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Research Article

Yield Response of Hybrid and Open Pollinated Maize (*Zea mays* L.) Varieties to Different Levels of Fertilizer Nitrogen under Rain-Fed Conditions in the Bono Region of Ghana

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Background. The experiment was undertaken at Nsapor, a suburb of Berekum municipality in the Bono Region of Ghana, from March 2019 to November 2019 to determine the suitable rate of fertilizer nitrogen application to optimize seed yield and yield attributes of Pannar 12 and Omankwa maize varieties in a semi deciduous agroecology of Ghana. Soil fertility is low in Ghana because of factors such as rampant annual bushfires, short fallow periods as a result of high human populations, continuous cropping, deforestation, and improper mining activities. There is also little information on crop variety and site-specific fertilizer recommendations in Ghana, resulting in inappropriate use of fertilizers by most Ghanaian farmers, culminating in low crop yields. *Methods*. Hybrid (Pannar 12) and open pollinated (Omankwa) maize varieties were treated with four rates of fertilizer nitrogen obtained from NPK 15-15-15 (0 kgN/ha, 90 kgN/ha, 120 kgN/ha and 150 kgN/ha) and laid out in a factorial combination in a randomized complete block design with three replicates. *Results*. Application of 150 kg/ha of fertilizer N to Pannar 12 variety resulted in grain yields of 6146 kg/ha and 6095 kg/ha in the major and minor rainy seasons, respectively. The results also showed that application of 120 kg/ha of fertilizer N to Omankwa variety gave grain yields of 4635 kg/ha and 5286 kg/ha in the major and minor rainy seasons, respectively. To optimize the grain yield of maize, farmers could use NPK 15-15-15 fertilizer as a source of nitrogen and apply 120 kgN/ha to Omankwa variety and 150 kgN/ha to Pannar 12 variety in both major and minor rainy seasons.

1. Introduction

Maize (*Zea mays* L.) is a significant cereal and multifunctional crop of the Poaceae (Gramineae) family. Wheat, maize, and rice are the world's leading staple cereals, each cultivated on 200 million ha of land [1]. Collectively, these three cereal crops are a principal part of human diet, which account for an estimated 42% of the world's food calories and 37% of protein intake [2]. The global maize area (for dry grain) amounts to 197 M ha, including large areas in sub-Saharan Africa (SSA), Asia, and Latin America [2]. Maize cultivation covers both emerging economies and the developed world, including 165 countries distributed across America, Asia, Europe, and Africa [2].

The United States, Brazil, France, India, and Italy are the top producers of maize. Partey et al. [3] reported that maize is an important cereal crop and accounts for more than half of the total cereal production in Africa. According to Ragasa et al. [4], maize is produced in sub-Saharan Africa mainly for food consumption, making it an important crop for food security.

Maize is used to feed humans and livestock and provides raw materials for industries for a variety of purposes, including maize starch, dextrose, maize syrup, and maize flakes [5]. Maize is grown for a variety of purposes, including animal feed (silage and grains), poultry feed (grains), and pigs feed (grains), as well as human consumption in the form of grains, sweet maize, and grain maize [2].

In terms of production and consumption, maize is Ghana's most important cereal crop. Because of the ready availability of market provided by urban centres, farmers usually intercrop it with cassava or grow it as a sole crop for subsistence purposes [6].

Most maize farmers in Ghana today utilize fertilizer to ensure that the nutrient status is refilled in order to boost yield. Ghana's government has set a target for increasing maize productivity. Ghana's agricultural policy has focused on fertilizer subsidies and targeted credit programmes in recent years in order to boost small farmers' agricultural output, improve food security, and ultimately alleviate poverty. Maize production in Ghana over the period 1992–2012 shows pronounced increases, starting from year 2008, although a significant drop occurred in 2011. The similarities in the trends of production and yields in the latter years could be only partly explained with the introduction of hybrid seed and the fertilizer subsidies in 2008 as the drop in productivity which occurred in 2011 reveals that weather conditions still play a significant role in production and productivity performances [7]. The productivity of the smallholder cropping systems in Ghana largely depends on inherent soil fertility and prevailing weather conditions since only limited amounts of fertilizer and pesticides are applied and irrigation systems are very limited [7]. The maize average yield in Ghana registered by the Ministry of Food and Agriculture in 2012 was 1.9 tonnes/ha, against an estimated achievable yield of around 2.5 to 4 tonnes/ha [7].

Application of nitrogen (N) fertilizer to maize plants could influence the development of leaf area, light interception, production, and partitioning efficiency [8, 9]. The applied quantity of nitrogen (N) has a positive effect on nutritive values of grains and the maize income [10]. According to Habtegebrial et al. [11], nitrogen (N) essentially maximizes soil productivity and nutrient use efficiency of crops. Nitrogen (N) fertilizers have varying effects on maize yield, and researchers found that applying nitrogen (N) with splits resulted in high grain production compared to applying nitrogen (N) solely at the base [12]. The right N fertilizer rate and time could increase grain weight by increasing effective grain-filling duration and rate [12–15].

Ojobor et al. [16] reported that soil nutrient mining through poor soil fertility management accounts for poor yields of crops such as maize. Decline in soil fertility is a key biophysical factor affecting maize production in Ghana. The soils in Ghana are poor in fertility due to such factors as continuous cropping with little or no fertilizer input, bush burning, deforestation, and removal of crop residues after harvest. Nitrogen (N) stress has been reported to reduce the number of grains per cob by maximizing kernel abortion, causing about 85% of the abortion during the first three weeks after flowering [17].

The objective of the study was, therefore, to determine the suitable rate of fertilizer nitrogen (N) application to optimize seed yield and yield attributes of Pannar 12 and Omankwa maize varieties in a semi deciduous agroecology of Ghana.

2. Materials and Methods

2.1. Experimental Site. The experiment was undertaken at Nsapor, a suburb of Berekum municipality of the Bono Region of Ghana, from March 2019 to November 2019. The three-year fallowed land was previously cultivated to an intercrop of maize, cassava, cocoyam, pepper, and garden eggs.

Berekum is found in the western part of the Bono Region. It is located between latitudes $27' \, 12.24''$ N and longitudes $-2^{\circ} \, 35' \, 2.54''$ W [18]. The area has a bimodal rainfall regime, namely, major rainy and minor rainy seasons. The major rainy season runs from mid-March until the end of July, with the highest rainfall in June. The minor rainy season follows, which lasts from September to mid-November. A four-month dry period between December and March is experienced. During this period, trees shed their leaves and appear brown. Cold and dry conditions caused by the oppressive harmattan winds which come from the north are also experienced. The predominant vegetation type is semi deciduous woodland, which covers about 80% of the entire central stretch of land, with isolated areas of forested savannah in the municipality's northern and eastern corners. The soils in the area are primarily well-drained forest ochrosols, formed by the weathering of intermediate or moderately acidic rocks [18].

