

Foliar and granular fertilizer application on the growth and yield performance of maize. A cross-sectional study.

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Abstract

Background

The study aimed to investigate the effect of foliar and granular fertilizer application on the growth and yield performance of maize.

Methodology

A field experiment was conducted in Hapuyyo Sub-county, Kyegegwa District, Uganda, during the 2025B and 2026A seasons. A Randomized Complete Block Design with 10 fertilizer treatments and three replications was used. DK 7:7:7 maize was subjected to granular, foliar, combined, and control treatments. Growth and yield parameters were measured from randomly selected plants. Data were analysed using RCBD ANOVA, with Tukey's HSD test at 5% significance. Normality and homogeneity assumptions were assessed using Shapiro-Wilk and Levene's tests.

Results

Of 200 maize farmers surveyed, 59.0% were male, and 74.5% had grown maize for more than 10 years. The experimental soil was acidic (pH 5.6), with low organic carbon (8.9 g/kg), nitrogen, and phosphorus, but adequate potassium and 15.2% moisture. Fertilizer treatments significantly affected stem height to cob ($p=0.011$), plant height to tassel ($p<0.0001$), leaf area index ($p<0.0001$), biomass ($p<0.0001$), and grain yield ($p<0.0001$), but not number of leaves ($p=0.131$), cobs per plant ($p=0.913$), or grain rows per cob ($p=0.159$). Plant height ranged from 170.23–199.8 cm, while grain yield ranged from 1,893–3,790 kg/ha. T10 recorded the highest yield (3,790 kg/ha), followed by T9 (3,762 kg/ha), whereas the control recorded the lowest.

Conclusion

Fertilizer application significantly influenced plant height, leaf area index, biomass, and yield, but not leaves, cobs per plant, or grain rows.

Recommendation

Community and parish demonstration plots should provide practical evidence on fertilizer types, rates, and application methods.

Keywords: Granular fertilizer; Foliar fertilizer; Maize growth; Grain yield; Nutrient management; Fertilizer application.

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Background of the study

Fertilizer application is an important component of crop production because the method of application influences nutrient availability and subsequent plant utilization. Following application, nutrients may undergo processes such as percolation, volatilization, and fixation into insoluble forms, which can reduce the amount available for plant uptake (Hignett, 2013). Fertilizers are natural or manufactured substances, whether organic or inorganic, that supply plants with nutrients required for physiological processes and growth (Gupta & Hussain, 2014). They contain chemical elements that promote plant growth and productivity, making appropriate fertilizer management important for achieving improved crop performance (Finez & Talimbay, 2023).

Granular fertilizer application provides a practical approach to nutrient management because of its ease of application, nutrient availability, and potential for efficient incorporation into the soil. Compared with conventional organic fertilizers such as compost and manure, processed granular fertilizers can provide more uniform nutrient distribution, longer storage stability, and improved integration into the soil. These characteristics have contributed to their use in sustainable agricultural production systems (Dirga Sapta Sara et al., 2025). However, the effectiveness of granular fertilizer depends on appropriate application methods and rates, which may influence nutrient uptake, maize growth, and ultimately grain yield.

The study aimed to investigate the effect of foliar and granular fertilizer application on the growth and yield performance of maize.

Methodology
Study area

Page | 2 The study was carried out in Hapuuyo Sub-county, Kyegegwa District, Tooro Sub-region, Western Uganda (Figure 2). Kyegegwa District is bordered by Mubende District in the West, Kiruhura in the South, Kibaale in the North, Kyenjojo in the North-West, and Kamwenge in the South-West. The coordinates of Kyegegwa District are 0.4818193 Latitude and 31.0550093 Longitude. The study area is part of a central plateau, characterized by hilly and rocky topography, which presents challenges for commercial agricultural production as a factor in maize production. Kyegegwa has a tropical savanna climate with dry and wet season climatic conditions. The daily temperatures typically range between 20 and 25 °C, but can drop to as low as 17 °C during the wet season and can rise to as high as 30 °C during the dry season. The average rainfall is between 1,200 and 1,500 mm. The main economic activity is farming, with crop production ranking high, followed by livestock. Under crop production, maize growing is practiced district-wide, and Hapuuyo Sub-county is the leading producer of maize in the district. (Crop *et al.*, 2017). Therefore, the study was carried out in Hapuuyo Sub-county, specifically on fertilizer application.

Experiment site

The experiment was carried out in Hapuuyo Sub-county, Iringa parish, Kyakasoro village, 7 kilometers off Kampala Fort Portal Road. Composite soil samples were collected and taken to the Makerere University soil laboratory to be

analysed for physical and chemical properties. The plot site was cleared of the vegetation and ploughed in July for planting in season 2025B, and in March for planting in season 2026A.

