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Research Article

Response of Two Maize (*Zea mays* L.) Varieties to Times of NPK (15-15-15) Fertilizer Application

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Nitrogen rate and time of application are among the major abiotic factors limiting the productivity of maize. The research was, therefore, carried out to examine the response of two maize varieties (Omankwa and Pioneer hybrid) to four different times of N : P : K 15 : 15 : 15 fertilizer application during the major growing season in Ghana. The experiment was arranged in a randomized complete block design with eight treatment combinations with three replications. Our findings showed that the two maize varieties responded to the time of fertilizer application differently. The interactive effect indicated that the application of fertilizer during planting produced the highest grain yield (4.7 tons ha^{-1}) of the Omankwa (open-pollinated variety) while the application of fertilizers two/four weeks after planting increased the grain yield (6.5 tons ha^{-1}) of the hybrid. The growth and yield parameters were not significantly affected by the treatment combinations. In order for farmers to obtain good yield, it is recommended that farmers should apply N : P : K 15 : 15 : 15 during planting for the Omankwa variety and 14/28 days after planting for the Pioneer hybrid variety in Ghana.

1. Introduction

In Ghana, maize is the most produced and consumed cereal crop with an increasing trend in its production [1] with an estimate of 750,000 ha as the annual production [2]. The production of maize is mainly done under rainfed conditions by under-resourced small holder farmers [3]. The crop is a great provider of calories and has virtually overcome millet and sorghum as a traditional staple food crop in northern Ghana [4]. Amanor-Boadu [5] reported that different traditions and culture influenced the consumption of the grain, and a large quantity is used as feed in the poultry industry. However, failure of maize to produce higher grains is as a result of inadequate supply of nutrients [6]. Furthermore, the reduction in the yield of the maize can be attributed to factors such as drought, pest and weed infestation, and limited use of improved seeds and fertilizers as well as low soil fertility [7]. Also, Adediran and Banjoko [6] found that using inorganic fertilizers on crops boosted yield, as there was a significant depletion of nutrients in yields where there is no application of NPK fertilizer.

Therefore, to produce maize successfully depends on the right application of production inputs that will maintain the environment as well as agricultural production. These inputs are soil tillage, weed control, application of fertilizers, and time of application. However, crop type influences the timing and amount of fertilizer application since some crops feed more on a particular nutrient than the others. For instance, maize consumes a lot of nitrogen; hence, it requires nitrogen application at four weeks after planting [8]. Also, Amali and Namo [9] observed that there was a high leaf area index of maize due to early application of fertilizer than late application of fertilizer. According to Sherchan et al. [10], maize responds to nitrogen and its application time changes due to the growing season, maturity period, and the genetic makeup of the crop. The time of fertilizer application can

influence the growth and yield of maize but the results of several studies have been inconsistent [11]. However, in Ghana, there is insufficient or no research on the effect of the timing of nitrogen fertilizer application to different varieties of maize. The study seeks to examine the response of two maize varieties (Omankwa and Pioneer hybrid variety) to times of N : P : K 15 : 15 : 15 fertilizer application.

2. Materials and Methods

2.1. Experimental Site Description and Experimental Layout. Field experiment was conducted at the Teaching and Research Module farm of the Department of Horticulture and Crop Production, University of Energy and Natural Resources, Dormaa Ahenkro Campus. The experimental site lies between latitude 7° 16′ 27.948″ N and longitude 2°47′ 53.714″ W in a semideciduous rainforest ecological zone in Ghana. The area experiences a bimodal rainfall pattern where the first rainy season starts from March to June and the second rainy season starts from August to October. The highest mean temperature of the district is about 30°C.

Our experiment was laid in a randomized complete block design with three replications. There were two factors, namely, (i) maize varieties (Omankwa and Pioneer Hybrid which were sourced from the Ministry of Food and Agriculture (MoFA), Dormaa Ahenkro) and (ii) time of fertilizer application. The experiment consisted of two controls (checks) due to the use of different maize varieties. The recommended dose of fertilizer was applied at 90 kg·N·ha^{-1}. The application of the fertilizer was performed using the split application method. The first application (60 kg·N·ha^{-1} of NPK 15 : 15 : 15) was performed per the various treatment application and the second application (30 kg·N·ha^{-1} of ammonium sulphate ($(NH_4)_2SO_4$)) was applied 6 weeks after sowing of the maize seeds to all the treatments except the control plots. The treatment combinations are shown in Table 1, and we replicated the treatments three times.

