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Influence of Timing of Basal Fertilizer Application on Growth and Yield of Maize (*Zea mays* L.) in the Guinea Savannah Agroecology of Ghana

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Abstract--The period of application of basal fertilizer in maize cultivation influences the yield of maize in Ghana. Therefore, inappropriate timing of basal fertilizer application in maize production is one of the major factors that reduces maize yield. Field experiments were conducted at the Tamale Technical University experimental field during the 2024 and 2025 cropping seasons from August to November each year to evaluate the effect of time of basal fertilizer application on the growth and yield of maize. The experiment was arranged in a Randomized Complete Block Design with three treatments and three replications. Data were collected on growth and yield parameters. The data were analyzed using analysis of variance, and treatment means were compared using the least significant difference test at a 5 % probability level. The results showed that timing of basal fertilizer application had a significant ($p < 0.05$) effect on the growth and yield parameters of maize. Maize plants that received basal fertilizer treatment at 4 WAP recorded the highest vegetative growth attributes while maize plants that received basal fertilizer treatment at 2 WAP produced the highest yield and yield components. The study concludes that the application of basal fertilizer at 2 WAP results in higher grain yield and yield components. It is therefore recommended that farmers apply basal fertilizer at 2 WAP to achieve optimum maize growth and grain yield.

Keywords— **basal fertilizer, Ghana, growth and yield parameters, guinea savannah, treatment, weeks after planting (WAP)**

INTRODUCTION

The domesticated maize initiated from human interaction with the wild undomesticated descendants, the teosinte of the parviglumis and Mexican subspecies (Zea mays ssp. Parviglumis) 9000 years ago in Mexico (Prasanna, 2021). Maize is the oldest and widely cultivated cereal in the world. It is the most cultivated crop and with highest total grain yield in the African continent (Prasanna, 2012). Maize is not only a food product but also a raw material for industrial use.

Maize is a tall, determinate annual C4 plant varying in height from 1 to 2 meters producing large, slender, opposite leaves whose lengths are about ten times their widths. The leaves are borne alternately along the length of a solid stem.The roots can move deeper into the soil thus improving the water and nutrients absorbing capacity of the crop. The leaves also have a higher transpiration rate and photosynthetic efficiency, enhancing the efficient use of chemical energy from sunlight for photosynthesis while regulating water loss by opening or closing the stomata, thus increasing the ability to produce carbohydrates for improved growth. Maize is highly tolerant to water stress and also easily adapt to poor soil conditions.

In Ghana, maize grows well in various ecological zones across the country (Angelucci, 2019). It is mostly produced by smallholder farmers under rain-fed conditions in Ghana. Maize accounts for at least 62 % of the total annual grain production (Obour *et al*., 2022). It is the primary staple food crop, supplying the most calories for the Ghanaian populace, and plays a critical role in ensuring household food security (Wongnaa *et al*., 2019). Despite maize's pivotal role in Ghana's economy, Assefa and Ayalew (2019) reported a significant decline in attainable grain yield per unit area. Average yield of maize is usually less than 2 tons/ha on farmers' fields compared with a potential yield of 6 tons/ha (MoFA, 2017). This yield gap is primarily attributed to the cumulative impact of abiotic and biotic stresses, such as poor soil fertility, inappropriate timing of fertilizer application, irratic rainfall pattern and the fall army worm infestation (Logah *et al.*, 2010). Trenberth *et al*. (2014) reported that the combined effects of the abiotic and biotic stresses pose significant threats to Ghana's maize production, food security, and economic stability.

Lucy *et al*. (1998) reported that the kind of crop cultivated dictates the time and frequency of fertilizer application. Some crops are high consumers of particular nutrients than the others. The authors also reported that maize is a high consumer of nitrogen and needs nitrogen application at four weeks after planting. The amount and time of NPK application are important management decisions for maize production. The aim of NPK management is to minimize loss and maximize crop up take (Grant *et al*., 1989). Despite the widespread use of fertilizers, maize yields remain low for many farmers, and this might be due to inapproprite timing of application.

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There is a need to determine the most appropriate time for basal fertilizer application that will enhance maize growth and yield. The study therefore sought to evaluate the effect of time of basal fertilizer application on the growth and yield of maize.