Experimental design and treatments

The total experimental area was 420 m² (30 m long and 14 m wide). The experimental design was a Randomized Complete Block Design (RCBD) comprising ten treatments replicated three times (Table 1). The area was divided into three blocks, each block with 10 plots (treatments) and replicated three times, giving a total of 30 plots. Each plot measured 10 m² (4 x 2.5 m) and contained 8 rows and 6 columns of maize plants planted at a spacing of 75 x 30 cm. Each block was separated from the other by a distance of one metre, as were the plots. Maize variety DK 7:7:7 (hybrid) was used in the study, as well as NPK 20:20:18 (Granular fertilizer) and NPK Growmax 20:20:20 (Foliar fertilizer). Granular fertilizer was applied in two doses, first application at planting, second dose 30 DAP. The experiment was repeated across two seasons to improve the stability and generalisability of treatment effect estimates.

Routine procedures and establishment

First season planting was done on 1st October 2025, while second season planting was on 5th March 2026 following the onset of rains. Maize was planted at a spacing of 75 by 30 cm, and one seed was planted per hole. For granular fertilizers, the first dose was applied at planting and the second dose at 30 DAP; germination percentage was 99%. Foliar fertilizer was mixed at the rate of 5g per litre of water and applied weekly after emergence. All the other agronomic practices, such as weeding and pest control, were carried out as required.

Table 1: Description of treatments and procedures

Treatment	Description
T1	No fertilizer applied. Only water was applied (control)
T2	Granular fertilizer 500g per plot/ 10g per plant
T3	Granular fertilizer 250g per plot/5g per plant
T4	Granular fertilizer 125 grams per plot/ 2.5g per plant
T5	Foliar fertilizer at 500g per plot
T6	Foliar fertilizer at 250g per plot
T7	Foliar fertilizer at 125 grams per plot
T8	Combination of treatment 2 and 5 (500 granular + 500 foliar)
T9	Combination of treatment 3 and 6 (250 granular + 250 foliar)
T10	Combination of treatment 4 and 7 (125 granular + 125 foliar)

Data collection

Maize growth parameters

Number of leaves: The number of leaves from 12 randomly selected and tagged plants from the middle rows at the tasseling stage was counted and recorded.

Leaf length and leaf width: Leaf lengths and widths of 12 selected plants were measured from four leaves of each plant using a ruler for the two seasons and recorded.

Plant/stem height to the cob and plant height from ground level to the base of tassel: These were measured from 12 randomly selected and tagged plants using a tape measure and recorded

Maize yield parameters

Weight of above-ground biomass (kg): The above-ground biomass of 12 plants from inner rows of each plot were randomly selected, harvested, sun-dried, and measured in kilograms using an electronic weighing scale and recorded.

Number of cobs per plant: The number of cobs per plant from 12 randomly selected and tagged plants was counted and recorded each season.

Number of grain rows per cob: After harvesting maize, the number of grain rows was counted on each cob from 12 selected and tagged plants and recorded each season.

Grain weight per plot (kg): Cobs from 12 randomly selected and tagged plants from each plot were harvested, shelled, and the grains weighed and recorded each season.

Weight of 200 grains per plot: 200 grains from each plot were randomly picked, weighed, and recorded each season.

Data analysis

Quantitative data obtained covering socio-demographic characteristics, awareness and knowledge levels, fertilizer-use practices, and farmers' responses were coded, entered into R statistical software, and analysed using descriptive statistics, including frequencies, percentages, means, and standard deviations. Chi-square tests were used to examine associations between selected socio-demographic characteristics, such as education level and farming experience, and farmers' knowledge or fertilizer-use practices where applicable. Open-ended responses from the questionnaire were reviewed, coded, and grouped into common themes to provide additional explanation of farmers' perceptions, experiences, and challenges related to fertilizer application.

Qualitative data obtained from the Key Informant Interviews were transcribed, reviewed, and coded manually. Similar responses were grouped into categories and organized into themes based on the study objectives. Thematic analysis was used to identify recurring views concerning fertilizer recommendations, application practices, challenges, benefits, and factors influencing fertilizer use among maize farmers. The findings from the key informants were used to complement the quantitative findings from the farmer questionnaire rather than being analysed statistically.

Data generated from the maize field experiment were subjected to Analysis of Variance (ANOVA) for a Randomized Complete Block Design (RCBD) to determine whether significant differences existed among the ten fertilizer treatments. Where significant differences were

detected, treatment means were separated using Tukey's Honestly Significant Difference (HSD) test at the 5% significance level. Before ANOVA, the data were assessed for normality using the Shapiro-Wilk test and homogeneity of variance using Levene's test. The results indicated that the data met the assumptions of normality and homogeneity of variance, supporting the use of parametric ANOVA.

Ethical considerations

Strict ethical protocols were observed throughout the research process to protect the rights and welfare of all participants. The study was conducted upon receiving formal approval from the Research Ethics Committee (REC) of Bishop Stuart University, after which permission was sought from the Kyegegwa District Local Government and Hapuuoyo Sub-county authorities to access the study communities. Informed consent was obtained from all participants using standardized consent forms translated into the local language (Runyankole), ensuring that participants fully understood the purpose of the study, procedures involved, and their rights. For illiterate participants, the consent information was read aloud in the presence of a witness, and a thumbprint was accepted instead of a signature.

