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Assessing The General Performance and Marketability of Onions Under Different Areas On S, Ca and Mg Supplementation in Kenya

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ABSTRACT

Onion (Allium cepa) is a vital crop serving both as a dietary staple and a source of income for farmers, with significant market benefits. However, its potential as a functional food is limited by poor growth, low yields, and reduced bioactive compounds, which diminish marketability. Therefore, this research aimed to investigate the effects of sulfur (S), calcium (Ca), and magnesium (Mg) supplementation on onion growth, yield, and bioactive compounds. A Randomized Complete Block Design (RCBD) was adopted across major onion production areas in Kenya: Kisaju-Kajiado and Koma-Machakos. Experimental treatments included varying levels and combinations of S, Ca, and Mg supplementation. Preliminary tests including Levene's, Kolmogorov-Smirnov, Durbin-Watson, Shapiro-Wilk, Cox and Snell, Nagelkerke, and McFadden tests were performed to assess normality, linear and multinomial regression, and collinearity using SPSS software. Analysis of Variance (ANOVA) was performed, and where significant differences were found, Post Hoc tests were conducted. Significant differences were observed, leading to rejection of the null hypothesis. The treatment with S, Ca, and Mg at 40 kg/ha significantly produced the best performing onions as well as market returns on the 'Red Creole' onion variety. Kisaju-Kajiado was also found to be the optimal location for onion production, with high return-on-investment profits. This research is recommended for farmers intending to improve onion performance and marketability. The study concludes that S, Ca, and Mg supplements significantly improve onion growth, yield, and bioactive compounds, thereby increasing marketability.

Keywords: Bioactive compounds, growth, yield, bioactive compounds, Marketability.

INTRODUCTION

Onion production is faced with poor growth in the field, as well as low yields which end up affecting the general performance of the crop in different areas leaving a huge gap for most farmers (Tuula et al., 2014). There is also need to better the performance of the crop by improving its growth traits, increasing the yields since it is a source of livelihood to most farmers therefore increasing its market value as well as return profits (Muhammad et al., 2024). With focus on sustainability and quality food, there is need to boost onion nutrition in order to achieve food security (Xavier et al., 2026).

Therefore, as was the objective of the research, supplementation of S, Ca and Mg aimed to address the challenges as other studies have also proven the method effective, for example (Baek et al., 2020).

Research Objective

To assess the general performance as well as marketability of onions under different areas on S, Ca and Mg supplementation.

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Research Hypothesis

$H_0$5: The general performance as well as marketability of onions under different agro-climate areas has no significant difference on S, Ca and Mg supplementation.

Delimitation

This research only confined itself to the main aim, "Assessing the General Performance and Marketability of Onions Under Different Areas on S, Ca and Mg Supplementation in Kenya", and did not seek to go beyond the subject.

Assumptions of the Study

This research assumed that all experimental plots were uniformly identical and any variations assumed to be random and natural. The variance of the errors was assumed to be constant across all treatment levels, as well as the independence of observation that all extraneous and external factors such as weeding, watering and other management factors were uniformly applied so that only the independent variables affected the outcome to ensure constant management.

LITERATURE REVIEW

The existing literature on nutrient supplementation in onion production reveals consistent evidence that sulfur, calcium, and magnesium play important roles in onion growth and quality. Studies by Nasim et al. (2023) and Shreya et al. (2020) have demonstrated significant effects of sulfur application on growth rate. Hussein and Ridha (2021) reported that spraying onions with organic sulfur and hydrogen peroxide led to significant improvements in plant height (up to 45 cm), leaf width (up to 1.5 cm), and yield weight (up to 250 g).

However, these studies were conducted in specific contexts (West Bengal, India, and Iraq) and did not examine the combined effects of sulfur, calcium, and magnesium supplementation across different agro-climatic zones in Kenya. The present study addresses this gap by examining the combined effects of these nutrients on onion growth, yield, and marketability in two distinct Kenyan agro-climatic zones. Furthermore, while previous research has focused primarily on agronomic outcomes, this study integrates economic analysis through cost-benefit assessment, providing practical guidance for farmers seeking to optimize their returns.

Onion contains bioactive compounds such as organosulfur compounds, flavonoids, ascorbic acid, and carbohydrate probiotics which have diverse health benefits in the human body (Tuula et al., 2014).

According to Glenda et al. (2025), the authors reports no significant differences in the establishment percentages between red, yellow and white onions; reporting onion establishment percentages to be around 700,000 to 800,000 plants/ha, the difference only emerging on the yield where red onion had the highest with 16 to 70tons/acre, followed by yellow with 15 to 25tons/acre, then white with 15 to 20 tons/acre.

In an experiment by Amin et al. (2020) where they treated onions with different levels of sulfur and magnesium, they report to discover that treating of onions with magnesium was found promising in respect to plant height, number of leaves per plant, bulb weight, bulb diameter as well as bulb yield/ha.

A "perfect" onion plant can sprout and average of 13 green leaves per plant depending on the variety, growing conditions as well as environment (Chala et al., 2022). When grading and sorting, onion can yield 2.5 to 3.5cm bulb widths for small size, 4.5-5.5cm for medium sized-bulbs and 6.5 to 8.5cm for large-sized bulbs (Dubey & Singh, 2021). While the study indicates gap for increasing the establishment percentage of onions, onion height this study aims to vary the same across different areas for performance comparison.

Mzwakhile et al. (2024) in their report indicates that sulfur application increased instances where bulb splits were recorded at rates of 1.6% on the levels increment. A gap was evident in the study on the increment forcing more study to be done on how to reduce the splitting instances as was the aim of this study. These splitting cases reduce the performance of onions in the field affecting the market as well by lowering the yields.

Petropoulos et al. (2017) in his report on a SHEP PLUS analysis, onions planting have projected revenue of KSh 600,000 to KSh 2,000,000. A report published by Kenya Agricultural and Livestock Research Organization [KALRO] (2024) reports that varieties such as Bombay Red and Red Creole varieties are high yielding and profitable and with proper management practices, yield and average of 15,000 to 25,000/acre and with profit margins exceeding KSh 1 million.

METHODOLOGY

Study Area

The research was conducted from December-May in two sites namely: Kisaju-Kajiado County, which is a which is a warm, dry, semi-arid climate (classification Cwb) with an annual optimum daily temperature of 15 – 25^{0}C and average annual precipitation of about 101.01 millimeters, which is about 3.98 inches of precipitation with a total of 188.92 rainy days with 51.76% probability of raining, while the second experiment in Koma-Machakos County, which is a Tropical wet and dry or savanna climate receiving average temperature of 18.9°C and about 912 millimeters, which is about 35.9 inches of precipitation with an average of 147 rainy days annually.

Kisaju is located south of Isinya area approximately 1^o 37'13" S latitude and 36^o 49'32" S E longitude while Koma is located 63 km East of Nairobi along Kangundo road with primary coordinates of -1.29601, 37.21879. Kisaju site area is characterized by well-drained alluvial soils giving them a loose rich ash grey-brown color while Koma area on the other hand is characterized by sticky heavy cracking black cotton soils giving them a dark color, all suitable for onion production.

Experimental Design and Research Procedure

Field Experimental research due to treatments of Sulfur, Calcium and Magnesium administered to "Red Creole", "Texas Grano" and "White Lisbon" onion varieties at different levels to measure the effects on the growth, yield and bulb development with a control (T1). RCBD was used with 18 random treatment combinations of the supplements replicated into three blocks, raised 15cm high and 30cm apart, making a total of 54 plots per site.

Treatments, Combinations and Application Rates

- T1=S+Ca+Mg@0kg/ha
- T2=S+Ca+Mg@30kg/ha
- T3=S+Ca+Mg@40kg/ha
- T4=S+Ca+Mg@60kg/ha
- T5=S@40kg/ha
- T6=Ca+Mg@30kg/ha

This is on 1x 1 M plots size with 1 meter spacing between blocks and 30cm within plots in blocks with a total population of 810 individuals per site. Sulfur was applied as ammonium sulfate (21% N, 24% S), calcium as calcium nitrate (19% Ca, 15.5% N), and magnesium as magnesium sulfate (10% Mg, 13% S).