2.2. Land Preparation. The land was demarcated and cleared. The cleared weeds were left on the land to serve as mulch to help conserve moisture. The land was lined and pegged. The plot size was 15 m × 33 m (495 m^2) with 24 plots in total and 8 plots per replication. Each replication (block) consisted of 8 treatments with an alley of 2 m between each replication. The maize seeds were sown one seed per stand at a spacing of 75 cm × 25 cm. Planting was conducted in May, 2021. Regular weeding of the field was carried out throughout the experimental period. Defiance 4.8% ME with the active ingredient emamectin benzoate was sprayed to control the effect of harmful pests such as fall army worm on the maize plants. Other agronomic practices were similar to the local cropping techniques for high yield in Ghana.

2.3. Determination of Soil Physical and Chemical Properties. Before the land preparation, we collected soil samples with an auger from the experimental field at a depth of 0–20 cm for soil physical and chemical properties analysis at the Soil Science Laboratory of the Kwame Nkrumah University of Science and Technology, Kumasi. For the physical and chemical analysis, the standard procedures described by Motsara and Roy [12] was followed.

2.4. Determination of Growth and Yield of Maize. We collected the growth and yield data from five (5) tagged plants. The growth data was collected from 2 weeks after planting (WAP) to 5 weeks after planting. The data collected on the growth parameters were the number of leaves per plant, leaf area (cm^2), plant height (cm), and stem girth (cm). The number of leaves per plant was counted from the maize plant; the leaf area was calculated using the formula proposed by Egharevba et al. [13] and Qian et al. [14] as lamina length x maximum width x 0.75; the plant height was measured using a measuring tape from the ground to highest insertion of the last uppermost; and the stem girth was measured using a Vernier caliper. Data on the yield included cob length (cm), number of grains per cob, 1000 seed weight (g), and the grain yield (tons/ha). The cob length was measured using a measuring tape; number of grains per cob was counted on the tagged plants in each plot; 1000 seed weight of dried maize seeds from each treatment was counted; and the grain yield was weighed using a Scout STX2201 weighing scale (OHAUS Corporation, Parsippany, NJ 07054, USA).

2.5. Statistical Analysis. The data collected on the growth and yield of maize were subjected to the general analysis of variance using GenStat Release 11.1 (Copyright 2008, VSN International Ltd.). The post hoc comparison of mean separation was carried out using the least significant difference (LSD) at $p = 0.05$ probability level. The graphs were plotted using SigmaPlot for windows version 11.0.

3. Results

3.1. Initial Soil Characteristics. The initial physical and chemical properties of the soil at the experimental site are presented in Table 2. The results of the analysis showed that the soil was loamy in texture with sand making 48.08% of the particles. The soil has a pH value of 5.99 which is slightly acidic with very low organic carbon (0.998%) and organic matter (1.72%). Similar results were obtained by Essel et al. [15].

3.2. Effect of Different Times of NPK Fertilizer Application on the Growth Parameters of Maize

3.2.1. Plant Height (cm). There was a marginal increase in the plant height from 2WAP to 5WAP (Figure 1). At 5WAP, the application of the fertilizer for the Omankwa variety saw treatment T3 recording the highest plant height (141.46 cm) whereas treatment T1 recorded the lowest plant height (131.33 cm). Furthermore, in the case of the Pioneer variety, treatment T3 recorded the highest plant height while treatment T1 recorded the least (136.87 cm).

Table 1: Treatments used in the experiment.

S/N	Treatments combination	Abbreviations
1.	Omankwa + application of NPK at planting	V1T1
2.	Omankwa + application of NPK 14 days after planting	V1T2
3.	Omankwa + application of NPK 28 days after planting	V1T3
4.	Omankwa + zero application of NPK (control)	V1T4
5.	Pioneer hybrid + application of NPK at planting	V2T1
6.	Pioneer hybrid + application of NPK 14 days after planting	V2T2
7.	Pioneer hybrid + application of NPK 28 days after planting	V2T3
8.	Pioneer hybrid + zero application of NPK (control)	V2T4

Table 2: Initial soil characteristics at a depth of 0–20 cm from the experimental plot prior to sowing of maize seeds.