2.2. Soil Sampling and Characterization. Before planting, samples of soil were taken with an auger at a depth of 0–30 cm. The samples were taken from four separate locations on each plot and then combined to form a composite sample, which was air-dried for four days before being sieved for big particles, debris, and stones. The soil analysis was carried out at the soil science laboratory of the Department of Crop and Soil Sciences at the Kwame Nkrumah University of Science and Technology, Kumasi. The standard procedures described by Motsara and Roy [19] were followed during the initial soil analysis. Tables 1 and 2 show the physico-chemical properties of the soil at the experimental site.

2.3. Climatic Data at the Experimental Site. The rainfall and temperature data are shown in Table 3. Two separate experiments were conducted. The first experiment was undertaken from March to June, 2019, which had a total rainfall amount of 372.7 mm, while the second experiment took place from July to November, 2019, with a total rainfall amount of 439.6 mm. The temperature data recorded during the first experiment were higher than those recorded during the second experiment.

2.4. Experimental Design and Treatments. Two experiments were undertaken at the same location. Two varieties of maize, Omankwa and Pannar 12, and four levels of fertilizer nitrogen, including 0 kgN/ha (control), 90 kgN/ha, 120 kgN/ha, and 150 kgN/ha of NPK 15-15-15 were evaluated as a 2×4 factorial experiment in a randomized complete block

Table 1: Initial physical properties of soil at the experimental site (source: [20]).

Soil separates	% composition
Sand	82
Silt	8
Clay	10
Texture	Sandy loam

Table 2: Initial chemical properties of soil at the experimental site (source: [20]).

Parameters	Value
pH (1 : 2.5 H_2O)	5.61
Organic carbon (%)	1.64
Total nitrogen (%)	0.15
Organic matter (%)	2.83
Calcium (me/100 g)	8.31
Magnesium (me/100 g)	1.70
Potassium (me/100 g)	0.45
Sodium (me/100 g)	0.16
Phosphorus (ppm)	2.63
Total exchangeable bases (me/100 g)	10.61
Exchangeable acidity (me/100 g)	0.55
Effective cation exchange capacity (me/100 g)	11.16
% base saturation	95.07

Table 3: Rainfall and temperature data at the experimental site in 2019 (source: [21]).

Months	Average temperature (°C)	Minimum temperature (°C)	Maximum temperature (°C)	Rainfall (mm)
January	26.3	20	32.6	0.5
February	27.8	21.5	34.1	21.5
March	27.8	22.2	33.5	47.1
April	27.4	22.2	32.6	70.4
May	26.9	22.1	31.7	114.2
June	25.6	21.5	29.7	141
July	24.5	21.5	28	27.7
August	24.1	20.7	27.6	59.3
September	25	21.2	28.8	127
October	25.7	21.3	30.1	153.6
November	26.4	21.3	31.6	72
December	26	20.5	31.5	14

design (RCBD) with three replicates. In all, there were eight treatments per block, namely, Omankwa × 0 kgN/ha, Omankwa × 90 kgN/ha, Omankwa × 120 kgN/ha, Omankwa × 150 kgN/ha, Pannar 12 × 0 kgN/ha, Pannar 12 × 90 kgN/ha, Pannar 12 × 120 kgN/ha, and Pannar 12 × 150 kgN/ha.

2.5. Plant Culture. The experimental site was manually and chemically cleared prior to planting. Crop management practices such as refilling, thinning, rogueing, control of weeds, diseases, and insect pests such as fall armyworms and application of fertilizers were carried out.

2.5.1. Preparation of Land, Field Layout, and Sowing. The land was prepared by clearing the vegetation with a cutlass and carrying out the subsequent removal of stumps. Two weeks after slashing, the regrowths were treated with a systemic weedicide called sunphosate (glyphosate) at a dosage of 10 ml per litre of water. The land was then demarcated into plots of 2.4 m × 3.2 m with 1 m between plots and 1 m between blocks, for a total land area of 61.44 m^2. The seed unit of the Ministry of Food and Agriculture (MoFA) in Berekum provided seeds of the two maize types (Omankwa and Pannar 12). After obtaining a germination rate of 95%, the seeds were planted on April 4th and July 15th, 2019, in experiments one and two, respectively. Two maize seeds were planted per hill at 80 cm between rows and 40 cm within rows.

2.5.2. Replanting and Thinning. Refilling of vacancies was conducted a week after sowing. Two weeks after sowing, the seedlings were thinned to one plant per hill.

2.5.3. Weed Management. Weed control was conducted manually by hoeing as and when necessary, but two major weedings were conducted at 2nd and 5th weeks after planting.

2.5.4. Pests and Diseases. Pests such as fall armyworms were chemically controlled. The plants were sprayed with emamectin benzoate at a rate of 100 ml per 15 litres of water using a knapsack sprayer against fall army worm (*Spodoptera frugiperda*) at regular intervals.

2.5.5. Application of Fertilizer. NPK 15-15-15 fertilizer was applied to crops as per the treatment imposed. Thus, control plots received no fertilizer, plots with 90 kg N/ha received 600 kg/ha of NPK 15-15-15, plots with 120 kg N/ha received 800 kg/ha of NPK 15-15-15, and plots with 150 kg N/ha received 1000 kg/ha of NPK 15-15-15 throughout the study. Fertilizers were side-banded and split-applied at two and four weeks after sowing at their half rates per each application in both the major and minor seasons of 2019. There was no presowing application of fertilizer in both trials.

2.5.6. Harvesting. Harvesting was conducted at physiological maturity for the first experiment on 10th July, 2019 and on 20th November, 2019 for the second experiment.

2.6. Data Collection. Data on yield parameters were collected at harvest. Yield components were taken from four sampled plants per plot, while seed yield was taken from an area of 4 m^2 and converted into kg/ha.

2.6.1. Number of Cobs per Plant. The number of cobs or ears of the four selected plants per plot was counted, and the average was determined by dividing all the harvested cobs by four.

2.6.2. Cob Diameter. The diameter of cobs from all the four sampled plants was measured with vernier callipers, and the mean was calculated by summing up all the diameters of the cobs and then dividing the total diameter by the number of cobs from the four plants.

2.6.3. Cob Length. With a measuring tape, the length of each dehusked cob from four sampled plants was measured, and total of the lengths was divided by the number of cobs from the four plants to get the mean cob length.

2.6.4. Number of Grains per Cob. After drying and shelling, the number of seeds of four cobs from each plot was counted. The average was calculated by dividing the total number of grains by the number of cobs.

2.6.5. Cob Weight. The weight of four harvested cobs after being dehusked was taken with an electric balance. The total weight was then divided by the number of plants sampled.

2.6.6. Hundred-Seed Weight. One hundred seeds were counted from every plot, and the weight was taken.

2.6.7. Number of Rows of Grains per Cob. The number of rows of grains per cob from the four selected plants per each plot was visually counted and recorded. The average was then calculated.

2.6.8. Number of Grains per Row. The number of grains per row of each of the four cobs from each plot was counted and averaged.

2.6.9. Harvest Index (HI). This was determined as a percentage ratio of economic and biological yield.

Thus,

$$\mathrm{HI} = \frac{\text{Economic yield}}{\text{Biological yield}} \mathrm{X}100. \tag{1}$$

2.6.10. Grain Yield. Data were recorded in each plot after the grains had been oven-dried for 3 days at a temperature of 60°C and converted into kg/ha.