Participation was entirely voluntary, and all respondents were clearly informed of their right to refuse participation or withdraw from the study at any point without any consequences or penalties. To guarantee confidentiality, all data were anonymized by using unique codes instead of participants' names, ensuring that individual identities cannot be linked to the responses in any publications or reports arising from this research.

Informed consent

Written informed consent was obtained from all participants prior to their inclusion in the study. Participants were informed about the purpose of the study, procedures involved, potential risks and benefits, and their right to withdraw at any time without penalty.

Results

Demographic characteristics

This section presents the socio-demographic profile of the 200 smallholder maize farmers surveyed in Hapuuoyo Sub-county, Kyegegwa District. The demographic characteristics of respondents, including sex, age, education level, farming experience, land ownership, and area cultivated, are presented in Table 2.

Table 2: Demographic characteristics

Characteristic	Category	Frequency (n)	Percent (%)
Gender	Female	82	41.0
	Male	118	59.0
Age (years)	18 – 30	39	19.5
	31 – 45	90	45.0
	46 – 60	60	30.0
	Above 60	11	5.5
Highest level of education	No formal education	45	22.5
	Primary school	98	49.0
	Secondary school	42	21.0
	Tertiary/Vocational	12	6.0
	University	3	1.5
Main occupation	Farming only	160	80.0
	Farming and Business	34	17.0
	Farming + Casual Labor	6	3.0
Years growing maize	Less than 2	4	2.0
	2-5	14	7.0
	6-10	33	16.5
	More than 10	149	74.5
Total land owned (acres)	Less than 1 acre	29	14.5
	1 – 2.9 acres	65	32.5
	3 – 5 acres	61	30.5
	More than 5 acres	45	22.5
Maize planted last season (acres)	Less than 1	73	36.5
	1 – 2.9	74	37.0
	3 – 5	34	17.0
	More than 5	19	9.5

Source: Field Survey Data (2025/2026)

The findings on demographic characteristics reveal that the majority of respondents were male (59.0%), with most farmers being in their economically active years, as 45.0% fall within the 31-45 age bracket and an additional 30.0% are aged 46-60 years, indicating that maize farming is largely sustained by middle-aged adults who possess substantial agricultural experience. This is further corroborated by the finding that 74.5% of respondents have been growing maize for more than 10 years, suggesting a deeply entrenched farming tradition and accumulated indigenous knowledge that could be leveraged for agricultural extension interventions.

However, educational attainment remains a critical challenge, with nearly three-quarters (71.5%) of farmers having only primary education or no formal education at all (49.0% and 22.5%, respectively), while only 7.5% have attained tertiary or university education. This pattern is consistent with rural Uganda's human capital constraints and likely contributes to the limited adoption of recommended fertilizer practices as observed in the study area. The occupational data show that 80.0% of respondents rely exclusively on farming as their primary livelihood, with the remaining 20.0% supplementing their income through casual labor or trading/business activities, underscoring the heavy dependence on agriculture for household subsistence and income generation.

Landholding patterns reveal that 67.5% of farmers operate on less than 3 acres, while only 22.5% own more than 5 acres, and similarly, 73.5% planted less than 3 acres of maize in the last season, confirming that maize production is predominantly a smallholder activity consistent with national statistics where 70-90% of Uganda's maize is produced on gardens of less than 1.5 acres. These small land sizes present both opportunities and constraints for fertilizer interventions; while the compact acreage could make targeted fertilizer application more manageable, the limited land also restricts farmers' capacity to absorb financial risks associated with fertilizer investments, as any potential loss represents a significant proportion of their total production and household food security.

The predominance of smallholder farmers with low formal education and extensive farming experience suggests that effective fertilizer promotion strategies in Kyegegwa must prioritize practical, field-based demonstrations and farmer-to-farmer learning approaches rather than relying solely on written materials or classroom-style training, as farmers in this context tend to respond better to observable evidence and experiential learning. Overall, these demographic characteristics highlight the need for targeted, context-specific agricultural extension programs that address the unique socioeconomic circumstances of smallholder maize farmers, particularly regarding access to affordable

fertilizers, appropriate application knowledge, and risk-mitigation strategies to enhance adoption rates and ultimately improve maize productivity in the district.

Investigating the Effect of Foliar and Granular Fertilizers on Growth and Yield Performance of Maize

This section presents the findings on the effects of foliar and granular fertilizers on the growth and yield of maize, addressing the second specific objective of the study. Understanding the comparative effects of these fertilizer types and their combinations on maize growth parameters (plant height, leaf area index, biomass) and yield components (cob weight, grain yield, 200-grain weight) is essential for providing evidence-based recommendations to farmers in Kyegegwa District. The results are presented in the following sub-sections: soil properties of the experimental site, growth parameters, yield parameters, and treatment comparisons.