All supplements were applied as soil drenches in three split applications: at transplanting, at 30 days after transplanting, and at 60 days after transplanting. Soil samples were collected prior to planting from each site at a depth of 30 cm using a zigzag sampling method. Samples were analyzed for pH, organic matter, total nitrogen, available phosphorus, exchangeable potassium, calcium, magnesium, and sulfur.

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Table 1 Experimental Treatments, Levels and Treatment Combinations

Treatments

Levels

	T_1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
RC	RCT_1	RCT_2	RCT_3	RCT_4	RCT_5	RCT_6
TG	TGT_1	TGT_2	TGT_3	TGT_4	TGT_5	TGT_6
WL	WLT_1	WLT_2	WLT_3	WLT_4	WLT_5	WLT_6

Plot Layout

Table 2 Plot Layout Displaying Random Treatments and Treatment Combinations

Blocks

Treatment Levels

BLOCK A	**BLOCK B**	**BLOCK C**
WLT_1	RCT_6	WLT_1
WLT_6	WLT_5	RCT_3
TGT_5	RCT_5	TGT_6
RCT_4	TGT_1	WLT_2
WLT_2	RCT_2	RCT_4
RCT_6	WLT_6	RCT_6
TGT_6	TGT_5	RCT_1
TGT_4	TGT_6	RCT_2
RCT_5	RCT_4	TGT_3
TGT_3	TGT_4	TGT_5
RCT_3	TGT_2	WLT_4
WLT_1	WLT_4	TGT_4
RCT_1	RCT_1	WLT_5
WLT_2	WLT_1	WLT_1
WLT_4	RCT_3	WLT_6
RCT_5	TGT_3	TGT_2

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TGT_3	WLT_3	TGT_3
TGT_2	TGT_2	RCT_5

Field Activities

Soil samples, 12 inches deep, approximately 30cm deep and mixed to one heap, were randomly collected using zigzag method, well labelled and packed in small cartons and sent to the lab for analysis before planting. Plots measuring 10x30m were identified and prepared for the experiment layout. Nursery preparation and seed sowing 1cm deep and row spacing of 20cm apart was done and nursery divided into 3 sections containing the trial varieties: "Red Creole (RC)", "Texas Grano (TG)" and "White Lisbon (WL)" respectively each containing 10 lines of seeds and a mulch installed. The seedlings were transplanted when they had fully emerged. The seeds were certified and of good quality with a germination percentage of almost 100% for all the varieties.

Figure 1 Nursery Beds Preparation

Before transplanting in the field, following the RCBD experimental design, the fields were partitioned into plots of 18 and replicated to form three blocks namely A, B and C in both sites as per the experimental design and layout. During blocks plots preparation, raised beds of 15cm high and 30cm apart trenches were created where transplanting was done on 1x1m square plots each containing a plant population of 15 heads per hill. Seedlings were planted approximately about 1cm deep into the soil in a spacing of 50x15cm apart and watering observed.

Figure 2 RCBD Plots

Onion bulbs were harvested by uprooting when 75% of the leaves were seen to be dry and bent. Protected curing was then initiated in the open sun for the bulb shoots to completely dry where sorting and grading were further done after all required data was taken, and samples from each plot sent to the lab for composition analysis.

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During harvesting, data from plant samples were randomly selected from the entire population and used in the analysis and tests. Simple random probability sampling technique was used, where each member (n) of the population (N) was given an equal chance of selection by drawing numbers out of the 15 from each plot to act as a representation of the rest of the population. The selection put into consideration of the population integer per plot independently, that is, 10 plants from a scale of 1-15 plants, across all the 18 plots per block, translating to 540 individuals in the entire plot of 810 individuals. The formula below as proposed by Nikhil et al. (2024) was used in selection of the samples from the population:

$$k = \frac{N}{n}$$

:

$$\text{where, k} = \text{sampling interval, N} = \text{population size and n} = \text{sampling size.}$$

RESULTS AND DISCUSSIONS

Preliminary tests such as normality test were performed and ensured that the data followed normal distribution before analysis. Linear as well as multinominal regression analysis were also done with collinearity, Durbin-Watson residual tests and it was ensured that strong relationships existed between the independent/treatment variables and the test/dependent variables. Chi-square analysis was also performed on the same and it was confirmed that there was a likelihood of the independent variables predicting the outcomes of the dependent variables and that the models were suitability for conducting the tests. After data passed pretests, T-test analysis was performed as well as ANOVA mean group difference analysis at 0.05 significance level, and where significant differences were found present, LSD and Duncan post-hoc analysis was conducted.

Analysis on General Performance of Onions Under Different Agro-Climate areas Under Different S, Ca and Mg Supplements

This section presents the general description of the respective dependent outcome variables of the study as affected by the different independent treatment variables of Sulfur, Calcium and Magnesium, including their combinations at different levels. ANOVA as well as MANOVA tests were performed to check for significance differences in and within the mean groups and the results were summarized and presented in form of tables and graphs in order of the objective variables indicators: site 1 vs site 2 general onion performance and production, to determine the general overall best site, suitable treatment as well as variety. Post-hoc test was performed where significant differences were observed as a result of the ANOVA tests to check specifically what brought about the differences and to what extent. MANOVA test was essential to check the complex mixed interaction effects within the variables.

Figure 3 A Legacy Dialog Graph on the General Performance of Onions by Site

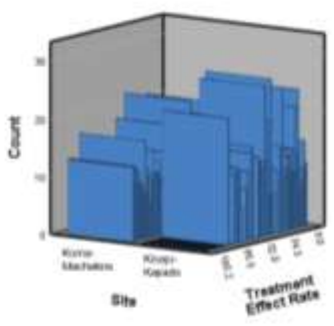

Figure 3 displays legacy dialog means graph of the different supplementation treatments as well as the variety on the general performance of onions across the different study sites to determine the best site in relation to the general production and marketability of onions.

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As displayed, onions grown in Kisaju-Kajiado had a good significant general performance and production in relation to the yield and bioactive compounds. The sight was significantly evaluated for having the best growth, yield and bulb development of onions, producing onions with the highest bioactive compound, producing onions with the best post-harvest and storage quality as well as produced quality onions that fetched good market returns on analysis, when boosted with S, Ca and Mg supplements in the field. This report indicates that for farmers intending to invest in onion production, Kisaju area in Kajiado is significantly ideal for production of good quality market onions with increased average returns per unit as supported by Briggx et al. (2026).

Table 3 MANOVA Tests on the General Comparisons of Onions in the Different Sites

Multivariate Tests[a]						
Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.999	43129.632[b]	12.000	641.000	.000
	Wilks' Lambda	.001	43129.632[b]	12.000	641.000	.000
	Hotelling's Trace	807.419	43129.632[b]	12.000	641.000	.000
	Roy's Largest Root	807.419	43129.632[b]	12.000	641.000	.000
Site	Pillai's Trace	.496	52.620[b]	12.000	641.000	.000
	Wilks' Lambda	.504	52.620[b]	12.000	641.000	.000
	Hotelling's Trace	.985	52.620[b]	12.000	641.000	.000
	Roy's Largest Root	.985	52.620[b]	12.000	641.000	.000
a. Design: Intercept + Site						
b. Exact statistic						

Table 4 indicates the multivariate analysis on the groups means variances of the different independent variables of site, supplements and variety done on the general performance of onions under the different agro climates in relation to the S, Ca and Mg supplement treatments, and their significant p value levels, testing if there were significant differences in variances or not. In MANOVA, four primary multivariate test statistics; Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root were used to evaluate whether the independent categorical groups differ collectively across multiple continuous dependent variables, and a significant p-value ($p < 0.05$) across these metrics means the respective groups have different combined mean profiles.

Therefore, from the MANOVA table results, according to Pillai's Trace test we can conclude that general onion performance was significantly dependent on the site selection for onion production. The test was chosen as the main and safest default choice because it is the most robust and powerful test against violations of statistical assumptions like unequal group sizes or heterogeneous covariance matrices, also resulting to higher value means and stronger effects. This was indicated by the significance level value of $p < .05$. What this means is that if you want to produce onions of good quality and market value, it is very essential to consider the best site selection before engaging. This is because, regardless of the supplements you put in place to boost your production, the basics must be followed on where you are doing your farming at, and that is the best suitable site for increased optimum production.