MATERIALS AND METHODS

Experimental site

The field experiments were conducted at the experimental field of the Faculty of Agriculture and Natural Resources, Tamale Technical University (TaTu) in the Northern region of Ghana during the 2024 and 2025 cropping seasons. The area records an annual rainfall of about 750 mm to 880 mm. The region experiences significant temperature variation, with average monthly temperature around 27º C (81 F). The hottest month is typically March, with temperature potentially reaching 41º C (106 F). In the dry season, the humidity from November to March is about 20 % to 30 %. In the wet season, the humidity from April to September is around 80-90 %. The soil of the experimental site is sandy–loamy which has high water holding capacity. The site's vegetation which consists of woodlands, trees and grasslands, with the Guinea Savanna being the wettest of the three Savanna Zones.

Site preparation, experimental design and planting

The land was cleared, ploughed, harrowed and ridged. The prepared land was then demarcated into 9 plots. The size of each plot was 3m x 3m. Three seeds were planted per hill and later on thinned to two seedlings per hill. Spacing within the rows of plants was 35 cm, whiles spacing between the rows of plants was 75 cm. The design used was a Randomized Complete Block Design with three replications. The NPK fertilizer (15:15:15) was applied at the rate of 60 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1} as basal fertilizer. There were three different timing regimes of NPK basal fertilizer application; application at planting, application at 2 weeks after planting, and application at 4 weeks after planting. Urea was also applied as a top dress at the rate of 30 kg N ha^{-1} two weeks after the basal fertilizer treatments. The maize variety (lake) was used for this study.

Cultural practices

Weeding was done manually. The first weeding was done at two weeks after planting. The second, third and fourth weeding were done at the 5, 8 and 11 weeks after planting respectively. The control of pests (fall army worm) was done at the third week after planting by spraying the field with neem extract. The spraying of the field with the neem extract was repeated at the sixth week after planting.

Data collection and statistical analysis

Field measurements were taken on a number of growth and yield parameters including the following: plant height, number of leaves, leaf area, dry biomass weight, root length, days to 50 % tasselling, days to 50 % pollen shed, days to 50 % silking, anthesis-silking interval, grain yield, 100-grain weight, cob length, number of ears per plant and number of kernels per cob. The data for the 2024 and 2025 field studies were combined and analyzed using Gent Stat statistical package edition 12. Analysis of Variance (ANOVA) was then computed and the means separated using the Least Significant Difference (LSD) at 5 % level of probability. Correlation analysis was also done to determine the relationship among the growth and yield parameters.

RESULTS AND DISCUSSIONS

Plant height

There was a significant difference (P<0.05) among treatments with respect to plant height (Table 1). The application of basal fertilizer at four weeks after planting (4 WAP) recorded the highest plant height of 74.45 cm while the basal fertilizer application at two weeks after planting (2 WAP) recorded the lowest plant height of 63.45 cm (Figure 1). The application of basal fertilizer at 4 WAP was significantly different from that of the basal fertilizer application at 2 WAP, but was however, not significantly different from the application of basal fertilizer at planting which produced a plant height of 72.8 cm.

Table 1. Combined analysis of variance for maize growth and yield parameters as affected by time of basal fertilizer application during the 2024 and 2025 cropping seasons.

Source of Variation	df	Plant Height (cm)	Leaf Area (cm²)	Dry Biomass Weight (kg/plot)	Root Length (cm)	Days to 50% pollenshed	Grain yield (kg/ha)	Hundred Seed Weight (kg)	Cob Length (cm)
Treatment (T)	2	0.015	0.026	0.001	0.006	0.809	0.016	0.003	0.009
Replication (R)		0.107	3.986	8.167	0.470	4.167	0.049	4.167	1.307
TxR	2	0.214	36.430	16.330	0.941	8.333	0.097	8.334	2.613
Residual	2								
Total	6								
SE		1.0350	20.010	0.0004	0.1594	9.2300	0.0748	27.000	0.4810
CV(%)		1.5	6.0	0.7	0.9	14.7	3.7	6.1	2.3

SE means Standard Error; CV = Coefficient of Variation

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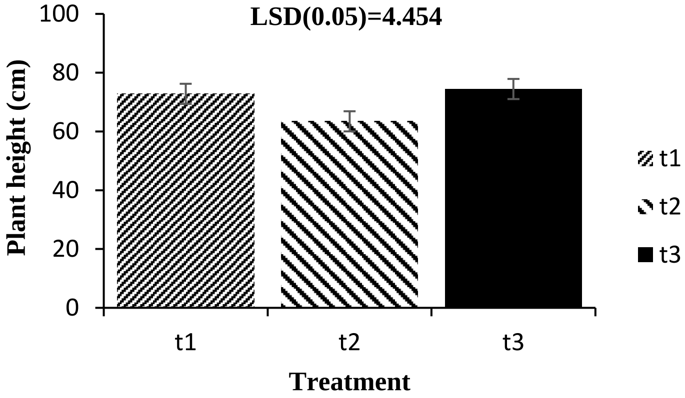