Thus,

$$\text{Grain yield in kgha}^{-1} = \frac{\text{Yield/plot}}{\text{Plot size}} \mathrm{X}10000. \tag{2}$$

2.6.11. Stover Yield. The above-ground parts of the randomly chosen plants per plot were chopped into pieces, placed in envelops, and oven-dried for three days at 600 °C until constant weights were obtained.

2.7. Data Analysis. Using the Genstat statistical programme (Numerical Algorithms Group, Oxford, England), the data were subjected to analysis of variance [22]. In comparing treatment means, the least significant difference (LSD) at a probability level of 5% was used.

3. Results

3.1. Cob Length, Number of Cobs per Plant, and Cob Diameter. In the major season of 2019, cob length did not differ significantly ($P > 0.05$) between the two varieties of maize, but it was significantly influenced by the rate of fertilizer nitrogen (N) application (Table 4). The fertilizer nitrogen (N) rates differed significantly from the control, which produced the shortest cobs. The longest cobs were produced when 120 kg/ha of fertilizer nitrogen (N) was applied to maize plants. Among the fertilizer treatments, 90 and 150 kg/ha of fertilizer nitrogen (N) did not differ in cob length, but it varied significantly ($P < 0.05$) from application of fertilizer nitrogen (N) at 120 kg/ha. The interaction between variety and fertilizer nitrogen (N) rates was significant ($P < 0.05$) for cob length (Table 5). The interaction between Omankwa and application of fertilizer nitrogen (N) at 120 kg/ha culminated in the production of longest cobs. Conversely, plants of Omankwa that were not treated at all with fertilizer nitrogen (N) produced the shortest cobs.

In the minor season of 2019, cob length varied significantly ($P < 0.05$) between the two varieties of maize and among the fertilizer treatments (Table 4). Pannar 12 produced longer cobs than Omankwa. The fertilizer nitrogen (N) rates differed significantly from the control, which produced the shortest cobs. The longest cobs were produced when 150 kg/ha of fertilizer nitrogen (N) was applied to maize plants. Among the fertilizer treatments, 90 and 120 kg/ha of fertilizer nitrogen (N) did not vary in cob length, but varied significantly from the application of fertilizer nitrogen (N) at 150 kg/ha.

The interaction between variety and fertilizer nitrogen (N) rates was significant ($P < 0.05$) for cob length (Table 5). The interaction between Pannar 12 and application of fertilizer nitrogen (N) at 150 kg/ha resulted in longest cobs, while plants of Omankwa which received 90 kg/ha of fertilizer nitrogen (N) produced the shortest cobs.

In both seasons of 2019, the number of cobs per plant was not significant ($P > 0.05$) with treatment application (Tables 4 and 5).

Results of cob diameter showed a significant ($P < 0.05$) effect with treatment application throughout the study (Tables 4 and 5). The cob diameter was significantly higher in Omankwa than in Pannar 12 (Table 4). The control produced the least cob diameter, and this differed greatly from all the rates of fertilizer nitrogen (N) application. Application of 120 kg/ha of fertilizer nitrogen (N) gave the highest cob diameter, and it varied significantly from the other rates of fertilizer N application. Application rates of 90 and 150 kg/ha of fertilizer nitrogen (N) did not vary from each other in terms of cob diameter (Table 4). The interaction between variety and fertilizer nitrogen (N) rates was significant ($P < 0.05$) for cob diameter (Table 5). The interaction between Omankwa and the application of fertilizer nitrogen (N) at 120 kg/ha produced the highest cob diameter. Conversely, plants of Omankwa that did not receive fertilizer nitrogen (N) throughout the study produced the least cob diameter.

Cob diameter was significantly ($P < 0.05$) higher in Pannar 12 than Omankwa in the minor season of 2019 (Table 4). The control treatment gave the least cob diameter, and this varied significantly from all the rates of fertilizer nitrogen (N) application. Application of 150 kg/ha of fertilizer nitrogen (N) gave the highest cob diameter and varied significantly from the other rates of fertilizer nitrogen (N) application. Application rates of 90 and 120 kg/ha of fertilizer nitrogen (N) did vary from each other in terms of cob diameter (Table 4). The interaction between Pannar 12 and application of fertilizer nitrogen (N) at 150 kg/ha produced the highest cob diameter, while the application rate of nitrogen at 90 kg/ha to Omankwa produced the least cob diameter (Table 5).

3.2. Number of Grain Rows per Cob, Number of Grains per Grain Row, and Number of Grains per Cob. The results of number of grain rows per cob, number of grains per grain row, and number of grains per cob are shown in Tables 6 and 7. Varieties of maize and rates of fertilizer nitrogen (N) significantly ($P < 0.05$) affected the number of grain rows per cob in the major season of 2019. Omankwa was higher (15.31) in number of grain rows per cob than Pannar 12 (13.23). Application of fertilizer nitrogen (N) at 120 kg/ha gave the highest number of grain rows per cob (14.96) and differed significantly only from the control which had the lowest number of grain rows per cob (13.42). All other treatment means were similar. The interaction between variety and fertilizer nitrogen (N) rates was significant ($P < 0.05$) for the number of grain rows per cob. The highest treatment interaction was noticed in plants of Omankwa treated with 120 kg/ha of fertilizer nitrogen (N), whereas the least treatment interaction was associated with plants from Pannar 12 treated with 120 kg/ha of fertilizer N.

In the minor season of 2019, varieties of maize and rates of fertilizer nitrogen (N) did not significantly ($P > 0.05$) affect the number of grain rows per cob.

The number of grains per grain row varied significantly ($P < 0.05$) between the two varieties of maize in the major season of 2019. Omankwa outperformed Pannar 12 in this parameter (Table 6). Application of fertilizer had no significant ($P > 0.05$) influence on the number of grains per grain row. The interaction between variety and fertilizer nitrogen (N) rates was significant ($P < 0.05$) for the number of grains per grain row. Application of 120 kg/ha of fertilizer nitrogen (N) to plants of Pannar 12 and Omankwa resulted in the highest and lowest treatment interactions, respectively.

The number of grains per grain row did not vary significantly ($P > 0.05$) between the two varieties of maize, but differed significantly ($P < 0.05$) among the fertilizer treatments in the minor season of 2019. The application rate of 150 kgN/ha resulted in the production of the highest number of grains per row (35.41), which significantly ($P < 0.05$) varied from the control treatment which had the least number of grains per row (29.49). The interaction between variety and fertilizer nitrogen (N) rates was significant ($P < 0.05$) for the number of grains per row (Table 7). The application rate of 150 kg/ha of fertilizer nitrogen (N) to plants of Pannar 12 resulted in the highest interaction effect, while plots of Pannar 12 which did not receive any fertilizer N produced the lowest treatment interaction effect (28.94).

In the major season of 2019, number of grains per cob was not significant ($P > 0.05$) with treatment application (Tables 6 and 7).