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Table 4 MANOVA Test on the General Performance of Onions in the Different Sites

Pairwise Comparisons				
Dependent Variable	(I) Site	(J) Site	Mean Difference (I-J)	Sig.[b]
Establishment_%	Kisaju-Kajiado	Koma-Machakos	.721*	.000
	Koma-Machakos	Kisaju-Kajiado	-.721*	.000
Onion Height	Kisaju-Kajiado	Koma-Machakos	11.356*	.000
	Koma-Machakos	Kisaju-Kajiado	-11.356*	.000
Number of Shoots	Kisaju-Kajiado	Koma-Machakos	-.615*	.005
	Koma-Machakos	Kisaju-Kajiado	.615*	.005
Gross Market Prices per kg	Kisaju-Kajiado	Koma-Machakos	81.442*	.000
	Koma-Machakos	Kisaju-Kajiado	-81.442*	.000
Based on estimated marginal means				
*. The mean difference is significant at the .05 level.				
b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).				

Table 5 indicates the multivariate specific site pairwise comparisons of the respective output variables data on the group mean variance of the different independent variables of site, supplements and variety done on the onion gross market prices per kg, and their significant p value levels, showing significant differences.

The table shows that for onion establishment percentage, height, number of shoots, bulb/shoots splitting and the average gross market prices per kg were statistically significantly different between both sites indicated by p values of $p < .05$. However, the onion bioactive compounds had no statistically significant differences among both sites with p values $p > .05$ except for the organosulfur levels which proved to show statistically significant differences among the sites indicated by p value of $p < .05$.

The superior performance of onions in Kisaju-Kajiado compared to Koma-Machakos can be attributed to several factors. The well-drained alluvial soils of Kisaju, with their loose, ash grey-brown color, may provide better aeration and nutrient availability compared to the heavy cracking black cotton soils of Koma-Machakos. Additionally, the climatic conditions in Kisaju, with lower rainfall and higher temperatures, may be more suitable for onion production, which generally prefers well-drained soils and moderate moisture conditions. The significant interaction between site and treatment effects suggests that the response to nutrient supplementation varies depending on soil and climatic conditions. This finding is consistent with the broader literature on site-specific nutrient management, which emphasizes the importance of tailoring fertilizer recommendations to local conditions. The higher net profitability of red onions compared to yellow onions, despite lower gross market prices, reflects the market preference for red onions due to their higher bioactive compound content and perceived health benefits. This finding has important implications for farmers' variety selection decisions, suggesting that red onions may offer higher returns despite potentially lower yields or prices.

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Establishment Percentage

Figure 4 A Summary Graph on Onion Treatment Effects on the Establishment Percentage

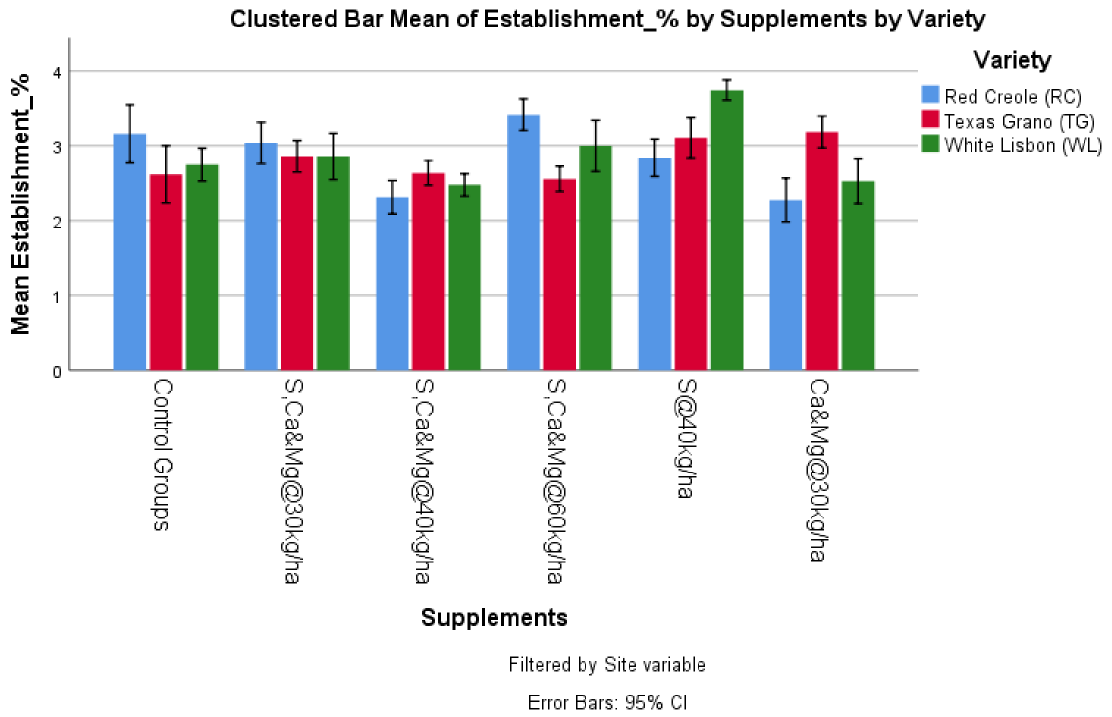

Figure 4 displays clustered bar means graph of the different supplementation treatments as well as the variety on the establishment percentage of onions across the different study sites. The figure as well includes error bars to display the level of variances across the mean groups of the data. The data was given scale intervals based on the establishment percentage levels as: excellent (90 to 100%), good (80 to 89%), fair (70 to 79%) and poor (< 70%). The scale intervals were calculated and assigned in relation to the total number of plants at the time of harvesting.

According to the results, Sulfur application at 40 kg/ha on "White Lisbon" spring onions significantly showed the lowest field establishment percentage with close to 3.5%, while a combination of S, Ca and Mg at 40 kg/ha and Ca and Mg at 30 kg/ha significantly had the highest field establishment percentage with close to 2% respective in both sites. Significant differences were observed within the variety groups as well. 1 represented 90 to 100% establishment, 2 represented 80 to 89%, 3 represented 70 to 79% of the total growth and 4 represented > 70% plants growth. This study therefore although fails to agrees with Glenda et al. (2025) who reported red onions to producing more average yields followed by yellow onion then white, it strongly agrees with them that despite the differences in establishment, they have a very slight to zero margin.

According to the results when compared to the control treatment, all the supplement treatment levels as well as combinations significantly proved increased establishment percentages and reached maturity when compared to the control, except for S, Ca and Mg at 40 kg/ha which had a lower establishment percentage. Therefore, S, Ca and Mg supplementation were found essential to promoting the onion establishment percentage for the onions to reach maturity. It is recommended to use any of the onion varieties at any of the levels for increased establishment percentages to increase production and marketability of the produce except for treatment of S, Ca and Mg at 40kg, which resulted to reduced establishment percentages. However, despite the low percentages on S, Ca and Mg at 40kg, all the supplement treatments significantly had a fair establishment percentage of 70 to 79% with all the varieties significantly recording good establishment level of 80 to 89% as well.

Table 5 T-test on Treatment Effects on the Establishment Percentage of Onions

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Independent Samples Test								
		t-test for Equality of Means						
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
Site	Equal variances assumed	2.513	504	.012	.117	.047	.026	.209
	Equal variances not assumed	2.674	255.811	.008	.117	.044	.031	.204
Supplements	Equal variances assumed	3.087	504	.002	.535	.173	.195	.876
	Equal variances not assumed	2.776	191.383	.006	.535	.193	.155	.916
Variety	Equal variances assumed	-3.570	504	.000	-.282	.079	-.438	-.127
	Equal variances not assumed	-3.194	190.042	.002	-.282	.088	-.457	-.108

Table 6 indicates the t-test done on the establishment percentage means of groups of the different independent variables of site, supplements and variety, and their significant p value levels testing if there were significant differences in variances or not.

On the test, significant differences were present on the establishment percentages across the different treatment levels of sites and supplementation and the establishment percentage. The significant differences were indicated by the level of significance difference of $p < .05$.

The site as found to play a part in onion height significant differences according to the experiment could be argued to be true since the two sites were completely different in their climatic characteristics as well. This might have influenced the treatments applications at different ways, as well as the varieties, which might have also adapted differently to the areas in response to the supplementation, thus bringing the variations. This is to keep note of the differences in soil properties in the areas as well.