Figure 1. Influence of time of basal fertilizer application on plant height during the 2024 and 2025 cropping seasons. Measurements were done at 6 weeks after planting (WAP).
t1= application of basal fertilizer at planting; t2= application of basal fertilizer at 2 WAP; t3= application of basal fertilizer at 4 WAP. Error bars represent standard error of means.

The application of NPK basal fertilizer at 4 WAP produced the highest plant height as compared to the basal fertilizer application during planting and at 2 WAP. This finding is probably as a results of the fact that the plants given the basal fertilizer at 4 WAP were able to effectively utilize the nutrients for growth and development at the time of application. This finding contravenes the report of Alvarado *et al*. (2022) who emphasized the importance of early fertilization for optimizing growth and yield in leguminous crops. The authors added that early nutrient availability allows plants to allocate more resources to growth, leading to improved overall biomass production. The application of basal fertilizer during planting probably was not appropriate because the nutrients would have been leached and therefore unavailable for the utilization of the plants during the period of growth and development. The application of basal fertilizer at 2 WAP probably was not also appropriate because, the nutrients were applied rather too early for plants to judiciously utilize it for their growth and development. This might have resulted in the production of relatively shorter plants as compared to plants that were given basal fertilizer at 4 WAP.

Dry biomass weight

There was a significant difference ($P<0.05$) among treatments with respect to dry biomass weight (Table 1). The basal fertilizer application at 4 WAP recorded the highest dry biomass weight (0.062 kg/plot) while the basal fertilizer application at 2 WAP recorded the lowest dry biomass weight of 0.045 kg/plot (Figure 2). Basal fertilizer application at 4 WAP was significantly different from the application at 2 WAP, but not significantly different from application at planting which produced a biomass weight of 0.0575 kg/plot.

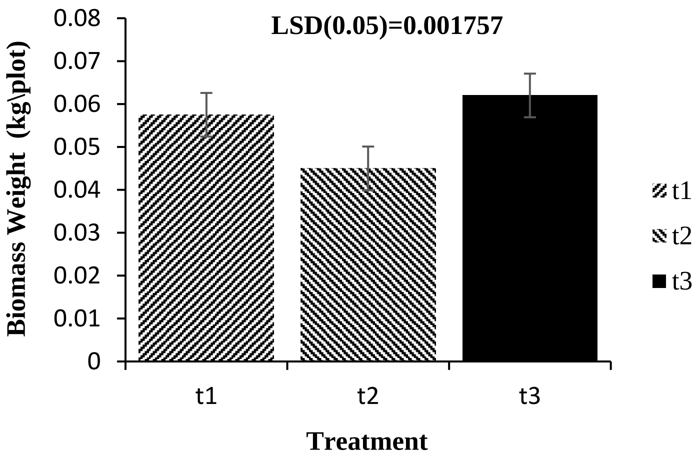

Figure 2. Influence of time of basal fertilizer application on dry biomass weight during the 2024 and 2025 cropping seasons. Measurements were done at 6 weeks after planting (WAP).
t1= application of basal fertilizer at planting; t2= application of basal fertilizer at 2 WAP; t3= application of basal fertilizer at 4 WAP. Error bars represent standard error of means.

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The application of NPK basal fertilizer at 4 WAP produced the highest dry biomass weight as compared to the basal fertilizer application during planting, and the application at 2 WAP. This finding might have occurred as a results of vigorous growth, greater leaf expansion and enhanced photosynthesis, which translated into higher accumulation of dry matter. This finding contravenes the report of Bhat *et al*. (2022) who observed that early nutrient uptake plays a significant role in the early establishment of plants, and that the poor performance of fish bean in the plots treated with fertilizer after flowering suggests that late application of fertilizer was not beneficial to plant growth and biomass yield. The application of basal fertilizer during planting was probably not the appropriate time because the nutrients would have been lost to the plants, through run-off, during their growth and development period; leading to the accumulation of moderate to low dry biomass weight of the plants. The application of basal fertilizer at 2 WAP probably was also not appropriate because, the nutrient was applied too early to contribute much to a leaf or stem expansion, canopy size and photosynthetic capacity, leading to low dry biomass accumulation. This might have resulted in the production of relatively lower dry biomass weight as compared to both plants that were given fertilizer at planting and 4 WAP.