Soil Properties of the Experimental Site

The soil analysis results revealed that the experimental site had generally poor to marginal soil fertility status, characterized by acidic pH (5.6), low organic carbon (8.9 g/kg), deficient total nitrogen, low available phosphorus, high clay content (57%), and low cation exchange capacity (50 mmol/kg), with only exchangeable potassium and soil moisture falling within adequate ranges. The pH of 5.6 indicates slightly acidic conditions, which is below the optimal range of 6.0–7.2 recommended for maize production and suggests potential aluminum toxicity and reduced availability of essential nutrients such as

phosphorus, calcium, and magnesium, consistent with the weathered Ferralsols commonly found in the Tooro Sub-region.

The very low organic carbon (8.9 g/kg) and total nitrogen levels reflect continuous cultivation without adequate organic matter replenishment, a common characteristic of smallholder farms in Kyegegwa District where crop residues are often removed or burned, leading to progressive soil degradation and nutrient depletion. The low available phosphorus is particularly concerning given that phosphorus is essential for root development, energy transfer, and grain formation, and its deficiency in acidic soils is exacerbated by fixation into insoluble forms. The high clay content (57%) indicates a heavy-textured soil that, while having the potential for high nutrient retention, also presents challenges such as poor drainage, slow water infiltration, and increased risk of nutrient fixation, particularly phosphorus. The low cation exchange capacity (50 mmol/kg) suggests limited ability to retain and exchange positively charged nutrients, making the soil vulnerable to nutrient leaching and requiring more frequent fertilizer applications to meet crop demands. The adequate exchangeable potassium (within adequate range) and soil moisture (15.2%) provide some favorable conditions for maize growth; however, these positive attributes are insufficient to compensate for the multiple fertility constraints identified. Overall, these baseline soil conditions provided an appropriate context for evaluating the effects of the different fertilizer treatments, as the observed crop responses can be attributed to the applied fertilizers rather than to inherently high soil fertility, thereby ensuring that the experimental findings are relevant to the typical soil conditions faced by smallholder farmers in the study area.

Table 3: Initial Soil Properties on the Experimental Site, Hapuuoyo Sub- County

Parameter	Analysis Result
pH (water)	5.6
Organic Carbon (g/kg)	8.9
Total Nitrogen (g/kg)	Low
Phosphorus (M3) (mg/kg)	Low
Potassium (exchangeable) (mmol/kg)	Adequate
Cation Exchange Capacity (mmol/kg)	50
Soil Moisture (%)	15.2
Clay (%)	57
Silt (%)	25
Sand (%)	18

Source: Field Experimental Data (2026)

Effects of Fertilizer Treatments on Maize Growth Parameters

The effects of fertilizer treatments on maize growth parameters, including plant height to the cob, plant height to the tassel, number of leaves, leaf area index, and above-ground biomass, are presented in Tables 4 and 5. These

parameters were used to assess the growth response of maize to the different fertilizer treatments, with measurements taken at the specified growth stages during the two experimental seasons.

Stem Height to the Cob (cm)

Stem height to the cob ranged from 102 to 111 cm across the fertilizer treatments, with an overall mean of 105.6 cm, and the differences among the treatment means were not significant ($p > 0.05$) (Table 10).

Plant Height to the Tassel (cm)

Plant height to the tassel showed significant variation among the fertilizer treatments ($p < 0.05$) (Table 10). Maize plants that received foliar fertilizer alone and those that received combinations of foliar and granular fertilizers were generally taller than the control. Among the granular fertilizer treatments, plants receiving the highest granular fertilizer rate of 500 g per plot (10 g per plant) recorded a significantly greater height of 189.38 cm compared with those receiving the lowest granular fertilizer rate of 125 g per plot (2.5 g per plant), which recorded 170.23 cm ($p < 0.05$). The tallest plants were recorded under the combined granular and foliar treatments, particularly T8, which recorded 199.8 cm. However, there were no significant differences between the heights of plants receiving foliar fertilizer alone and those receiving the combined foliar and

granular fertilizer treatments.

Number of Leaves

The number of leaves per plant ranged from 11.6 to 12.6, with an overall mean of 12.2 leaves, and the differences among fertilizer treatments were not significant ($p > 0.05$) (Table 10).

Leaf area index (lai)

Leaf area index (LAI) varied among the fertilizer treatments, with differences observed between the control and the fertilizer-treated plots and among the different fertilizer rates and combinations (Table 11).

Above-ground biomass

Above-ground biomass differed among the fertilizer treatments, with the control and lower-rate granular fertilizer treatments recording relatively higher biomass values of approximately 5.47–5.48 kg per plot, while the combined fertilizer treatments T8, T9 and T10 recorded comparatively lower biomass values of approximately 4.91–5.06 kg per plot (Table 5).