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Onion Height

Figure 5 A Summary Graph on Treatment Effects on Onion Height

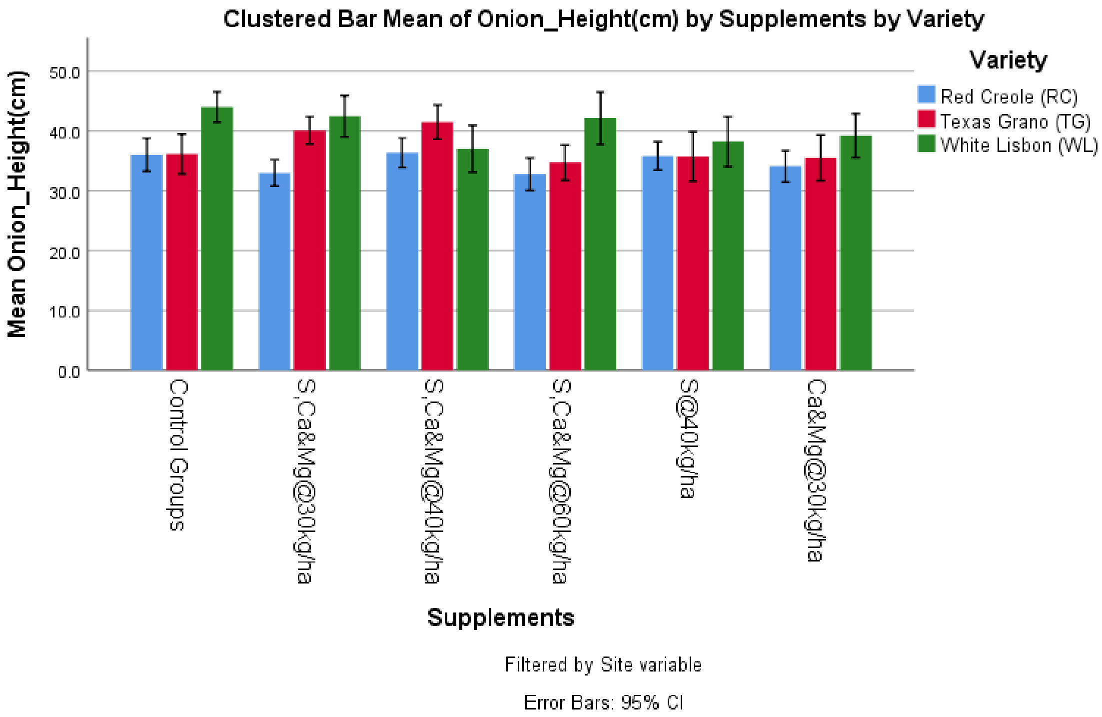

Figure 5 displays clustered bar means graph of the different supplementation treatments as well as the variety on the height of onions across the different study sites. The figure as well includes error bars to display the level of variances across the mean groups of the data.

As displayed by the graph results, the different supplement treatments played a significant role in the differences in the average heights of onions. For example, on the control treatment 1, where no treatments were applied, the highest onion height was recorded on “white Lisbon” onions whereas the lowest average heights were recorded when S, Ca and Mg were applied at 30 kg/ha and at 60 kg/ha.

However, despite the significant differences in supplement treatments, the variations observed withing the varieties themselves were minimal across all the treatments. This research strongly agrees with Amin et al. (2020) who stated that onions can grow to heights of up to 15cm to 45 cm from the ground regardless of the variety as shown in the graph above. The research however partially agreed with Hussein and Ridha (2021) in their study as well found that spraying onions with organic sulfur as well as hydrogen peroxide led to highest significance in plant height.

The minimal variations on the onion height across the varieties as a result of the supplementation treatments could be argued to be true as onion heights are not much resulted from modifications in the soil, but are as a result of genetic traits of the plant since there was sufficient sunshine in the sites and no shading or hindrance from extraneous variables was present. In order to achieve taller plants, it was found appropriate not to apply any treatments of S, Ca nor Mg at any level (0 kg/ha).

However, during the data collection, it was observed that the taller the plat was, the smaller the bulbs were, which ultimately significantly affected the bulb diameter as well as the weights for bulb onion varieties all together. On the contrary, for farmers intending to grow onions for scallions, the treatment was found best and appropriate giving a mean of 39.6 cm on “White Lisbon”, which is a scallion variety, as it significantly led to increase in heights, which boosted the average biomass measure for increased marketability of their produce. This ends up reducing the marketability of onions.

Table 6 ANOVA Analysis on Treatment Effects on the Heights of Onions

Univariate Analysis of Variance					
Tests of Between-Subjects Effects					
Dependent Variable: Onion Height					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	59079.648[a]	35	1687.990	14.823	.000
Intercept	1435667.811	1	1435667.811	12607.059	.000
Site	38835.489	1	38835.489	341.027	.000
Supplements	1444.131	5	288.826	2.536	.027
Variety	6675.828	2	3337.914	29.311	.000
Site * Supplements	2553.448	5	510.690	4.485	.000
Site * Variety	3748.401	2	1874.200	16.458	.000
Supplements * Variety	987.804	10	98.780	.867	.564
Site * Supplements * Variety	1769.164	10	176.916	1.554	.115
Error	125265.901	1100	113.878		
Total	184345.550	1135			
a. R Squared = .320 (Adjusted R Squared = .299)					

Table 7 indicates the univariate analysis group mean variance of the different independent variables of site, supplements and variety done on the onion height, and their significant p value levels, testing if there were significant differences in variances or not.

According to ANOVA analyses conducted on average onion height as a result of the treatments applied, significant differences were recorded in their means. Significant differences were recorded in the various respective sites and within the varieties on the onion heights. Significant differences were also recorded among the supplements application in the respective sites and among the varieties in the respective sites as well on the onion heights. This was indicated by level of significance difference of $p < .05$ level of significance. However, on the contrary, no significant differences were recorded within the supplements themselves towards the onion heights as they had a level of significance difference of $p > .05$ at the level of significance. The supplements and varieties combined effect on the heights on onions proved no significant difference as well with p values of $p > .05$ level. a combine effect of site*supplement*variety did not prove any significant difference as well on the onion heights with a p value of $p > .05$ level of significance.

This could be argued to be true since the variety has to have a significant influence on the onion height since all the varieties have different genetic make-ups; as well, the site could as well result to significant differences due to the variations in temperatures which influence differently the growth of onions; however, on the contrary, the supplements alone could not boost the heights.

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Table 7 Post Hoc Analysis on Supplement Effect on the Heights of Onions

Homogeneous Subsets					
	Supplements	Means	N	Subset 1	Subset 2
Duncan[a,b,c]	Ca& Mg at 30 kg/ha	36.3	192	36.260	
	S at 40 kg/ha	36.4	180	36.357	
	S, Ca& Mg at 60 kg/ha	36.5	188	36.452	
	S, Ca& Mg at 40 kg/ha	38.7	207		38.736
	S, Ca& Mg at 30 kg/ha	38.7	189		38.750
	Control Groups	39.6	180		39.593
	Sig.			.871	.466
Means for groups in homogeneous subsets are displayed. Based on observed means. The error term is Mean Square (Error) = 113.878.					
a. Uses Harmonic Mean Sample Size = 188.914.					
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.					
c. Alpha = .05.					

Table 8 represents Duncan Post Hoc analysis test performed on the onion heights where significant differences were recorded to determine which specific treatments caused the variances and at what levels on the supplements.

The significant mean differences in onion heights were recorded within all supplement treatment groups as no value fell in the same subset groups. This result indicates that regardless of the onion planting region or site and the variety in use, different levels of S, Ca and Mg significantly affect the heights of onion in relation to the point time of measure.

Table 8 Post Hoc Analysis on Variety Effect on the Heights of Onions

Multiple Comparisons Dependent Variable: Onion Height									
			(I) Variety	(J) Variety	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	95% Confidence Interval

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	Means	N						Lower Bound	Upper Bound
LSD	34.7	387	Red Creole	Texas Grano	-3.002*	.7623	.000	-4.498	-1.506
				White Lisbon	-6.159*	.7860	.000	-7.701	-4.617
	37.7	397	Texas Grano	Red Creole	3.002*	.7623	.000	1.506	4.498
				White Lisbon	-3.157*	.7813	.000	-4.690	-1.624
	40.9	352	White Lisbon	Red Creole	6.159*	.7860	.000	4.617	7.701
				Texas Grano	3.157*	.7813	.000	1.624	4.690
		Based on observed means. The error term is Mean Square (Error) = 113.878.							
		*. The mean difference is significant at the .05 level.							