Days to 50 % pollen shed

There was no significant difference (P>0.05) among the treatments with respect to days to 50 % pollen sheds (Table 1). The basal fertilizer application at 2 WAP recorded the highest number of days to 50 % pollen shed (65 days) while the basal fertilizer application at 4 WAP recorded the lowest number of days to 50 % pollen shed (60 days) (Figure 3). The basal fertilizer application at 2 WAP was significantly different from that of fertilizer application at 4 WAP in terms of days to 50 % pollen shed, but was however, not statistical different from fertilizer application at planting which took 63 days for 50 % pollen shed.

The application of NKP basal fertilizer at 2 WAP produced the highest number of days to 50 % pollen shed as compared to the basal fertilizer application during planting and at 4 WAP. The basal fertilizer applied at 2 WAP might have been leached and was therefore unavailable at the root zone for the utilization by the plants for their growth and development. This might have slowed down the physiological readiness, there by delaying tassel formation and pollen shedding. The fertilizer application during planting was probably not the right time because the seeds had not germinated to utilize the nutrients. Therefore, the nutrients would have been absorbed by other soil organisms such as fungi, algae, and earth worms and therefore unavailable for the utilization of the plants during the period of growth and development. This would have slowed down the plants' transition to the reproductive stage. Consequently, resulting in delayed pollen shed among the affected plants. The application of fertilizer at 4 WAP is probably the most appropriate time because, the nutrient was utilized by the plant. As a result of this, tassel development and pollen shed occurred earlier. This might have resulted in the lowest number of days to pollen shed.

Leaf area

There was significant difference (P<0.05) among treatments with respect to leaf area (Table 1). The basal fertilizer application at 4 WAP recorded the highest leaf area (0.0393 m²) while basal fertilizer application at 2 WAP recorded the lowest leaf area of 0.0304 m² (Table 2). Fertilizer application at 4 WAP was significantly different from that of the fertilizer application at 2 WAP, but was not significantly different from fertilizer application at planting which produced a leaf area of 0.0377 m².

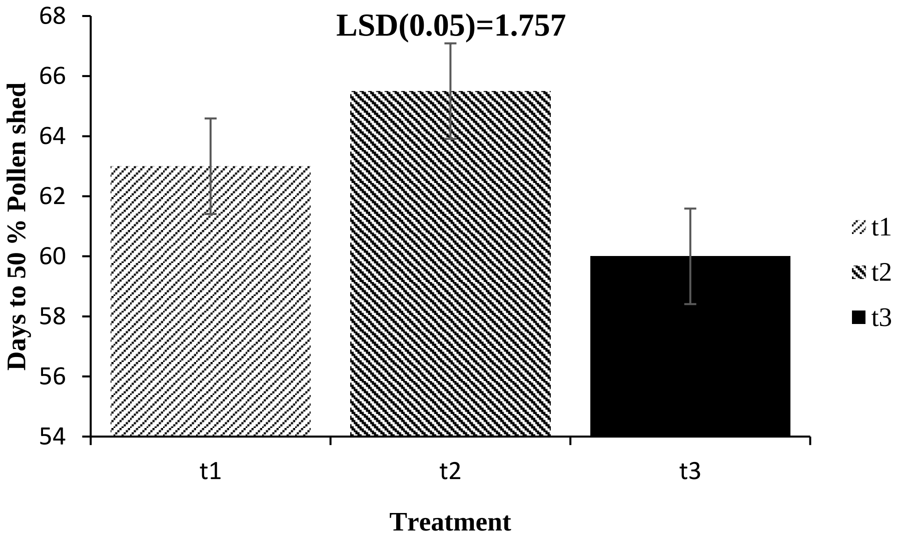

Figure 3. Influence of basal fertilizer application on days to 50 % pollen shed during the 2024 and 2025 cropping seasons. Measurements were done at 6 weeks after planting (WAP).
t1= application of basal fertilizer at planting; t2= application of basal fertilizer at 2 WAP; t3= application of basal fertilizer at 4 WAP. Error bars represent standard error of means.

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Table 2. Variation in time of basal fertilizer application and its effect on growth and yield of maize.