The number of grains per cob did not differ significantly ($P > 0.05$) between the two maize varieties, but varied significantly among the different rates of fertilizer nitrogen (N) in the minor season of 2019. The application rate of 150 kgN/ha produced the highest number of grains per cob (466.4) and varied significantly ($P < 0.05$) from the control (Table 6). It also differed significantly ($P < 0.05$) from the application rate of 90 kgN/ha, but did not vary from the fertilizer rate of 120 kgN/ha. The control treatment produced the least

Table 4: Cob length, number of cobs per plant, and cob diameter of two varieties of maize under different rates of fertilizer nitrogen (N) at harvest in both major and minor seasons of 2019.

Treatments	2019 Major season			2019 Minor season		
	Cob length (cm)	No. of cobs per plant	Cob diameter (cm)	Cob length (cm)	No. of cobs per plant	Cob diameter (cm)
Pannar (P-12)	19.45	1.03	3.11	17.81	1.00	3.29
Omankwa (OM)	19.60	1.10	3.30	16.44	1.00	2.96
LSD (5%)	NS	N S	0.16	0.78	NS	0.14
Control	16.98	1.00	2.95	16.29	1.00	2.97
90 kgN/ha	19.38	1.05	3.19	16.67	1.00	2.99
120 kgN/ha	21.96	1.10	3.52	17.38	1.00	3.22
150 kgN/ha	19.77	1.10	3.16	18.15	1.00	3.29
LSD (5%)	1.60	NS	0.23	1.11	NS	0.20
CV (%)	6.60	10.90	5.90	5.20	0.00	5.10

LSD: least significant difference; CV: coefficient of variation.

Table 5: Effect of variety and rate of fertilizer nitrogen (N) interaction on cob length, number of cobs per plant, and cob diameter at harvest in both major and minor seasons of 2019.

Treatments	2019 Major season						2019 Minor season					
	Cob length (cm)		No. of cobs per plant		Cob diameter (cm)		Cob length (cm)		No. of cobs per plant		Cob diameter (cm)	
	P-12	OM	P-12	OM	P-12	OM	P-12	OM	P-12	OM	P-12	OM
Control	17.71	16.25	1.00	1.00	2.98	2.92	16.61	15.96	1.00	1.00	3.07	2.87
90 kgN/ha	19.84	18.92	1.00	1.10	3.12	3.25	17.55	15.79	1.00	1.00	3.11	2.86
120 kgN/ha	20.63	23.29	1.10	1.10	3.25	3.79	17.80	16.96	1.00	1.00	3.31	3.12
150 kgN/ha	19.63	19.92	1.00	1.20	3.09	3.23	19.26	17.04	1.00	1.00	3.60	2.98
LSD (5%)		2.26		NS		0.33		1.57		NS		0.28
CV (%)		6.60		10.90		5.90		5.20		0.00		5.10

Table 6: Number of grain rows per cob, number of grains per grain row, and number of grains per cob of two varieties of maize under different rates of fertilizer nitrogen (N) at harvest in both major and minor seasons of 2019.

Treatments	2019 Major season			2019 Minor season		
	Grain rows per cob	Grains per row	Grains per cob	Grain rows per cob	Grains per row	Grains per cob
Pannar (P-12)	13.23	38.38	507.0	13.21	32.79	432.9
Omankwa (OM)	15.31	34.80	532.0	13.04	32.66	426.3
LSD (5%)	0.88	2.59	NS	0.36	2.11	NS
Control	13.42	36.10	485.0	13.06	29.49	386.0
9 kgN/ha	14.21	36.03	511.0	13.00	32.69	424.6
120 kgN/ha	14.96	36.83	543.0	13.25	33.32	441.3
150 kgN/ha	14.50	37.40	539.0	13.17	35.41	466.4
LSD (5%)	1.24	NS	NS	0.50	2.98	40.78
CV (%)	7	8.1	10.70	3.10	7.30	7.70

number of grains per cob (386.0). The interaction between variety and fertilizer nitrogen (N) was significant ($P < 0.05$) for the number of grains per cob (Table 7). Plants of Pannar 12 treated with 150 kgN/ha obtained the highest number of grains per cob (499.40), while those of Omankwa which did not receive any fertilizer produced the least treatment interaction effect (386.20) (Table 7).

3.3. Cob Weight, Harvest Index, and Hundred-Seed Weight. Results of cob weight, harvest index, and hundred-grain weight in the major season of 2019 are presented in Table 8 and Figures 1–3. Cob weight did not differ significantly ($P > 0.05$) between the two varieties, but was significantly ($P < 0.05$) affected by application of different rates of fertilizer nitrogen (N). The highest cob weight was observed in

Table 7: Effect of variety and rate of fertilizer nitrogen (N) interaction on the number of grain rows per cob, number of grains per row, and number of grains per cob at harvest in both major and minor seasons of 2019.

Treatments	2019 Major season						2019 Minor season					
	Grain rows/cob		Grains/row		Grains/cob		Grain rows/cob		Grains/row		Grains/cob	
	P-12	OM	P-12	OM	P-12	OM	P-12	OM	P-12	OM	P-12	OM
Control	13.30	13.58	36.15	36.05	479.00	491.00	13.33	12.83	28.94	30.04	385.80	386.20
90 kgN/ha	13.10	15.33	37.63	34.44	492.00	530.00	13.00	13.00	32.40	33.00	420.70	428.60
120 kgN/ha	13.00	16.92	40.73	32.92	529.00	557.00	13.17	13.33	32.40	34.30	425.70	457.00
150 kgN/ha	13.60	15.40	38.99	35.81	528.00	550.00	13.33	13.00	37.40	33.40	499.40	433.40
LSD (5%)	1.75		5.18		NS		0.71		4.21		57.68	
CV (%)	7.00		8.10		10.70		3.10		7.3		7.70	

application of 120 kg/ha of fertilizer nitrogen (N), while the control produced the least cob weight. The control varied significantly from fertilizer nitrogen (N) applied at 120 and 150 kg/ha. Application of fertilizer nitrogen (N) at 90 kg/ha differed significantly from its application at 120 kg/ha for cob weight. All other treatment means were similar. The interaction between variety and fertilizer nitrogen (N) rates was significant for cob weight (Figure 1). Results of the harvest index and hundred-grain weight showed no significant ($P > 0.05$) effect with treatment application (Table 8 and Figures 3 and 4).

Results of cob weight, harvest index, and hundred-seed weight in the minor season of 2019 are presented in Table 8 and Figures 2, 5, and 6. The main effects of variety and fertilizer nitrogen (N) on cob weight, harvest index, and hundred seed weight were not significant ($P > 0.05$) (Table 8). The interaction between variety and fertilizer nitrogen (N) rates was significant for cob weight and harvest index (Figures 2 and 5). However, the interaction between variety and fertilizer nitrogen (N) was not significant for hundred-seed weight (Figure 6). Interaction between variety and fertilizer nitrogen (N) for cob weight was significant ($P < 0.05$) with the highest interaction effect being observed in application of 150 kgN/ha to Pannar 12, whereas the lowest interaction effect was noticed in Pannar 12 treated with no fertilizer nitrogen (N) (Figure 2). The interaction effects for the harvest index were significant ($P < 0.05$). The highest interaction effect was noticed in Omankwa variety treated with no fertilizer nitrogen (N), while the least was associated with Omankwa variety treated with 120 kg/ha of fertilizer nitrogen (N) (Figure 5).