Soil properties	Values
Chemical properties	
pH (1 : 2.5, H_2O)	5.99
Available P (mg/kg)	33.61
Total N (%)	0.14
Exchangeable bases (cmol/kg)	
K^+	0.795
Ca^{2+}	2.2
Mg^{2+}	1.2
Na^+	0.078
Exchangeable acidity (cmol/kg)	
Al^{3+}	0.418
H^+	0.217
Soil organic carbon (%)	0.998
Soil organic matter (%)	1.72
Physical properties	Soil
Sand (%)	48.08
Clay (%)	16.04
Silt (%)	35.88
Textural class	Loam

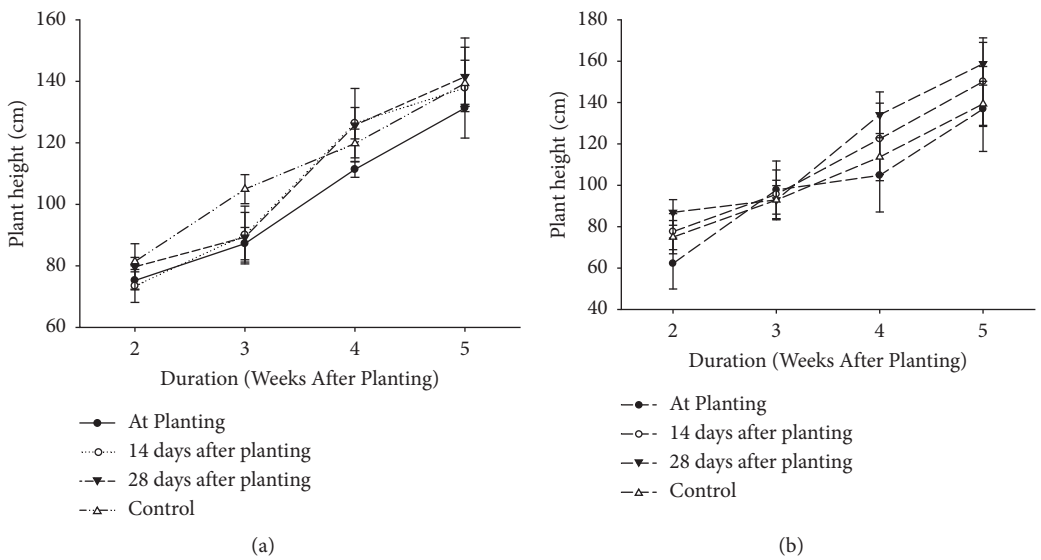

Figure 1: Effect of different times of fertilizer application on the plant height (cm) of (a) Omankwa variety and (b) Pioneer hybrid variety of maize.

3.2.2. Stem Girth (cm). The stem girth of the maize plants increased with increasing day. The widest stem girth was recorded from treatment T2 (8.10 cm) while the smallest was recorded from the control (T4) (7.33 cm) for the Omankwa variety. Nonetheless, for the Pioneer variety, treatment T3 recorded the largest stem girth (9.23 cm) whereas the smallest stem girth was recorded from treatment T1 (Figure 2).

3.2.3. Number of Leaves. There was a gradual increase in the number of leaves with respect to the weeks after planting for both varieties of maize (Figure 3). During 5WAP, the highest number of leaves (15.27) was recorded in treatment T2 while the lowest was recorded from treatment T3 (14.77) for the Omankwa variety. However, for the Pioneer hybrid variety, the highest number of leaves (16.43) was recorded in treatment T3 whereas treatment T1 recorded the lowest number of leaves (14.60).

3.2.4. Leaf Area (cm^2). Figure 4 shows the effect of different times of fertilizer application on the leaf area of different varieties of maize. After 5WAP, treatment T3 recorded the highest leaf area (650.41 cm^2) whereas treatment T1 produced the least leaf area (511.52 cm^2) for Omankwa variety. With regards to the pioneer hybrid variety, the highest leaf area was recorded from treatment T4 (control) (708.68 cm^2) and the least leaf area was recorded in treatment T1 (602.29 cm^2).

3.3. Effect of Different Time of NPK Fertilizer on the Yield Parameters of Maize. The mean (±SD) of the yield parameters (cob length (cm), number of grains per cob, 1000 seeds weight (g) and the grain yield (tons ha^{-1})) of the maize plant is presented in Table 3. The analysis of variance of the statistical analysis showed statistical significant difference ($p < 0.05$) of effect of the various treatments on the varieties (Table 4).

3.3.1. Cob Length. For the Omankwa variety, the longest cob length (14.54 cm) was recorded from the application of the fertilizer after 28 days of planting whereas the application of no fertilizer (control) recorded the least cob length (13.11 cm). However, for the Pioneer hybrid variety, the application of the fertilizer at the time of planting, produced significantly the longest cob length (16.47 cm) while the lowest cob length (14.03 cm) was recorded from the application of the fertilizer 14 days after planting (Table 3).