Table 4: Maize Growth Characteristics as Influenced by Fertilizers

Treatment	Stem height to cob (cm)	Plant height to tassel (cm)	Number of leaves	Leaf area index	Biomass (kg/plot)
Control (T1)	104	173.96 ^c	11.6	4.06 ^c	5.48 ^a
Granular 500g (T2)	111	189.38 ^{ab}	12.2	4.30 ^{bc}	5.24 ^{abc}
Granular 250g (T3)	109	182.46 ^{bc}	12.1	4.42 ^{abc}	5.47 ^a
Granular 125g (T4)	103	170.23 ^c	11.9	4.61 ^{ab}	5.48 ^a
Foliar 500g (T5)	106	193.8 ^{ab}	12.5	4.69 ^{ab}	5.25 ^{ab}
Foliar 250g (T6)	103	189.42 ^{ab}	12.5	4.59 ^{ab}	5.10 ^{bcd}
Foliar 125g (T7)	106	191.6 ^{ab}	11.8	4.49 ^{abc}	4.99 ^{cd}
Granular + Foliar (T10)	103	188.23 ^{ab}	12.5	4.86 ^a	5.02 ^{bcd}
Granular + Foliar (T9)	102	186.79 ^{ab}	12.6	4.73 ^{ab}	4.91 ^d
Granular + Foliar (T8)	109	199.8 ^a	12.6	4.81 ^a	5.06 ^{bcd}
Mean	105.6	186.4	12.2	4.56	5.20
F-Prob.	0.011	<.0001	0.131	<.0001	<.0001
LSD _(0.05)	9.110(ns)	12.669	0.962(ns)	0.499	0.253

Source: Field Experimental Data (2026)

Leaf area index

The leaf area indices for all the treatments were greater than that of the control (4.06), apart from those of treatments that received granular 500g (T2), granular 250g (T3), and foliar 125 g (T7). This shows that fertilization, particularly combined treatments, enhanced leaf expansion (photosynthetic area).

LAI significantly increased with fertilizer application, especially in Granular + Foliar T10 and T8 (4.86 and 4.81)

versus the control (4.06). This is agronomically important because LAI is directly linked to light interception and photosynthetic capacity. rate and area rather than leaf initiation.

Biomass yield per plot

For the case of biomass, all treatments that received granular fertilizer alone as well as those that received 500g of foliar fertilizer (T5) had similar ($p > 0.05$) biomass to the control

(Table 4). The biomass weights for the rest of the treatments were significantly ($p < 0.05$) lower than that of the control. For those that received foliar fertilizer, the treatment that received the highest amount of foliar fertilizer (500g) produced the highest amount of biomass (5.25 kg/plot) compared with the one that received the least amount of foliar fertilizer (4.99 kg/plot). No significant differences were observed among the treatments that received a combination of granular and foliar fertilizer.

This is the most agronomically interesting (and somewhat counterintuitive) result. Despite recording relatively lower leaf area index (LAI) and plant height, the control and lower-rate granular fertilizer treatments (125 g and 250 g) recorded the highest biomass yields (5.47–5.48 kg/plot). In contrast, the combined granular and foliar fertilizer treatments (T8, T9 and T10) recorded comparatively lower biomass yields (4.91–5.06 kg/plot), despite some of these treatments recording relatively higher values for particular vegetative

growth parameters.

Effects of Fertilizer Treatments on Maize Yield Parameters

According to the results in Table 11, the effect of fertilizer treatment on the number of cobs per plant and number of grain rows per cob was not significant ($p > 0.05$). Yield (kg/ha), however, differed significantly ($p < 0.05$) among treatments, with the control registering the lowest yield (1,893 kg/ha).

There were no significant ($p > 0.05$) differences among the combined Granular + Foliar treatments. The same trend was observed among the granular and foliar fertilizer treatments (Table 5). However, the combined Granular + Foliar treatments performed better ($p < 0.05$) than both the granular and foliar fertilizer treatments, apart from the foliar 125g fertilizer treatment.

Table 5: Maize Yield Parameters as Influenced by Granular and Foliar Fertilizers

Treatment	Cobs per plant	Grain rows per cob	Yield (kg/ha)
Control (T1)	1.21	14.4	1,893 ^e
Granular 500g (T2)	1.21	14.0	3,032 ^d
Granular 250g (T3)	1.21	15.0	3,121 ^d
Granular 125g (T4)	1.13	14.8	2,960 ^d
Foliar 500g (T5)	1.13	14.5	3,410 ^c
Foliar 250g (T6)	1.17	14.7	3,546 ^{bc}
Foliar 125g (T7)	1.08	14.8	3,621 ^{abc}
Granular + Foliar (T10)	1.04	14.7	3,790 ^a
Granular + Foliar (T9)	1.08	14.7	3,762 ^{ab}
Granular + Foliar (T8)	1.17	14.2	3,591 ^{abc}
Mean	1.14	14.58	3273
F-Prob.	0.913	0.159	<0.0001
LSD _(0.05)	0.206(ns)	0.85(ns)	234

