6.59	1.6381	0.0115494	*
Residuals	138	554.8	4.02			

Stalks Population Hippo Valley

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
REP	2	70.5	35.23	3.9674	0.02112	*
TREATMENT	6	62.7	10.45	1.177	0.32214	
DAS	9	23508.6	2612.07	294.1291	< 2e-16	***
TREATMENT: DAS	54	333.5	6.18	0.6954	0.93553	
Residuals	138	1225.5	8.88			

Stalks Population Triangle

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
REP	2	460.3	230.2	11.5791	2.25E-05	***
TREATMENT	6	1068.3	178	8.9576	2.92E-08	***
DAS	9	30382.3	3375.8	169.8353	< 2.2e-16	***
TREATMENT: DAS	54	977.1	18.1	0.9104	0.6467	
Residuals	138	2743	19.9			

Tiller Population Hippo Valley

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
REP	2	537	268.6	8.4712	0.0003388	***
TREATMENT	6	1541	256.8	8.0991	1.67E-07	
DAS	9	89770	9974.5	314.5458	< 2.2e-16	***
TREATMENT: DAS	54	2991	55.4	1.7469	0.0050483	
Residuals	138	4376	31.7			

Tillers population Triangle

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
REP	2	49	24.3	0.5128	0.5999	
TREATMENT	6	378	62.9	1.3294	0.2481	
DAS	9	139856	15539.6	328.3287	<2e-16	***
TREATMENT: DAS	54	1910	35.4	0.7473	0.8884	
Residuals	138	6531	47.3			