Table 9 represents LSD Post Hoc analysis test performed on the onion heights where significant differences were recorded to determine which specific treatments caused the variances and at what levels on the varieties.

As per the results, significant differences in average onion heights were also observed within all onion varieties in the experiment as a result of the supplement treatments applied regardless of the site. This was indicated by asterisks in the mean differences within the varieties` means as a result of the supplementation.

Number of Shoots

Figure 6 A Summary Graph on Onion Treatment Effects on Number of Shoots

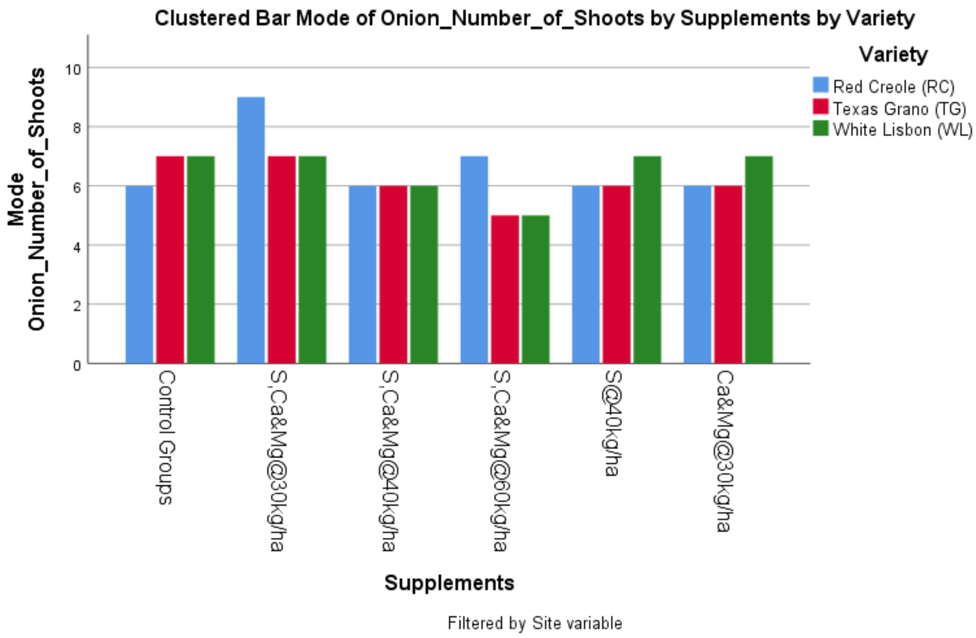

Figure 6 displays clustered bar means graph of the different supplementation treatments as well as the variety on the number of shoots of onions across the different study sites. The figure as well includes error bars to display the level of variances across the mean groups of the data.

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There were significant differences in the number of onion shoots in response to the supplementation treatments on the onion varieties based on the results presented. The average differences were significant nonetheless since the variations were minimal within the treatment groups. "Red Creole" red onion variety had the highest number of shoots when a combined treatment of S, Ca and Mg was applied at 30 kg/ha. Least number of shoots were recorded where a combined treatment of S, Ca and Mg was applied at 60 kg/ha on "Texas Grano" and "White Lisbon" varieties. Higher number of leaves were significantly reported when the combined treatments were applied at 60 kg/ha and at 30 kg/ha respectively. However, beyond application rates at 30 kg/ha, the treatments were found detrimental except for single treatment applications of Sulfur at 40 kg/ha and Ca and Mg at 30 kg/ha where the number of shoots were shown to grow to moderate average heights to the control. Also, in an experiment by Dubey and Singh (2021) where they treated onions with different levels of Sulfur and Magnesium, they report to discover that treating of onions with magnesium was found promising in respect to number of leaves per plant. Foliar Magnesium containing treatments showed significant increase in onion number of shoots due to its flushing effect, as well as Sulfur treatment which also boosts the shoots growth.

For onion farmers interested in increased number of leaves, S, Ca and Mg at 0kg/ha, S, Ca and Mg at 30kg/ha and Ca and Mg at 30 kg/ha were significantly found appropriate resulting to 7 shoots per plant on "White Lisbon" scallion variety. This is fully supported as farmers involved in bulb onions are not interested on the shoots which did not prove best in relation to them as compared to the scallion onion. However, there was no much need of investing in inputs towards the supplements for the number of onion shoots as no supplement treatment proved better.

Table 9 ANOVA Analysis on Treatment Effect on the Number of Onion Shoots

Univariate Analysis of Variance					
Tests of Between-Subjects Effects					
Dependent Variable: Onion Number of Shoots					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	692.128[a]	35	19.775	2.789	.000
Intercept	47052.975	1	47052.975	6635.123	.000
Site	28.531	1	28.531	4.023	.045
Supplements	121.744	5	24.349	3.434	.004
Variety	206.158	2	103.079	14.536	.000
Site * Supplements	79.630	5	15.926	2.246	.048
Site * Variety	121.264	2	60.632	8.550	.000
Supplements * Variety	55.832	10	5.583	.787	.641
Site * Supplements * Variety	63.921	10	6.392	.901	.531
Error	7474.441	1054	7.092		

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Total	62844.000	10 90			
Corrected Total	8166.569	10 89			
a. R Squared = .085 (Adjusted R Squared = .054)					

Table 10 indicates the univariate analysis group mean variance of the different independent variables of site, supplements and variety done on the number of shoots, and their significant p value levels, testing if there were significant differences in variances or not.

Based on the results, onion number of shoots had a significant difference from variations of the site difference, the supplement treatments, the variety as well as the site combinations. This was indicated by p values of $p < .05$ respectively. The treatment combinations of supplement and variety and site, supplement and variety however, did not show any significant differences in their means, indicated by p values of $p > .05$ respectively.

Table 10 Post Hoc Analysis on Supplement Effect on the Number of Onion Shoots

Homogeneous Subsets						
Onion Number of Shoots						
	Supplements		N	Subset		
		Mode		1	2	3
Dunca [a,b,c]	S, Ca& Mg at 60 kg/ha	5	178	6.47		
	Ca& Mg at 30 kg/ha	7	185			7.61
	Sig.			.080	.307	.068
Means for groups in homogeneous subsets are displayed. Based on observed means. The error term is Mean Square (Error) = 7.092.						
a. Uses Harmonic Mean Sample Size = 181.418.						
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.						
c. Alpha = .05.						

Table 11 represents Duncan Post Hoc analysis test performed on the onion number of shoots where significant differences were recorded to determine which specific treatments caused the variances and at what levels on the supplements.

These significant difference in number of onion shoots means as per the results was brough about by supplement treatments 4 and 6 across the subsets as there were no overlaps or repeated values along the subset groups.

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Table 11 Post Hoc Test of Variety Effect on the Number of Onion Shoots

Multiple Comparisons									
Dependent Variable: Onion Number of Shoots									
	Mode	N	(I) Variety	(J) Variety	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
LSD	6	372	Red Creole						
				White Lisbon	-.94*	.201	.000	-1.33	-.54
	6	384	Texas Grano						
				White Lisbon	-1.02*	.199	.000	-1.41	-.62
	7	334	White Lisbon	Red Creole	.94*	.201	.000	.54	1.33
				Texas Grano	1.02*	.199	.000	.62	1.41
Based on observed means. The error term is Mean Square (Error) = 7.092.									
*. The mean difference is significant at the .05 level.									

Table 12 represents LSD Post Hoc analysis test performed on the onion number of shoots where significant differences were recorded to determine which specific treatments caused the variances and at what levels on the varieties.

As per the means from the results, significant differences were recorded between “Red Creole” variety and “White Lisbon variety and between “Texas Grano” and “White Lisbon” as a result of the supplement treatments application. This was indicated by the asterisks in the mean differences. The report also indicated that means in “Red Creole” were lesser than means in “White Lisbon” group as indicated by the negative.

This could be argued to be true since different onion varieties have different growth traits including the onion number of shoots in comparison.