3.4. Grain Yield. In the major season of 2019, grain yield was not significantly ($P < 0.05$) affected by variety, but application of fertilizer nitrogen (N) affected it (Table 9). The application rate of 150 kgN/ha produced the highest grain yield, followed by 120 kgN/ha, 90 kgN/ha, and the control. The control treatment differed significantly from 150 kgN/ha. All other treatment means were similar. The interaction effect for grain yield was significant ($P < 0.05$) with the interaction between Pannar 12 and application of 150 kg/ha of fertilizer nitrogen (N) having the greatest effect (6146 kg/ha), while the least interaction effect (3958 kg/ha) was observed in Pannar 12 plants grown without fertilizer nitrogen (N) (Table 10).

In the minor season of 2019, grain yield was not significantly affected by variety, but application of fertilizer nitrogen (N) affected it (Table 9). Generally, the nutrient-applied treatments did better than the control treatment. The control treatment differed significantly ($P < 0.05$) from the nutrient-applied treatments in terms of grain yield, except for the application rate of 90 kgN/ha. Application rates of 120 and 150 kgN/ha were similar, but either of them varied significantly from the application rate of 90 kgN/ha. The interaction effect for grain yield was significant ($P < 0.05$) with the interaction between Pannar 12 and the application of 150 kg/ha of fertilizer nitrogen (N) being the best treatment combination (6095 kg/ha), while the worst interaction effect (3684 kg/ha) was observed in Omankwa plants grown without fertilizer nitrogen (N) (Table 10).

3.5. Stover Yield. The results of stover yield are presented in Tables 11 and 12. The results of stover yield revealed no significant ($P > 0.05$) differences between the two varieties, but fertilizer application significantly affected it in the major season of 2019. The application rate of 90 kgN/ha varied significantly from the control, while the application rates of 120 kgN/ha and 150 kgN/ha produced similar results, but did not vary significantly from the control (Table 11). The interaction between variety and fertilizer nitrogen (N) rates was significant for stover yield in the major season of 2019 (Table 12).

Maize variety did not significantly affect stover yield, but NPK 15-15-15 affected it in the minor season of 2019 (Table 11). The application rate of 90 kgN/ha recorded the highest stover yield. Application rates of 90 kgN/ha and 150 kgN/ha produced similar results, but varied significantly ($P < 0.05$) from the control, which recorded the least stover yield. The application rate of 120 kgN/ha differed significantly from the application rate of 90 kgN/ha and control, but was similar to the application rate of 150 kgN/ha. There were significant interaction effects between variety and NPK 15-15-15 for stover yield (Table 12).

Table 8: Cob weight, harvest index, and hundred-seed weight of two varieties of maize under different rates of fertilizer nitrogen (N) at harvest in both major and minor seasons of 2019.

Treatments	2019 Major season			2019 Minor season		
	Cob wt. (kg)	HI	100-seed wt. (kg)	Cob wt. (kg)	HI	100-seed wt. (kg)
Pannar (P-12)	0.20	0.60	0.03	0.18	0.58	0.03
Omankwa (OM)	0.19	0.59	0.03	0.17	0.58	0.03
LSD (5%)	NS	NS	NS	0.04	0.06	0.01
Control	0.16	0.59	0.03	0.17	0.61	0.03
90 kgN/ha	0.19	0.58	0.04	0.16	0.59	0.03
120 kgN/ha	0.23	0.64	0.04	0.17	0.52	0.03
150 kgN/ha	0.20	0.58	0.03	0.19	0.60	0.03
LSD (5%)	0.03	NS	NS	0.06	0.09	0.02
CV (%)	10.80	11.70	18.00	27.6	12.3	37.8

HI: harvest index.

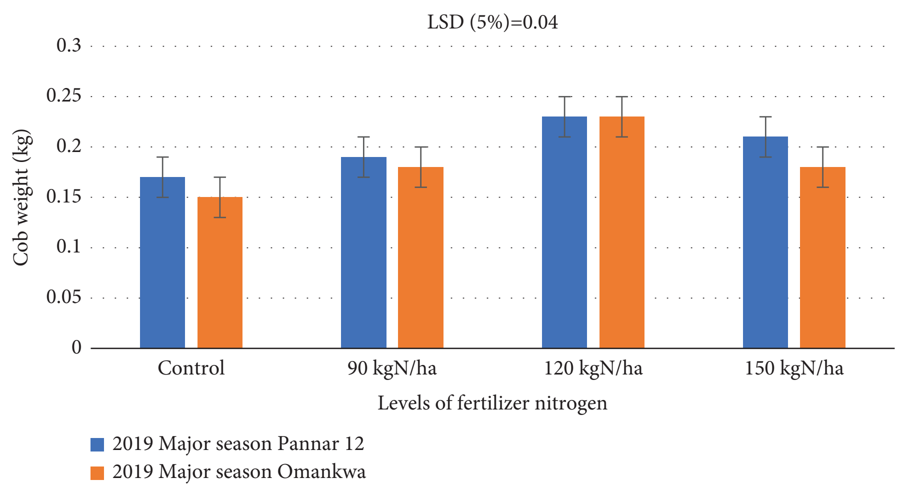

Figure 1: Effect of variety and rate of fertilizer nitrogen (N) interaction on cob weight at harvest in major season of 2019.

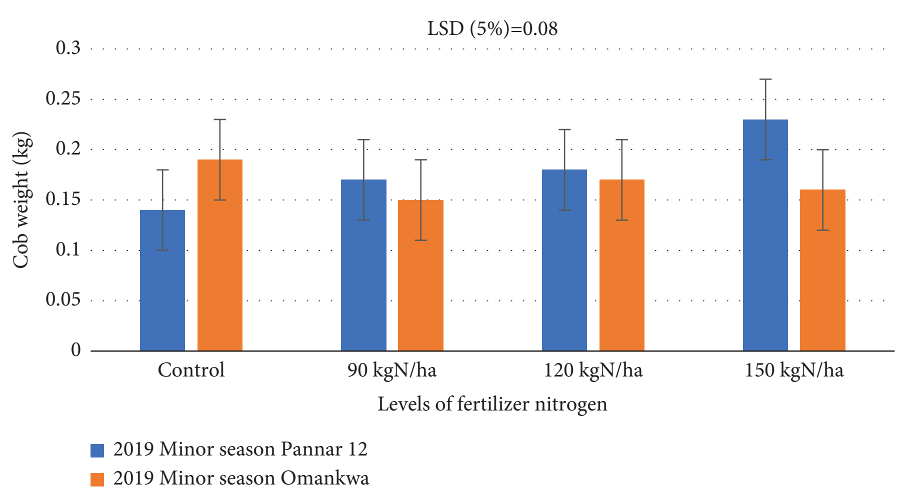

Figure 2: Effect of variety and rate of fertilizer nitrogen (N) interaction on cob weight at harvest in minor season of 2019.