Source: Field Experimental Data (2025/2026)

Discussion

Stem height to the cob ranged from 102 to 111 cm across the fertilizer treatments, with an overall mean of 105.6 cm, and the differences among the treatment means were not significant ($p > 0.05$) (Table 10). This indicates that, under the fertilizer rates and formulations evaluated in this study, fertilizer application did not produce a statistically

detectable effect on stem height to the cob. The limited variation among treatments may be associated with the relatively similar development of the lower stem region across the treatments. Fageria et al. (2009) reported that crop growth responses to nutrient application depend on the crop growth stage, nutrient availability, and the level of nutrient limitation. Therefore, the absence of significant differences in stem height to the cob suggests that the fertilizer

treatments used in this experiment did not substantially alter this particular growth parameter.

Plant height to the tassel showed significant variation among the fertilizer treatments ($p < 0.05$) (Table 10). Maize plants that received foliar fertilizer alone and those that received combinations of foliar and granular fertilizers were generally taller than the control. Among the granular fertilizer treatments, plants receiving the highest granular fertilizer rate of 500 g per plot (10 g per plant) recorded a significantly greater height of 189.38 cm compared with those receiving the lowest granular fertilizer rate of 125 g per plot (2.5 g per plant), which recorded 170.23 cm ($p < 0.05$). The tallest plants were recorded under the combined granular and foliar treatments, particularly T8, which recorded 199.8 cm. However, there were no significant differences between the heights of plants receiving foliar fertilizer alone and those receiving the combined foliar and granular fertilizer treatments. The greater plant height observed under some fertilizer treatments may be associated with improved nutrient availability, particularly nitrogen, which contributes to vegetative development and stem elongation. Fageria et al. (2009) reported that adequate nutrient availability promotes crop growth and development, while Brankov et al. (2020) reported that appropriate nutrient management can enhance maize growth characteristics. The lower height recorded under the 125 g granular treatment compared with the 500 g treatment may therefore indicate that the higher fertilizer rate provided greater nutrient availability for plant growth under the conditions of the experiment.

The number of leaves per plant ranged from 11.6 to 12.6, with an overall mean of 12.2 leaves, and the differences among fertilizer treatments were not significant ($p > 0.05$) (Table 10). This indicates that the fertilizer treatments did not produce a statistically significant effect on the number of leaves per plant. The narrow range observed among treatments suggests that leaf number remained relatively similar despite differences in fertilizer type and rate. Fageria et al. (2009) explained that crop growth responses to fertilizer application vary according to the growth characteristic being measured and the availability of nutrients during the relevant growth stages. Therefore, the absence of significant differences in leaf number indicates that the fertilizer treatments had limited influence on this particular growth parameter under the experimental conditions.

Leaf area index (LAI) varied among the fertilizer treatments, with differences observed between the control and the fertilizer-treated plots and among the different fertilizer rates and combinations (Table 11). The variation in LAI indicates differences in maize canopy development under the different nutrient treatments. Leaf area development is influenced by nutrient availability because nutrients such as nitrogen contribute to leaf formation and expansion. Fageria et al. (2009) reported that adequate nutrient availability supports leaf development and contributes to crop growth, while Brankov et al. (2020) reported that appropriate

nutrient management can improve vegetative growth characteristics in maize. The differences in LAI observed in this study may therefore be associated with differences in nutrient availability and uptake resulting from the fertilizer treatments.

Above-ground biomass differed among the fertilizer treatments, with the control and lower-rate granular fertilizer treatments recording relatively higher biomass values of approximately 5.47–5.48 kg per plot, while the combined fertilizer treatments T8, T9 and T10 recorded comparatively lower biomass values of approximately 4.91–5.06 kg per plot (Table 11). Thus, the treatments that recorded greater values for some individual vegetative growth parameters did not necessarily record greater above-ground biomass. The variation in biomass may be related to differences in nutrient availability, nutrient uptake, and plant responses to the different fertilizer rates and application methods. Fernández and Brown (2013) explained that the uptake and utilization of foliar-applied nutrients are influenced by physiological and environmental factors, while Xu et al. (2022) reported that crop responses to nitrogen application are influenced by nutrient-use efficiency and the relationship between nutrient supply and crop demand. Therefore, the differences in above-ground biomass observed among the treatments should be interpreted in relation to the overall growth response of the maize plants rather than assuming that greater plant height or leaf area necessarily results in greater biomass accumulation.

The leaf area indices for all the treatments were greater than that of the control (4.06), apart from those of treatments that received granular 500g (T2), granular 250g (T3), and foliar 125 g (T7). This shows that fertilization, particularly combined treatments, enhanced leaf expansion (photosynthetic area).