Shoots Width

Figure 7 A Summary Graph on Treatments Effects on Onion Shoots Width

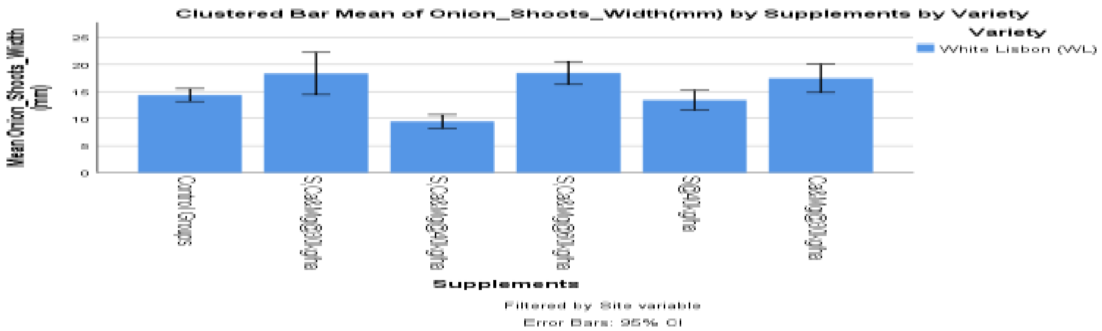

Figure 7 displays clustered bar means graph of the different supplementation treatments as well as the variety on the scallion onion shoots width across the different study sites. The figure as well includes error bars to display the level of variances across the mean groups of the data.

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As the results indicate; application of supplements at rates of 30 and 60 kg/ha of both S, Ca and Mg showed highest onion shoots width with close to 20mm in diameter: the least width was recorded in the treatment 40 kg/ha. these results were varied against the control treatment 1 where 0 application was made and the control recoded a moderate average onion shoot width to the other varieties. The graph proved significant differences in the means as a result of the supplements treatments administration. This research experiment is in strong agreement with Chala et al. (2022) in their study, who found that spraying onions with organic sulfur as well as hydrogen peroxide led to highest significance in leaf length.

This was demonstrated in the graph where application rates of sulfur at 30 kg/ha, 60 kg/ha significantly showed increased size of the shoots width. The onion shoots width response to the different supplementation treatments could be argued to have been attributed to the magnesium and calcium foliar sprays as well which resulted to huge biomass sizes especially for the scallion shoot varieties. All the supplement levels responded positively increasing the onion shoots width except for levels where S was applied at 40 kg/ha. this suggests that excess levels of S application led to negative impacts on the onion shoots width for the scallion onion varieties. It is recommended to use S, Ca and Mg at 30 kg/ha or 60 kg/ha for highest shoots width on “White Lisbon” scallion variety, resulting to average shoot widths of 18 mm. during data collection it was also observed that increased shoots width resulted to increased scallion biomass weight therefore increasing the net as well as gross returns.

Table 12 ANOVA Analysis on Treatment Effect on the Onion Shoots Width

Univariate Analysis of Variance					
Tests of Between-Subjects Effects					
Dependent Variable: Onion Shoots Width					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	993.228[a]	5	198.646	7.688	.000
Intercept	26510.958	1	26510.958	1026.081	.000
Supplements	993.228	5	198.646	7.688	.000
Error	3643.031	141	25.837		
Total	4636.259	146			
a. R Squared = .214 (Adjusted R Squared = .186)					

Table 13 indicates the univariate analysis tests of between-subjects effects on the group mean variance of the different independent variables of site, supplements and variety done on the onion shoots width, and their significant p value levels, testing if there were significant differences in variances or not.

According to the analysis results presented on the table, there was a significant difference in onion shoots width means indicated by the supplement treatments which showed a significance difference of $p < .05$.

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Table 13 Post Hoc Analysis on Supplement Effects on the Shoots Width of Onions

Homogeneous Subsets

Onion Shoots Width

	Supplements	Means	N	Subset			
				1	2	3	4
Duncan[a,b,c]	S, Ca& Mg at 40 kg/ha	9	11	9.45			
	S at 40 kg/ha	13	17		13.41		
	S, Ca& Mg at 30 kg/ha	18	14				18.36
	S, Ca& Mg at 60 kg/ha	18	26				18.46
	Sig.			1.000	.572	.059	.580

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square (Error) = 25.837.

a. Uses Harmonic Mean Sample Size = 18.994.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Table 14 represents Duncan Post Hoc analysis test performed on the onion shoots width where significant differences were recorded to determine which specific treatments caused the variances and at what levels on the supplements.

These significant difference in the onion supplementation treatment according to the analysis results were caused by variations within treatments 2, 3, 4 and 5 since their values fell on different subsets without any overlapping in same subset group.

Bulb/Shoots Splitting

Figure 8 A Summary Graph on Treatment Effects on Onion Bulb/Shoots Splitting

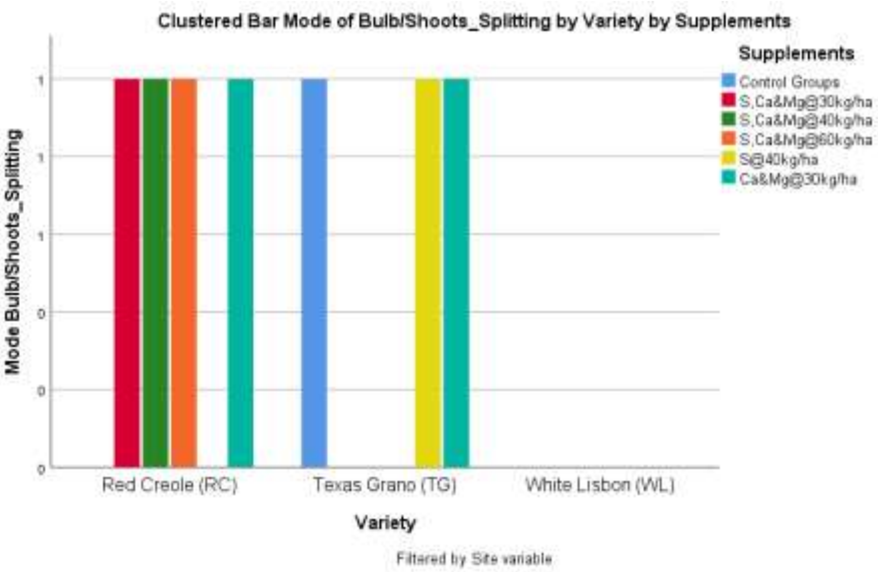

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Figure 8 displays clustered bar means graph of the different supplementation treatments as well as the variety on the bulb/shoots splitting of onions across the different study sites. The figure as well includes error bars to display the level of variances across the mean groups of the data.

From the representation, it is evident that "Red Creole" red variety significantly had the highest average number of split bulbs at supplement treatment 5 with an average: "Texas Grano" variety followed at supplement treatment levels 4: while "White Lisbon" onion recording the least shoot splits at treatment 3. According to the results of the research also, the control treatment 1 where no supplementation was done recorded the lowest average number of splits, indicating that with increase in treatment administration across onion varieties result to increased bulb/shoots splitting incidences. This research strongly agrees with the study conducted by Mzwakhile et al. (2024) reporting that application of calcium cyanide ($CaCN_2$) at 60 kg/ha resulted in significant increased incidences of sprouting.

All the supplementation levels treatments resulted to lower bulb/shoots splitting incidences, with most recording 0 cases across "Texas Grano" yellow onion variety as well as "White Lisbon" scallion variety. Therefore, based on the outcome, it is not recommended to invest in supplementing onions with S, Ca nor Mg treatments as no significant differences will result in the outcomes. It is recommended to plant yellow onion varieties as well as scallion varieties in order to achieve lower levels as well.

Table 14 ANOVA Analysis on Treatment Effects on Onion Bulb/Shoots Splitting

Tests of Between-Subjects Effects					
Dependent Variable: Bulb/Shoots Splitting					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	769.026[a]	35	21.972	19.333	.000
Intercept	756.325	1	756.325	665.475	.000
Site	77.601	1	77.601	68.279	.000
Supplements	41.866	5	8.373	7.367	.000
Variety	115.789	2	57.894	50.940	.000
Site * Supplements	69.009	5	13.802	12.144	.000
Site * Variety	7.447	2	3.723	3.276	.038
Supplements * Variety	95.517	10	9.552	8.404	.000
Site * Supplements * Variety	225.495	10	22.549	19.841	.000
Error	1250.171	1100	1.137		
Total	2019.197	1135			
a. R Squared = .381 (Adjusted R Squared = .361)					

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Table 15 indicates the univariate analysis tests of between-subjects effects on the group mean variance of the different independent variables of site, supplements and variety done on the onion bulb/shoots splitting, and their significant p value levels, testing if there were significant differences in variances or not.