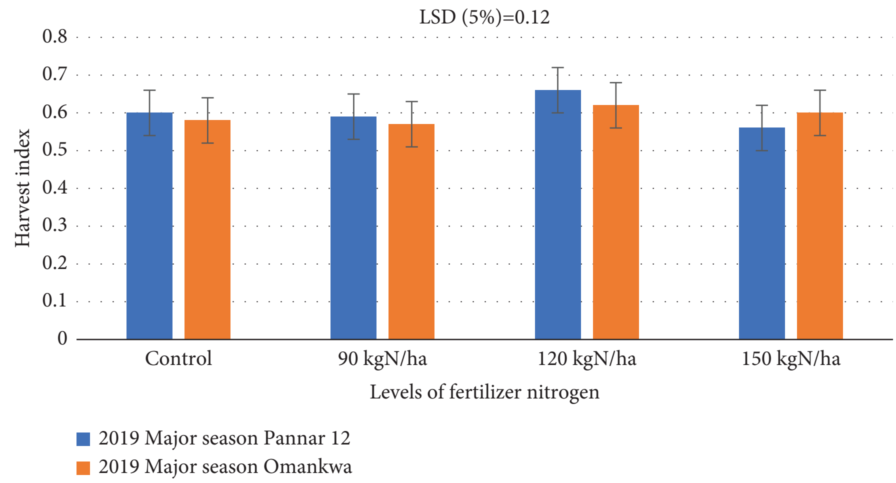

Figure 3: Effect of variety and rate of fertilizer nitrogen (N) interaction on the harvest index at harvest in major season of 2019.

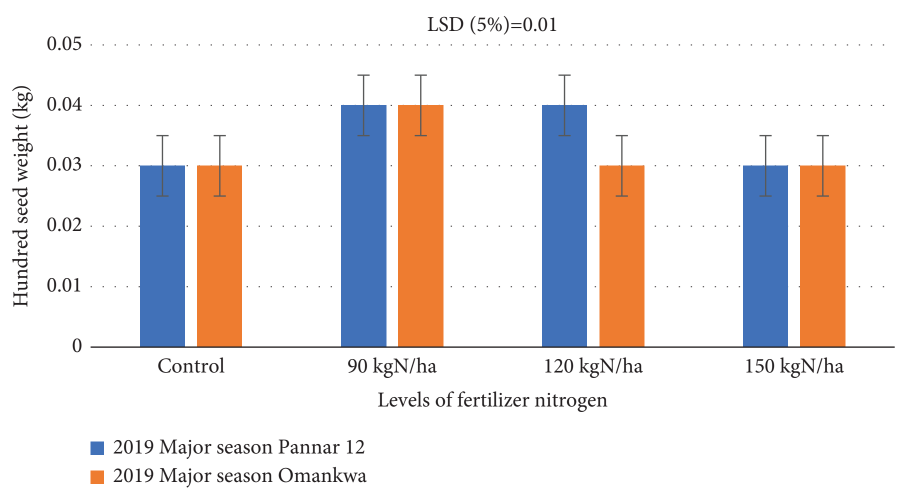

Figure 4: Effect of variety and rate of fertilizer nitrogen (N) interaction on hundred-seed weight at harvest in major season of 2019.

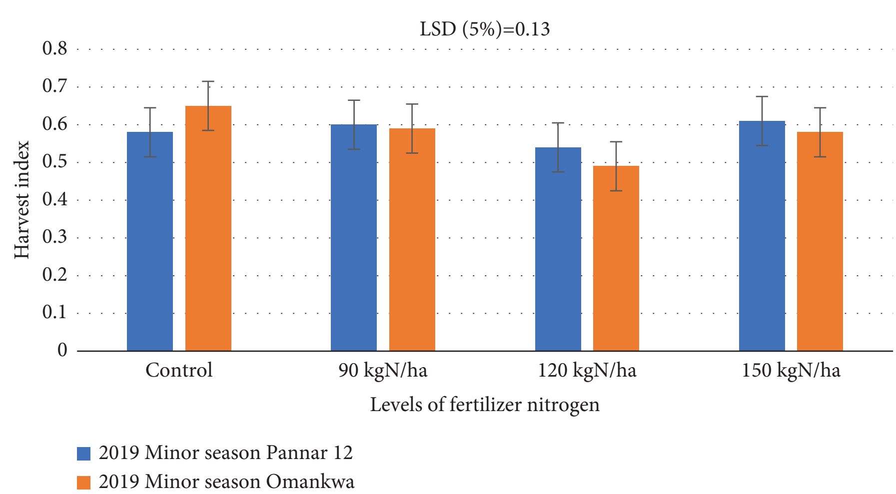

Figure 5: Effect of variety and rate of fertilizer nitrogen (N) interaction on the harvest index at harvest in minor season of 2019.

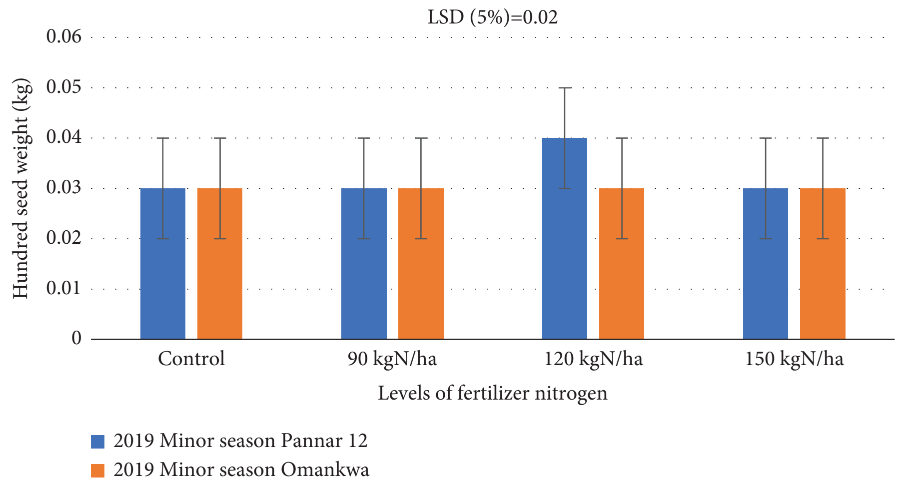

Figure 6: Effect of variety and rate of fertilizer nitrogen (N) interaction on hundred-seed weight at harvest in minor season of 2019.

Table 9: Grain yield of two varieties of maize under different rates of fertilizer nitrogen (N) at harvest in both major and minor seasons of 2019.

Treatments	2019 Major season Grain yield (kg/ha)	2019 Minor season Grain yield (kg/ha)
Pannar (P-12)	4889	5287
Omankwa (OM)	4375	5290
LSD (5%)	NS	NS
Control	4193	4141
90 kgN/ha	4375	4740
120 kgN/ha	4688	5482
150 kgN/ha	5273	5391
LSD (5%)	937.20	612.20
CV (%)	16.30	10.00

Table 10: Effect of variety and rates of fertilizer nitrogen (N) interaction on grain yield in both major and minor seasons of 2019.