Treatment	Grain Yield (kg/ha)	Leaf Area (m^2)	Cob Length (cm)	Hundred-Seed Weight (kg)
Basal fertilizer application at planting	1722.22	0.0377	18.1	0.0205
Basal fertilizer application at 2 WAP	2533.33	0.0304	24.8	0.0300
Basal fertilizer applicationat at 4 WAP	2500.00	0.0393	19.3	0.0230
Mean	2251.850	0.0358	20.73	0.0245
LSD (0.05)	357.770	0.0092	2.071	0.0017
SE	216.619	0.3645	0.660	0.0011
CV (%)	13.7	10.9	3.2	4.8

SE = Standard Error; LSD = Least Significant Difference; CV = Coefficient of Variation; WAP = Weeks After Planting

The application of basal fertilizer at 4 WAP produced the highest leaf area as compared to the basal fertilizer application during planting and fertilizer application at 2 WAP. This is probably as a result of the fact that, the plants given the fertilizer at 4 WAP were able to effectively utilize the nutrients. This enhanced chloropyll development and improved photosynthetic capacity, resulting in leaf expansions and canopy cover development. This increased light interception and photosynthesis. This finding is in line with the report of Lucy *et al*. (1998) who observed that maize is a heavy feeder of nitrogen and that, it requires nitrogen application at four weeks after planting. The application of fertilizer during planting probably was not appropriate because the nutrient would have been lost to the plants through leaching, thereby negatively affecting growth and development, which might have caused the reduction in chlorophyll content, leaf expansion and canopy cover. The application of fertilizer at 2 WAP probably was not appropriate because, the nutrients were applied too early for the plant to utilize it for growth and development of the leaf. This might have resulted in the production of relatively narrow leaf area as compared to plants that were given fertilizer at 4 WAP.

Hundred-seed weight

There was a significant difference (P<0.05) among treatments with respect to hundred-seed weight (Table 1). The basal fertilizer application at 2 WAP recorded the highest hundred-seed weight (0.0300 kg) while basal fertilizer application at planting recorded the lowest hundred seed-weight of 0.0205 kg (Table 2). The fertilization at 2 WAP was significantly different from that of fertilization at planting, but was however, not significantly different from fertilization at 4 WAP which produced a hundred-seed weight of 0.0230 kg. The application of NPK fertilizer at 2 WAP produce the highest hundred-seed weight as compared to the fertilizer application at planting and fertilizer application at 4 WAP. This might be due to the availability of nitrogen during flowering and silking, which could have enhanced the formation and development of kernel as compared to fertilizer application at planting and at 4 WAP. This study corroborates the observation mady by Obi *et al*. (2005) who reported that the availability of sufficient growth nutrients resulted in improved cell activities, enhanced cell multiplication, plant growth, high dry matter production and kernel development.

The application of basal fertilizer at planting probably did not make nutrients available during the flowering stage of the plant growth, resulting in less kernel formation and development. This might have resulted in the production of relatively lower amount of hundred-seed weight as compared to fertilizer application at 2 WAP.

Grain yield

There was a significant difference (P<0.05) among treatments with respect to grain yield (Table 1). Basal fertilizer application at 2 WAP recorded the highest grain yield of 2533.33 kg/ha while application at planting recorded the lowest grain yield of 1722.22 kg/ha (Table 2). The application of fertilizer at 2 WAP was significantly different from fertilizer application at planting, but was however, not significantly different from fertilizer application at 4 WAP which produced a grain yield of 2500 kg/ha. The application of basal NPK fertilizer at 2 WAP produced the highest grain yield per hectare as compared to the NPK applications during planting and at 4 WAP. This is probably because, at the critical stage of plant development during flowering, the nutrients were readily available for the plants utilization which enhanced grain filling as compared to the fertilizer application at planting. Similarly, Ndor and Faringoro (2020) investigated the effect of time of application of NPK fertilizer on the performance of cowpea, and reported that plots that received NPK fertilizer earlier at 2 WAP were superior in both vegetative and yield performance relative to when NPK fertilizer was applied prior to flowering. The application of fertilizer during planting probably was not appropriate because the nutrients would have leached and/or utilized by other competing organisms such as weeds, fungi and earth worms, and was therefore unavailable for the plants' utilization during the period of flowering and grain filling. This was probably the reason which led to poor grain filling and subsequently, low grain yield among the affected plants. This might have resulted in the production of relatively low grain yield as compared to both plants that were given fertilizers at 2 WAP and 4 WAP.