As per the table, all the treatments of site, supplements and variety had significant effects on the bulb/shoots splitting. This was evident with the significant differences in the mean values from the analysis which indicated that they had p values of .00, which is proves a strong level of significance against the test value which is $p < .05$. Treatment combinations of site and supplement, site and variety, supplement and variety as well as combination of site, supplement and variety also proved significant differences in the means of bulb/shoots splitting in onions as a result of the treatments. This was also indicated by their values of .00, .04, .00 and .00 which are $p < .05$.

Table 15 Post Hoc Analysis on Supplements Effects on Onion Bulb/Shoots Splitting

Homogeneous Subsets							
	Supplements		N	Subset			
		Mode		1	2	3	4
Duncan[a,b,c]	Control Groups	0	180	.61			
	Ca& Mg at 30 kg/ha	0	192			1.06	
	S at 40 kg/ha	0	180				1.34
	Sig.			.412	.052	.103	1.000
Means for groups in homogeneous subsets are displayed. Based on observed means. The error term is Mean Square (Error) = 1.137.							
a. Uses Harmonic Mean Sample Size = 188.914.							
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.							
c. Alpha = .05.							

Table 16 represents Duncan Post Hoc analysis test performed on the onion bulb/shoots splitting where significant differences were recorded to determine which specific treatments caused the variances and at what levels on the supplements.

Based on the results, the significant differences as a result of the supplementation were present supplement treatment levels of control as well as treatments 5 and 6 across all the subsets, indicated by the lack of overlaps in their row spaces.

Table 16 Post Hoc Analysis on Variety Effects on Onion Bulb/Shoots Splitting

-	-	**Multiple Comparisons** Dependent Variable: Bulb/Shoots Splitting	

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			(I) Variety	(J) Variety	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	95% Confidence Interval
	Mode	N						Lower Bound	Upper Bound
LSD	1	387	Red Creole	Texas Grano	.60*	.076	.000	.46	.75
				White Lisbon	.92*	.079	.000	.77	1.07
	0	397	Texas Grano	Red Creole	-.60*	.076	.000	-.75	-.46
				White Lisbon	.31*	.078	.000	.16	.47
	0	352	White Lisbon	Red Creole	-.92*	.079	.000	-1.07	-.77
				Texas Grano	-.31*	.078	.000	-.47	-.16

Based on observed means.

The error term is Mean Square (Error) = 1.137.

*. The mean difference is significant at the .05 level.

Table17 represents LSD Post Hoc analysis test performed on the onion bulb/shoots splitting where significant differences were recorded to determine which specific treatments caused the variances and at what levels on the varieties.

As presented, significant differences resulted from the varieties themselves where each variety's mean had significant effects on the bulb/shoots splitting. This was indicated by the presence of the asterisks present in all the mean difference values for the varieties.

Cost-Benefit Analysis of Optimized Supplementation Practices on Kenyan Onion Farmers

This section presents the general description of the respective dependent outcome variables of the study as affected by the different independent treatment variables of Sulfur, Calcium and Magnesium, including their combinations at different levels. ANOVA tests were performed to check for significance differences in and within the mean groups, and where the differences were found, Ducan and LSD Post Hoc were further performed to check the specific cause within the groups and at what levels the effects contributed to the differences. The results were summarized and presented in form of tables and graphs in order of the objective variables indicators: gross income returns and net profit margin.

Figure 9 A Summary Graph on Treatment Effects on Onion Gross Market Prices per kg

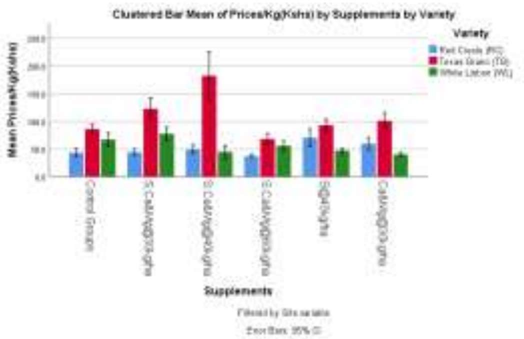

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Figure 9 displays clustered bar means graph of the different supplementation treatments as well as the variety on the gross market prices per kg of onions across the different study sites. The figure as well includes error bars to display the level of variances across the mean groups of the data.

The results indicate significant differences across the different treatments. Treatment 3 recorded the highest average gross market prices per kg of onions for “Texas Grano" yellow bulb onion variety. Treatment 4 had the least average gross market prices per kg of red bulb onions variety in Kenyan shillings. This report comfortably indicated that varying different level of treatments of S, Ca and Mg on different onion varieties results to significant effects on the average gross market prices per kg of the onions per kilogram in Kenyan shilling. This research agrees with Hussein and Ridha (2021) as well as Mohamed et al. (2024) who in their studies found that spraying onions with organic sulfur as well as hydrogen peroxide led to highest significance in plant yield weight

S, Ca and Mg at 30 kg/ha, 40 kg/ha and S at 40kg/ha proved better as compared to the control in relation to the gross market returns and were all recommended for use. However, in order to achieve ultimate gains S, Ca and Mg at 40 kg/ha was found appropriate with a gross market price mean of KSh 107.04 per 15 onions, on “Texas Grano” yellow onion variety.

Table 17 ANOVA Analysis on Treatment Effects on Onion Gross Market Prices per kg

Univariate Analysis of Variance					
Tests of Between-Subjects Effects					
Dependent Variable: Gross Market Prices per kg					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3561958.318[a]	35	101770.238	26.895	.000
Intercept	5230332.015	1	5230332.015	1382.240	.000
Site	868428.775	1	868428.775	229.503	.000
Supplements	135817.292	5	27163.458	7.179	.000
Variety	632420.437	2	316210.218	83.566	.000
Site * Supplements	142109.353	5	28421.871	7.511	.000
Site * Variety	202280.555	2	101140.278	26.729	.000
Supplements * Variety	240985.654	10	24098.565	6.369	.000
Site * Supplements * Variety	251775.537	10	25177.554	6.654	.000
Error	4162349.403	1100	3783.954		

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Corrected Total	7724307.720	1135			
a. R Squared = .461 (Adjusted R Squared = .444)					

Table 18 indicates the univariate analysis tests of between-subjects effects on the group mean variance of the different independent variables of site, supplements and variety done on the onion gross market prices per kg, and their significant p value levels, testing if there were significant differences in variances or not.

All the treatments and their combinations had strong significant differences with p values of $p < .05$. These significant differences are the ones that resulted in the variances in gross market prices per kg of the onion varieties.

Table 18 Post Hoc Analysis on Supplements Effects on Onion Gross Market Prices per kg

Homogeneous Subsets							
	Supplements		N	Subset			
		Means		1	2	3	4
Duncan[a,b,c]	S, Ca& Mg at 60 kg/ha	54.84	188	54.536			
	S at 40 kg/ha	72.03	180		72.033		
	S, Ca& Mg at 30 kg/ha	86.75	189			86.750	
	S, Ca& Mg at 40 kg/ha	107.04	207				107.035
	Sig.			.086	.288	1.000	1.000
	Means for groups in homogeneous subsets are displayed. Based on observed means. The error term is Mean Square (Error) = 3783.954.						
	a. Uses Harmonic Mean Sample Size = 188.914.						
	b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.						
	c. Alpha = .05.						

Table 19 represents Duncan Post Hoc analysis test performed on the onion gross market prices per kg levels where significant differences were recorded to determine which specific treatments caused the variances and at what levels on the supplements.

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Post Hoc analysis on the supplement treatments to determine the level of significant differences in the group means indicated significant differences across treatment groups 2, 3, 4 and 5 at all the subsets displayed by the lack of repeated or overlapping values across the subset group means.