Treatments	2019 major season Grain yield (kg/ha)		2019 minor season Grain yield (kg/ha)	
	P-12	OM	P-12	OM
Control	3958	4427	4297	3684
90 kgN/ha	4714	4036	5078	4401
120 kgN/ha	4740	4635	5677	5286
150 kgN/ha	6146	4401	6095	4688
LSD (5%)	1325.40		865.80	
CV (%)	16.30		10.00	

Table 11: Stover yield of two varieties of maize under different rates of NPK 15-15-15 at harvest in both major and minor seasons of 2019.

Treatments	Major season Stover yield (kg/plt.)	Minor season Stover yield (kg/plt.)
Pannar 12 (P-12)	0.4	0.4
Omankwa (OM)	0.4	0.4
LSD (5%)	NS	NS
Control	0.36	0.36
90 kgN/ha	0.43	0.43
120 kgN/ha	0.4	0.4
150 kgN/ha	0.41	0.41
LSD (5%)	0.05	0.02
CV (%)	9.9	9.9

Table 12: Effect of variety and rate of fertilizer nitrogen (N) interaction on stover yield of two varieties of maize at harvest in both major and minor seasons of 2019.

Treatments	Major season Stover yield (kg/plant)		Minor season Stover yield (kg/plant)	
	P-12	OM	P-12	OM
Control	0.35	0.37	0.35	0.37
90 kgN/ha	0.44	0.42	0.44	0.42
120 kgN/ha	0.38	0.41	0.38	0.41
150 kgN/ha	0.43	0.40	0.43	0.40
LSD (5%)	0.07		0.07	
CV (%)	9.9		9.9	

4. Discussion

4.1. Treatment Effects on Maize Grain Yield. Pannar 12 significantly had longer cobs than those of Omankwa in the minor season of 2019 perhaps due to the genetic ability of the former to utilize growth resources more efficiently than the latter (Tables 4 and 5). Application of 120 kg/ha and 150 kg/ha of fertilizer nitrogen (N) in the major season and minor season, respectively, were the best treatments in terms of cob length probably because nitrogen supply was adequate for increasing the length of maize cobs. The results are in agreement with those of Mahdi and Ismail [23] who reported that cob length increased with increasing nitrogen levels.

Results showed that variety and rate of fertilizer nitrogen (N) application had no significant ($P > 0.05$) effect on the number of cobs per plant throughout the study (Tables 4 and 5). The results could be attributed to low accumulation of dry matter in plants and inefficient translocation of photosynthates from source to sink, which may have impaired cob initiation, resulting in the reduced number of cobs per plant. The quantity of fertilizer nitrogen (N) applied may be insufficient to support cob initiation and development, and this supports studies by Moraditochaee et al. [24] who revealed that the number of cobs per plant increased with increasing nitrogen levels.

Results of cob diameter showed a significant effect with treatment application throughout the study (Tables 4 and 5). In the major season of 2019, the highest cob diameter was formed in Omankwa plants treated with 120 kgN/ha, while the highest cob diameter was produced in Pannar 12 following the application of 150 kg/ha of fertilizer nitrogen in the minor season of 2019 (Table 5). This suggests that an increase in nitrogen (N) rates increases cob diameter. High levels of nitrogen could have enhanced the formation of big cobs due to increased uptake of phosphorus and potassium, which are responsible for proper cob and seed formation. The results showed that Pannar 12 requires heavy doses of nitrogen (N) (150 kg/ha) to form big cobs in the minor season, whereas in the major season, 120 kg/ha of nitrogen (N) was sufficient to increase cob diameter in Omankwa. This significant increase in cob diameter with increase in nitrogen (N) levels may be due to the varieties' efficient response to physiological activities in terms of the growth rate and dry matter accumulation and partitioning in favour of cob formation.

Omankwa plants were better than those of Pannar 12 in the number of grain rows per cob (Tables 6 and 7), and the difference between the two varieties could be genetic. Environmental factors could have a low influence on the number of grain rows as this trait is genetically influenced. This explains why the main effects of fertilizer nitrogen (N) on the number of grain rows per cob were not significant.

The Pannar 12 variety treated with 120 kg/ha and 150 kg/ha of fertilizer nitrogen (N) in the major and minor seasons, respectively, of 2019 had probably the highest number of grains per row of grains. Pannar 12 variety was more efficient than the Omankwa variety in assimilate partitioning in favour of grain production (Tables 6 and 7). The results could also be ascribed to the production of long cobs in Pannar 12 relative to Omankwa. The increased number of grains per ear row with higher nitrogen (N) rates might have resulted from the greater assimilate partitioning to the seeds as a result of a longer growth period and higher photosynthate availability during the grain filling period. These results are consistent with those of El-Naggar et al. [25] who found that timing and split application of nitrogen considerably affected maize grain yield and yield components. Dawadi and Sah [26] suggested that a decrease in the number of grains per ear row under reduced N application could be attributed to poor development of sinks and reduced translocation of photosynthates.

Pannar 12 plants treated with 150 kgN/ha had the highest number of grains per cob (Table 7). An increase in the number of grains per cob at higher nitrogen (N) rates might be due to the lower competition for the nutrient, allowing the plants to accumulate more biomass with a higher capacity to convert more photosynthates into sinks, resulting in more grains per cob. These results are consistent with those of Hu et al. [27] who found that timing and split application of nitrogen increased kernel rows per ear, number of grains per row and per ear, ear length, and thousand grain weight. According to Adhikari et al. [28], a rate of 300 kg N/ha resulted in more grains at 30, 45, 60, and 75 days after planting than the control, showing that reducing nitrogen (N) losses from the soil and making optimum use of nitrogen (N) during crucial growth and development stages of maize would be more cost-effective. The impact of increasing the nitrogen (N) rate on maize production was stronger in early spring sowing than in late spring sowing because of the improved effect of nitrogen (N) fertilizer on the number of kernels per ear [29].

The application of 120 kg/ha of fertilizer nitrogen (N) to both Pannar 12 and Omankwa in the major season and application of 150 kg/ha of nitrogen (N) to Pannar 12 in the minor season of 2019 resulted in the highest cob weight (Figures 1 and 2). The results could be ascribed to the highest cob length, cob diameter, number of grains per row, and number of grains per cob recorded by Pannar 12 treated with 150 kg/ha of fertilizer nitrogen (N). The results suggest that increasing levels of N application could increase yield attributes of maize, especially hybrid maize probably due to efficiency in dry matter partitioning in hybrid maize (Pannar 12) relative to the open pollinated variety (Omankwa). The results of this study are in accordance with those of Gheith et al. [30] and Srivastava et al. [31] who found that yield and yield components of maize increased by increasing application rate of nitrogen (N).