3.3.2. Number of Grains per Cob. The highest mean number of grains per cob for the Omankwa variety was recorded from the application of the fertilizer after 28 days of planting whilst the least was recorded from the application of fertilizer 14 days after planting. In the case of the Pioneer variety, the application of the fertilizer 14 days after planting produced the largest number of grains per cob whereas the application of the fertilizer during planting produced the lowest number of grains per cob (Table 3).

3.3.3. 1000 Seeds Weight. The highest 1000 seeds weight for the Omankwa variety was recorded from application of fertilizer during planting and the lowest recorded from the application of the fertilizer after 28 days of planting. Nevertheless, for the Pioneer hybrid variety, the highest seed weight was recorded from application of the fertilizer after 28 days of planting while the least was recorded from application of fertilizer during planting (Table 3).

3.3.4. Grain Yield. The application of fertilizer during planting produced the highest grain yield (4.68 tons ha^{-1}) followed by application of the fertilizer after 28 days of planting (4.07 tons ha^{-1}) whilst the lowest grain yield was recorded from the application of fertilizer 14 days after planting in the Omankwa variety. However, for the pioneer hybrid variety, the application of the fertilizer after 28 days of planting recorded the highest grain yield (6.55 tons ha^{-1}) while application of fertilizer during planting recorded the lowest (5.62 tons' ha^{-1}) (Table 3).

4. Discussion

The time of fertilizer application plays a significant role on the yield of crops. The wrong time of fertilizer application might affect the loss of the nutrient and leads to wastage of the fertilizer as well as damaging the crop. However, in view of that the right time of applying fertilizer to crops influences the yield, nitrogen use efficiency, and reduces the loss of nutrients which prevents environmental damage as a result of leaching. The different times of fertilizer application to the various maize varieties marginally improved on the growth and yield of the maize plant. The earlier application of fertilizer enhances the production of leaf and leaf area index [9] and also promotes the growth and formation of healthy leaves [16]. According to Debele et al. [17], the best time of fertilizer application for large scale production of maize is during planting. The growth of the maize plants increased at a marginal rate for all the growth parameters studied over time. Several authors [18, 19] ascertained that N applied to maize plant is not effectively recovered when the fertilizer is applied during the time of planting due to the growth and development of the nodal root.

In determining the grain yield of maize, the number of grains per cob plays a crucial role. However, findings from our study indicate that an increase in the 1000 seeds weight contributed to the grain yield for both varieties. Amali and Namo [9] studied the effect of time of fertilizer on the growth and yield of maize. In their study, they reported that the application of fertilizer application early at 2 weeks after planting influences the yield of the maize. Similar observation was recorded for the Omankwa variety. However, the results obtained from their study was contrary to our findings for the Pioneer hybrid variety were the application of fertilizer after 28 days of planting produced the highest grain yield. In the study of Sangoi et al. [20], the late

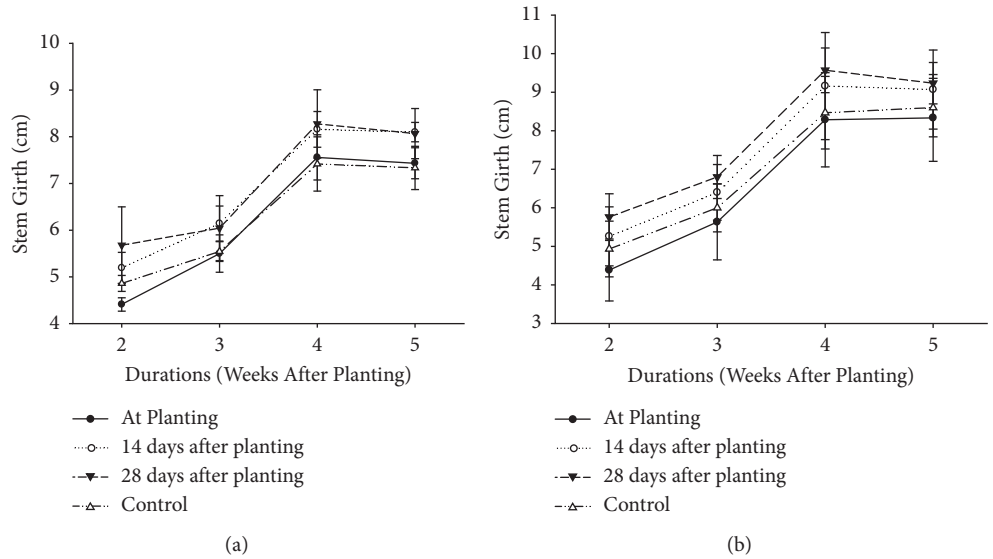

Figure 2: Effect of different time of fertilizer application on the stem girth (cm) of (a) Omankwa variety and (b) Pioneer hybrid variety of maize.