LAI significantly increased with fertilizer application, especially in Granular + Foliar T10 and T8 (4.86 and 4.81) versus the control (4.06). This is agronomically important because LAI is directly linked to light interception and photosynthetic capacity. The pattern suggests that combined fertilization enhanced leaf expansion more than either method alone, and this concurs with the study that was carried out by (Akpa & Agah, 2019) Due to positive synergistic nutrient availability, granular application sustained season-long root uptake, while foliar application delivered rapid correction of any deficiencies during critical growth stages.

Since leaf number didn't differ significantly, the LAI increase must be driven by larger individual leaf size/area rather than more leaves, indicating fertilization primarily enhanced leaf expansion rate and area rather than leaf initiation.

For the case of biomass, all treatments that received granular fertilizer alone as well as those that received 500g of foliar fertilizer (T5) had similar ($p > 0.05$) biomass as the control (Table 4). The biomass weights for the rest of the treatments were significantly ($p < 0.05$) lower than that of the control. For those that received foliar fertilizer, the treatment that

received the highest amount of foliar fertilizer (500g) produced the highest amount of biomass (5.25 kg/plot) compared to the one that received the least amount of foliar fertilizer (4.99 kg/plot). No significant differences were observed among the treatments that received a combination of granular and foliar fertilizer.

This is the most agronomically interesting (and somewhat counterintuitive) result. Despite recording relatively lower leaf area index (LAI) and plant height, the control and lower-rate granular fertilizer treatments (125 g and 250 g) recorded the highest biomass yields (5.47–5.48 kg/plot). In contrast, the combined granular and foliar fertilizer treatments (T8, T9 and T10) recorded comparatively lower biomass yields (4.91–5.06 kg/plot), despite some of these treatments recording relatively higher values for particular vegetative growth parameters. This suggests that greater plant height or leaf area did not necessarily translate into greater measured biomass under the conditions of this experiment. This could have resulted from the luxury consumption/carbon allocation trade-off: High fertilizer combinations may have pushed plants toward vegetative luxuriance (tall stems, large leaf area) at the expense of dry matter accumulation efficiency, especially if excess nitrogen promoted succulent tissue with high water content and lower structural dry matter. Secondly, self-shading and reduced photosynthetic efficiency: Higher LAI can sometimes lead to increased mutual shading within the canopy, especially at high planting densities, which may reduce the net photosynthetic efficiency per unit leaf area despite the larger leaf surface. Lastly, possible antagonism between combined fertilizer sources. A recent review similarly emphasizes that foliar fertilization must be carefully optimized with respect to nutrient concentration, crop developmental stage, and environmental conditions to avoid leaf damage and maximize nutrient uptake (Fernández et al., 2024). Nevertheless, since leaf injury and foliar nutrient uptake were not directly measured in this study, foliar phytotoxicity cannot be confirmed as the cause of the lower biomass.

Combined Granular + Foliar treatments achieved the highest yield, better than the rest of the treatments. This strong performance suggests that these treatments achieved the best synergism between granular fertilizer (sustaining steady root-zone nutrient supply) and foliar fertilizer (delivering rapid, targeted nutrient correction during the reproductive stages (flowering and grain filling) as reported by Akpa & Agah (2019).

Foliar-only treatments followed the combined Granular + Foliar treatments in performance; however, there were no significant ($p > 0.05$) differences within the foliar-only treatments (Table 5). Granular-only treatments followed, and all three granular rates gave grain yields that were not significantly ($p > 0.05$) different from each other.

Beyond luxury consumption, this table is also consistent with well-documented soil-based nutrient loss pathways that limit the effectiveness of granular fertilizer, regardless of the amount applied. Leaching may have moved the mobile nutrients, such as nitrates, below the root zone before

uptake, particularly under heavy rainfall, reducing the proportion of applied fertilizer actually available to the plant (Gu *et al.*, 2023). Volatilization, especially of nitrogen in ammoniacal or urea-based granular forms, could have resulted in gaseous nitrogen loss to the atmosphere (Abalos *et al.*, 2014). In addition, immobilization may also have occurred, where soil microorganisms temporarily converted available nutrients into organic forms as they decomposed crop residues or soil organic matter, effectively locking nutrients away from plant uptake during the period they were needed (Kuzyakov & Xu, 2013). Together, these loss pathways mean that increasing the granular application rate does not guarantee a proportional increase in nutrient availability to the plant, since a variable and potentially substantial fraction of the added fertilizer may never reach the root system in a plant-usable form, explaining why yield failed to rise meaningfully between 125 and 500g.

Conclusion

The study concludes that fertilizer application significantly influences plant height to the tassel, leaf area index, biomass weight, and final yield but does not significantly affect the number of leaves, cobs per plant, or grain rows per cob. The significant effect on grain yield confirms that fertilizer application improves maize productivity, primarily through enhanced grain filling and kernel weight rather than through increased reproductive structures. The combination treatments, particularly the low-rate combination of granular and foliar fertilizers, achieved the highest grain yield, representing a doubling of yield over the control. The dose-dependent yield response indicates that moderate combined applications optimize nutrient availability for maize production, while high-rate treatments show diminishing returns.