Table 19 Post Hoc Analysis on Variety Effects on Onion Gross Market Prices per kg

Multiple Comparisons									
Dependent Variable: Gross Market Prices per kg									
			(I) Variety	(J) Variety	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	95% Confidence Interval
	Means	N						Lower Bound	Upper Bound
LSD	52.61	387	Red Creole	Texas Grano	-62.727*	4.3942	.000	-71.349	-54.105
	115.33	389	Texas Grano	Red Creole	62.727*	4.3942	.000	54.105	71.349
				White Lisbon	58.631*	4.5035	.000	49.795	67.468
	56.70	352	White Lisbon						
				Texas Grano	-58.631*	4.5035	.000	-67.468	-49.795
Based on observed means. The error term is Mean Square (Error) = 3783.954.									
*. The mean difference is significant at the .05 level.									

Table 20 represents LSD Post Hoc analysis test performed on the onion gross market prices per kg where significant differences were recorded to determine which specific treatments caused the variances and at what levels on the varieties.

The multiple comparison of the mean variances in the onion varieties brought about by the supplement treatments application in relation to the prices per kg indicate significant differences between the red and the yellow bulb onion varieties as well as between the yellow bulb onion and the white scallion onion variety. These significant differences were indicated by the presence of asterisks in the mean difference values.

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Figure 10 Analysis Summary of Onion Net Profitability per kg

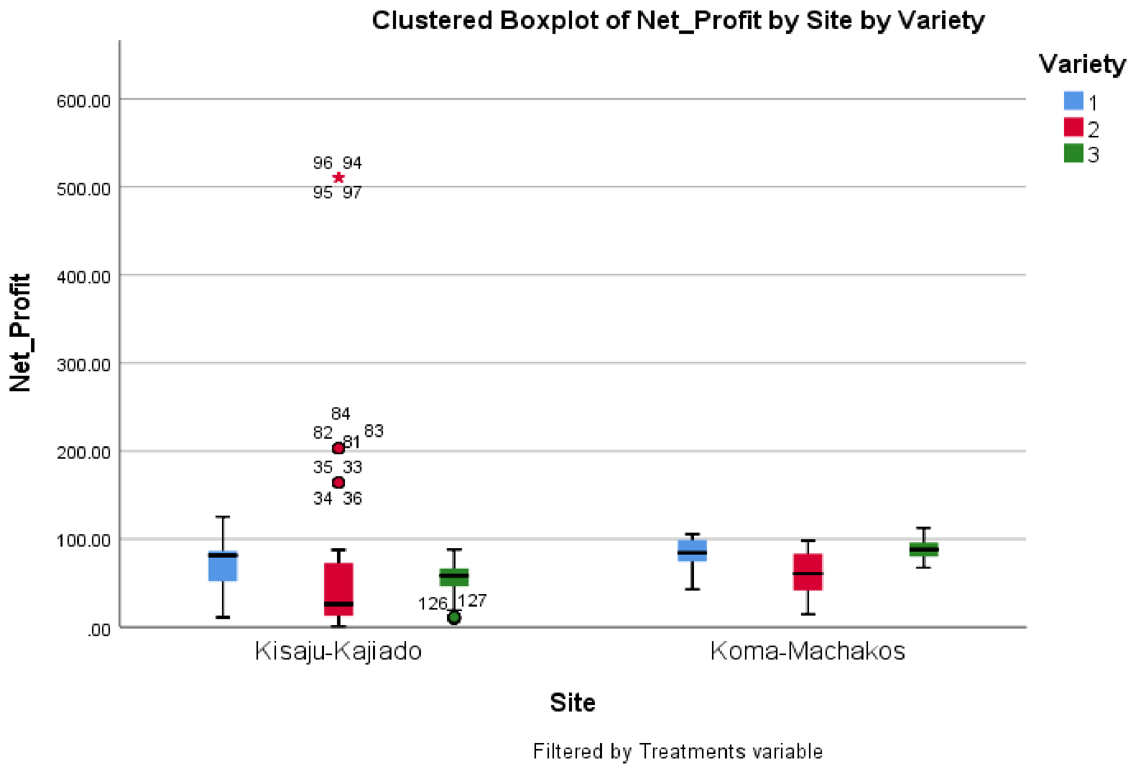

Figure 10 displays clustered box plots mean graph of the different supplementation treatments as well as the variety on the net profitability per kg of onions across the different study sites. The figure as well includes error bars to display the level of variances across the mean groups of the data.

According to the results, there seemed to be significant variations across all the varieties across both sites indicated by the error bar stretch, much variations were recorded in Kisaju-Kajiado site as compared to the Koma-Machakos site. There were also no outlies in the data except for yellow bulb onion variety in site 1 indicated by the asterisks and dots: this was as a result of surge in figures observed in select blocks, which the analysis suspected not only to be attributed by the study parameters alone, but might have had extraneous influences as well. Despite this, site 1 projected and proved higher net returns as indicated by the mean lines in the error bars and the error bars themselves as well.

Table 20 A Case Processing Summary on Analysis of Onions Net Profitability per kg

	Case Processing Summary			
	Site		Cases	
			Total	
		Means	N	Percent
Net Profit	Kisaju-Kajiado	76.94	601	100.0%
	Koma-Machakos	71.14	535	100.0%

	Treatments			
Net Profit	Control Group	66.04	180	100.0%
	S, Ca& Mg at 30 kg/ha	68.71	189	100.0%
	S, Ca& Mg at 40 kg/ha	103.49	207	100.0%
	S, Ca& Mg at 60 kg/ha	68.57	188	100.0%
	S at 40 kg/ha	65.71	180	100.0%
	Ca& Mg at 30 kg/ha	69.21	192	100.0%
	Variety			
Net Profit	Red Creole	77.44	387	100.0%
	Texas Grano	73.18	397	100.0%
	White Lisbon	71.82	352	100.0%

Table 21 indicates a summary analysis of the group mean variance of the different independent variables of site, supplements and variety done on the net profitability per kg for comparison on the best treatment groups.

Kisaju-Kajiado site location produced profitable onions as compared to the Koma-Machakos location with net returns of KSh 601/kg with average of 15 onions. From the display, “Red Creole” onion was found to be more profitable and contributed the highest values for the respective site, followed by yellow “Texas Grano” onion variety and lastly “White Lisbon” scallion onion variety. This result indicates that farmers intending to engage in onion productions might want to choose engaging in yellow onions production for increased net profitability per kg as they significantly fetch good returns.

S, Ca and Mg at 30 kg/ha, 40 kg/ha and S at 40kg/ha proved better gross market returns as compared to the control and were all recommended for use. However, in order to achieve ultimate gains S, Ca and Mg at 40 kg/ha was found appropriate with a gross market price mean of KSh 103.49 per 10 onion bulbs, on “Red Creole” onion variety alone with a mean of KSh 77.44.

The reason “Red Creole” variety had lower gross market price but higher net return profitability as compared to “Texas Grano” yellow onion variety was because the measure of market price was general in relation to the number of onions which made a kg. In context, a kg of red onion consisted of 10 onion bulbs on average, giving lesser bulbs per kg as compared to yellow with 15 onion bulbs, but red onions saved 5 bulbs per each kg sold to make extra kilograms, which increased the profitability, given the input cost was fixed across all the varieties.

CONCLUSION

In conclusion, this study provides empirical evidence that sulfur, calcium, and magnesium supplementation significantly improves onion growth, yield, and marketability in Kenyan agro-climatic zones. The key findings reveal that: (1) Kisaju-Kajiado is the optimal location for onion production, with superior growth, yield, bulb development, and market returns; (2) S, Ca, and Mg at 40 kg/ha produces the highest gross market returns on

'Texas Grano' and the highest net profit on 'Red Creole'; (3) red onions offer higher net profitability due to market preferences and price premiums; and (4) the response to nutrient supplementation is site-specific, highlighting the importance of location-specific recommendations.

These findings have important implications for farmers, extension services, and policymakers. For farmers, the findings provide specific recommendations for optimizing production and marketability. For extension services, the findings highlight the importance of site-specific nutrient management recommendations. For policymakers, the findings underscore the potential for improved nutrient management to enhance agricultural productivity and rural livelihoods. Future research should investigate the long-term effects of repeated nutrient supplementation on soil health and crop productivity, examine the balance between nutrient application and nutritional quality, and explore the potential for integrating organic and inorganic nutrient sources in onion production systems.

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