Correlation among growth and yield parameters of maize

The correlation coefficients among selected growth and yield parameters of maize are presented in Table 3. The results reveal both positive and negative relationships among the studied traits. These relationships indicate how different parameters influence one another during plant growth and yield formation. Grain yield showed significant positive correlation with number of leaves (0.5483*), leaf area (0.0251*), number of kernels per cob (0.6015**), and cob length (0.8843*). This implies that, when the number of leaves, leaf area, number of kernels per cob, and cob length

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Table 3. Phenotypic correlation co-efficients among growth and yield parameters of maize.

	Plant Height (cm)	Number of Leaves	Number of Ears Per Plant	Days to 50 % Tasseling	Days to 50 % Pollen Shed	Leaf Area (m²)	Root Length (cm)	No of Kernels per Cob	Cob Length (cm)	Grain Yield (Kg/ha)	Hundred-Seed Weight (kg)
Plant Height (cm)	-										
Number of Leaves	0.6167^{ns}	-									
Number of Ears Per Plant	0.0000^{ns}	0.0000	-								
Days to 50 % Tasselling	-0.8139^{ns}	-0.7833*	0.0000^{ns}	-							
Days to 50 % Pollen Shed	-0.9098^{ns}	-0.7585*	0.0000^{ns}	0.9398*	-						
Leaf Area (m²)	0.9551^{ns}	0.7318^{ns}	0.0000*	-0.7370*	-0.8688*	-					
Root Length (cm)	0.3162^{ns}	-0.3195^{ns}	0.0000^{ns}	0.2450^{ns}	0.0160^{ns}	0.3256^{ns}	-				
No. of Kernels per Cob	-0.4379^{ns}	0.3725*	0.0000^{ns}	-0.0122*	-0.1413*	0.2989*	-0.8613^{ns}	-			
Cob Length (cm)	0.1793^{ns}	0.6713^{ns}	0.0000^{ns}	-0.3979^{ns}	-0.3828^{ns}	0.3226^{ns}	0.1705*	0.2993^{ns}	-		
Grain Yield (Kg/ha)	-0.1903*	0.5483*	0.0000^{ns}	-0.1573*	-0.0346*	0.0251*	-0.4474*	0.6015**	0.8843*	-	
Hundred-Seed Weight (Kg)	0.2507^{ns}	0.1826*	0.0000^{ns}	-0.0999*	-0.3541*	0.3467*	0.3916*	0.1991^{ns}	0.5502^{ns}	0.1977*	-

*Significant at $P<0.05$, **Significant at $P<0.01$ and ^{ns}Non-significant at $P>0.05$

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increase grain yield also increases and vice versa. However, there was a significant negative correlation between grain yield and that of plant height (-0.1903*), days to 50 % tasseling (-0.1573*), days to 50 % pollen shed (-0.0346*), and root length (-0.4474*). This implies that grain yield increases with decreasing plant height, days to 50 % tasseling, days to 50 % pollen shed, and root length, and vice versa.

Conclusion and Recommendations

Conclusion

The timing of basal fertilizer application significantly affects maize growth and yield in the Guinea Savannah agroecology of Ghana. Application at 2 weeks after planting (WAP) improved grain yield, cob length, and 100-seed weight, while application at 4 WAP enhanced vegetative traits such as plant height, leaf area, root length, and biomass weight. Therefore, farmers aiming for higher grain yield should apply basal fertilizer at 2 WAP, whereas those targeting increased biomass should apply it at 4 WAP. Extension services are encouraged to guide farmers on optimal fertilizer timing, and further research should explore interactions with different maize varieties and soil fertility levels to refine these recommendations.

Furthermore, future research will explore using wireless sensor networks (WSNs) to optimize basal fertilizer application, specifically targeting the planting stage (0-7 days after planting). The WSNs will provide real-time data, enabling precise, automated fertilizer application for healthy growth and yield of maize while reducing environmental waste.

Data Availability

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Conflict of Interest

The authors have declared no conflicts of interest.

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Author Contributions

Alhassan Bawa: Conceptualization; Investigation; Supervision; Data curation; Formal analysis; Writing – original draft. Mansuru Salifu: Conceptualization; Data curation; Formal analysis; Supervision; Writing – review & editing. Abdul Fatawu Yakubu: Conceptualization; Data curation; Formal analysis; Project administration; Writing – review & editing. Fuseini Jibreel: Conceptualization; Data curation; Formal analysis; Project administration; Writing – review & editing.

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