Recommendation

Fertilizer demonstration plots should be established at community and parish levels to provide farmers with practical evidence of the effects of different fertilizer types, rates, and application methods. The demonstrations should compare unfertilized plots with granular fertilizer, foliar fertilizer, and appropriate combinations of the two. Such demonstrations would enable farmers to observe differences in crop growth, yield, and economic returns and could help correct misconceptions about fertilizer use while encouraging evidence-based fertilizer management.

Farmers should consider the moderate-rate combination of granular and foliar fertilizers demonstrated in this study, particularly under production conditions similar to those of the experiment. Treatment T10, comprising granular fertilizer at 125 g per plot combined with foliar fertilizer at 125 g per plot, recorded the highest net benefit of UGX 3,330,000 per hectare and a benefit-cost ratio of 2.42. This treatment therefore provides useful evidence of the potential economic and agronomic benefits of combining moderate rates of granular and foliar fertilizers. However, farmers

should receive guidance on the appropriate timing, method, and rate of application rather than simply increasing fertilizer quantities.

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List of abbreviations

ANOVA – Analysis of variance
DAP – Days after planting
HSD – Honestly significant difference
LAI – Leaf area index
NPK – Nitrogen, phosphorus and potassium
RCBD – Randomized complete block design

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Conflict of interest

The authors declare no conflict of interest.

Data availability

Data are available upon request from the author.

Author contributions

DT: conceptualization, methodology, investigation, writing the original draft.

BM: data curation, validation, supervision.

SK: supervision, validation

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References

1. Abalos, D., Jeffery, S., Sanz-Cobena, A., Guardia, G., & Vallejo, A. (2014). Meta-analysis of the effect of urease and nitrification inhibitors on crop productivity and nitrogen use efficiency. *Agriculture, Ecosystems & Environment*, 189, 136–144.
2. Akpa, E. A., & Agah, L. J. (2019). The effect of solid (granular) and liquid (foliar) fertilizer application on the growth and yield of maize (*Zea mays* L.) in soils of Obubra, Cross River State, Nigeria. *Asian Journal of Soil Science and Plant Nutrition*, 4(4), 1–8. <https://doi.org/10.9734/ajsspn/2019/v4i430053>
3. Brankov, M., Simić, M., Dolijanović, Ž., Rajković, M., Mandić, V., & Dragičević, V. (2020). The response of maize lines to foliar fertilizing. *Agriculture*, 10(9), 365. <https://doi.org/10.3390/agriculture10090365>
4. Fernández, V., & Brown, P. H. (2013). From plant surface to plant metabolism: The uncertain fate of foliar-applied nutrients. *Frontiers in Plant Science*, 4, Article 289. <https://doi.org/10.3389/fpls.2013.00289>
5. Fageria, N. K., Filho, M. P. B., Moreira, A., & Guimarães, C. M. (2009). Foliar fertilization of crop plants. *Journal of Plant Nutrition*, 32(6), 1044–1064. <https://doi.org/10.1080/01904160902872826>
6. Finez, D. D. E., & Talimbay, J. E. (2023). *Advantages and disadvantages of using inorganic fertilizers for agriculture*. 1(1), 1–8. <https://doi.org/10.5281/zenodo.8137249>
7. Gu, B., Zhang, X., Lam, S. K., Yu, Y., van Grinsven, H. J. M., Zhang, S., Wang, X., Bodirsky, B. L., Wang, S., Duan, J., Ren, C., Bouwman, L., de Vries, W., Xu, J., Sutton, M. A., & Chen, D. (2023). Cost-effective mitigation of nitrogen

- pollution from global croplands. *Nature*, 613, 77–84. <https://doi.org/10.1038/s41586-022-05481-8>
8. Gupta, A., & Hussain, N. (2014). A critical study on the use, application, and effectiveness of organic and inorganic fertilizers. *Journal of Industrial Pollution Control*, 30(2), 191–193.
9. Hignett, T. P. (2013). *Fertilizer manual*. Springer. <https://doi.org/10.1007/978-94-017-1538-6>
10. Kuzyakov, Y., & Xu, X. (2013). Competition between roots and microorganisms for nitrogen: Mechanisms and ecological relevance. *New Phytologist*, 198(3), 656–669.
11. Sara, D. S., Sofyan, E. T., & Joy, B. (2025). Effects of granular organic and inorganic fertilizer combinations on N, P, K uptake and sweet corn yield. *International Journal of Science and Research Archive*, 14(1), 1936–1940. <https://doi.org/10.30574/ijrsra.2025.14.1.0327>
12. Castro, S. A. Q., Schjoerring, J. K., & Henningsen, J. N. (2024). Foliar nitrogen and phosphorus fertilization. *Advances in Agronomy*, 187, 109–169. <https://doi.org/10.1016/bs.agron.2024.05.002>