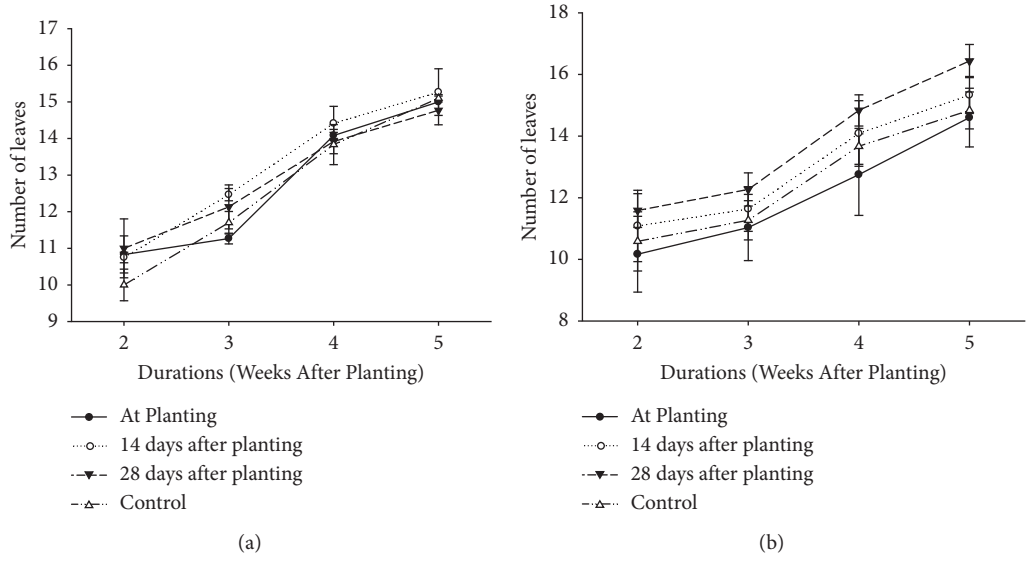

Figure 3: Effect of different times of fertilizer application on the number of leaves of (a) Omankwa variety and (b) Pioneer hybrid variety of maize.

application of fertilizers significantly influences the grain yield of the maize as compared to the application of the fertilizer during the time of planting. Abebe and Feyisa [21] also confirmed that the application of fertilizer during 10–15 days after planting significantly influences the yield.

Katsvairo et al. [22] reported that different varieties of maize differ in their response to nitrogen fertilizer application. The results of the present study showed that the grain yield of the Pioneer hybrid variety was greater than the grain yield obtained for the Omankwa variety which could be attributed to different ways of nutrient accumulation and use efficiency. In addition, the yield of the best performing fertilizer application time for both varieties yielded 4.68 and 6.50 tons ha^{-1} respectively in our present study and was

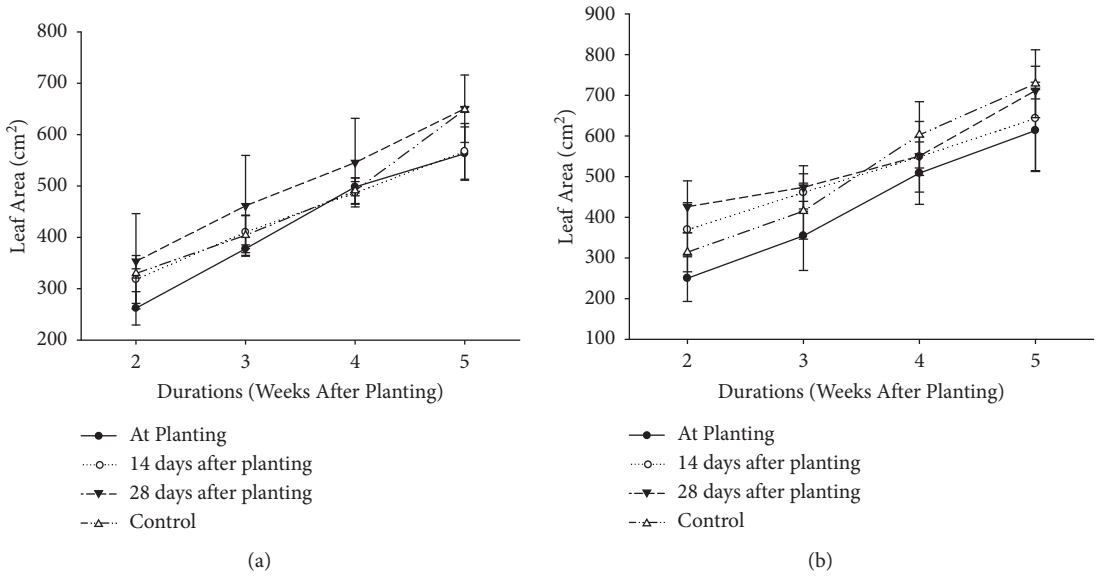

Figure 4: Effect of different time of fertilizer application on the leaf area (cm^2) of (a) Omankwa variety and (b) Pioneer hybrid variety of maize.

Table 3: The interaction effect of the response of the maize varieties to different the time of fertilizer application on the yield and yield components.

Treatments	Cob length (cm)	NGCOB	1000 SW (g)	Grain yield (tons ha^{-1})
V1T1	$14.51^a \pm 0.87$	$382.27^a \pm 38.19$	$339.03^a \pm 27.17$	$4.68^a \pm 0.53$
V1T2	$14.43^a \pm 1.73$	$314.80^a \pm 18.90$	$328.27^a \pm 15.01$	$3.70^a \pm 0.41$
V1T3	$14.54^a \pm 1.15$	$343.73^a \pm 26.02$	$311.97^a \pm 27.84$	$4.07^a \pm 0.89$
V1T4	$13.11^a \pm 0.52$	$338.90^a \pm 21.07$	$312.90^a \pm 10.18$	$3.94^a \pm 0.32$
V2T1	$16.47^a \pm 2.04$	$464.60^a \pm 50.03$	$348.03^a \pm 39.26$	$5.62^a \pm 1.62$
V2T2	$14.03^a \pm 1.73$	$486.20^a \pm 38.97$	$356.70^a \pm 6.49$	$6.03^a \pm 0.83$
V2T3	$16.21^a \pm 1.07$	$471.33^a \pm 18.64$	$373.27^a \pm 15.48$	$6.55^a \pm 0.42$
V2T4	$15.04^a \pm 0.84$	$471.33^a \pm 4.01$	$353.17^a \pm 20.24$	$5.73^a \pm 0.33$
LSD ($p = 0.05$)	NS	NS	NS	NS
CV (%)	8.8	7.3	5.6	13.7

Mean (±std. dev.) values followed by the same letters are not significantly different using the least significance difference test (LSD) at $p = 0.05$ probability level. NGCOB, number of grains per cob; 1000 SW, 1000 seeds weight; NS, not significant.

Table 4: Analysis of variance for yield components as influenced by varietal, time of fertilizer application, and interaction effects during the 2021 growing season.

Source of variation	df	Cob length (cm)	NGCOB	1000 SW (g)	Grain yield (tons/ha)
Variety (V)	1	0.028*	0.001**	0.001**	0.001**
Time of fertilizer application (T)	3	0.165	0.588	0.755	0.592
V × T	3	0.365	0.131	0.166	0.246
Residual	14				
Total	23				
Std. error		1.30	29.96	19.14	0.69
CV (%)		8.8	7.3	5.6	13.7

*Significant at $p = 0.05$; **Significant at $p = 0.001$; *df*, degree of freedom.

relatively higher than the average yield of maize (1.7 tons ha^{-1}) in Ghana.

5. Conclusions

The study was undertaken to examine the response of maize varieties to different times of fertilizer (N : P : K 15 : 15 : 15) applications on the growth and yield parameters. The investigation revealed that the maize varieties responded differently to the time of application with respect to the growth parameters and grain yield. In addition, the application of the fertilizer after 28 days after planting to the Omankwa variety produced the highest mean plant height and leaf area whereas the application of the fertilizers after 14

days of planting enhanced the stem girth and the number of leaves. However, for the Pioneer hybrid variety, the application of the fertilizers after 28 days of planting influenced and produced the highest plant height, stem girth, and number of leaves. Also, with regards to the grain yield, the results from the study showed that the pioneer variety performed better when the fertilizers was applied 28 days after planting, whereas, for the Omankwa variety, the application of fertilizer during the planting phase.

Data Availability

All the data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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