The harvest index is the physiological efficiency and ability of a crop to convert the total dry matter into economic yield. The highest interaction effect was noticed in Omankwa variety treated with no fertilizer nitrogen (N), while the least was associated with Omankwa variety treated with 150 kg/ha of fertilizer nitrogen (N) in the minor season of 2019 (Figure 5). The results could mean that plants of Omankwa variety treated with no fertilizer nitrogen (N) were more efficient in the conversion of total dry matter into grains than other plants. The results are contrary to the findings of Lawrence et al. [32] who reported that the harvest index in maize increased when nitrogen (N) rates were increased. The observation of this study could also be attributed to damage from drought stress. This is because damage from drought stress could restrict sink size due to abortion of the kernels during flowering [33, 34], resulting in a decrease in the harvest index. The authors in [33] also reported that erratic rainfall could reduce the harvest index and accumulation of dry matter in maize. Westgate [35] reported that water stress during grain filling constrained kernel growth because of low availability of assimilates, leading to the reduced harvest index.

Generally, the nutrient-applied treatments increased grain yield over the control (no fertilizer) treatment in both seasons of the trial (Tables 9 and 10). The highest grain yields

(6146 kg/ha and 6095 kg/ha in the major and minor rainy seasons, respectively) were produced when Pannar 12 was treated with 150 kg/ha of fertilizer nitrogen (N) which could be ascribed to the highest NUE and yield attributes of cob weight, cob length, cob diameter, number of grains per row, and number of grains per cob recorded in that treatment combination (Table 10). This means that increasing levels of nitrogen (N) application could increase the yield and yield attributes of maize, especially hybrid maize probably due to efficiency in dry matter partitioning in hybrid maize (Pannar 12) relative to the open pollinated variety (Omankwa). This is because hybrids respond to fertilizers better than open pollinated varieties. Studies by Ahmad et al. [36] and Noor Shah et al. [37] revealed that increasing nitrogen (N) availability increased maize yield.

Application of 120 kgN/ha to the Omankwa variety gave grain yields of 4635 kg/ha and 5286 kg/ha in the major and minor rainy seasons, respectively. The results could mean that 120 kg/ha of fertilizer nitrogen is sufficient to increase grain yields in Omankwa, an open pollinated maize variety. The results of this study are in accordance with those of Halvorson et al. [38] who reported a significant increase in maize grain yield with rates up to 224 $kg\,N\,ha^{-1}$ under irrigated conditions. In a similar study, Ma et al. [39] also observed that maize grain yield increased significantly with rates up to 120 $kg\,N\,ha^{-1}$. These results are consistent with those obtained by Asif et al. [40], Wasaya et al. [41], and Hu et al. [27] who observed that when the nitrogen (N) rate was increased, the average yield increased in a progressive and positive manner.

Grain yields of both the hybrid and open pollinated maize varieties were higher in the major season than in the minor season (Tables 9 and 10). The results could be due to ideal growth conditions during the most critical growth phase of the maize plants in the major season. The suitable growth conditions in the major season of 2019 included favourable rainfall distribution, adequate temperature, suitable soil-water relationships, and efficient dry matter partitioning, culminating in favourable vegetative and reproductive growth. The rainfall figures recorded at the experimental site in 2019 (Table 3) indicated that rainfall amount and distribution were ideal for maize plants within the first three months of growth in the major season of 2019. This certainly could have supported cob formation and grain filling, resulting in big cobs and heavy grains. However, a different pattern of precipitation was observed in the first three months of growth of maize plants grown in the minor season of 2019. This is because the rainfall amount was not adequate within the first two months of growth, which adversely affected the reproductive growth of the plants. According to Zaidi et al. [42], severe moisture stress causes different levels of damage depending on the developmental stage, and previous studies have indicated that the maize crop is highly susceptible to drought from the seedling to tasselling phases of growth.

The highest stover yield of 0.43 kg/plant was produced when Pannar 12 was treated with 150 kg/ha of fertilizer nitrogen (N) and that result could be ascribed to the highest shoot dry matter production and yield attributes of cob weight, cob length, cob diameter, number of grains per row, and number of grains per cob recorded in that treatment combination (Table 12). The results could be due to the fact that the application of 150 kgN/ha could have increased the availability of the nutrient in proportion to the need of the Pannar 12 plants for nitrogen (N) uptake based on their growth stage over an extended duration. This may have enabled the Pannar 12 plants to absorb adequate nitrogen (N) from the soil for enhanced photosynthesis and the accumulation of higher amounts of biomass. Consistent with the results of this study, Alemayehu and Shewarega [43] found the highest maize biomass yields in response to the application of N fertilizer at the rate of 92 $kg\,N\,ha^{-1}$ in three split applications of 1/4 at planting, 2/4 at the mid vegetative stage, and 1/4 at tasselling.

5. Conclusions and Recommendations

5.1. Summary of Results

(i) Application of NPK 15-15-15 increased the grain yield of Pannar 12 and Omankwa throughout the study.

(ii) The interaction between variety and fertilizer N rates was significant for number of grains per cob, cob weight, cob length, cob diameter, and grain yield.

(iii) Application of 120 kg/ha and 150 kg/ha of fertilizer N in the major season and minor season, respectively, produced the longest and biggest cobs.

(iv) Cob weight was significantly increased due to the application of 120 kgN/ha to plants of both Omankwa and Pannar 12 in the major season of 2019.

(v) In the minor season of 2019, cob weight was significantly increased due to the application of 150 kgN/ha to plants of Pannar 12.

(vi) The application rate of 150 kgN/ha produced the highest grain yield, followed by 120 kgN/ha, 90 kgN/ha and the control, or 0 kgN/ha.

5.2. Conclusions

(i) Generally, the yield and yield components of maize increased with increasing levels of fertilizer nitrogen.

(ii) Results of the study showed that the application of 120 kg/ha of fertilizer nitrogen improved grain yield in Omankwa maize variety in both major and minor rainy seasons, while the application of 150 kg/ha of fertilizer nitrogen to Pannar 12 increased grain yield in both major and minor rainy seasons.

5.3. Recommendations

(i) To optimize the grain yield of maize, farmers could use NPK 15-15-15 fertilizer as a source of nitrogen and apply 120 kgN/ha to Omankwa variety and

150 kgN/ha to Pannar 12 variety in both major and minor rainy seasons.

(ii) This study was undertaken in a semi deciduous forest agro-ecology in one location where the test crops were grown with NPK 15-15-15 fertilizer under rainfed conditions. It is, therefore, recommended that in future studies, urea, NPK 23-10-10, NPK 20-10-10, and other sources of mineral fertilizer nitrogen are tested on Omankwa, Pannar 12, and other improved maize cultivars in multilocations.

Data Availability

The data used to support the findings of this research could be obtained from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this article.

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References

[1] D. J. Kennett, K. M. Prufer, B. J. Culleton et al., "Early isotopic evidence for maize as a staple grain in the Americas," *Science Advances*, vol. 6, no. 23, Article ID eaba3245, 2020.

[2] Faostat, *Agriculture Organization of the United Nations (FAO)*, FAO, Rome, Italy, 2021.

[3] S. T. Partey, N. V. Thevathasan, R. B. Zougmoré, and R. F. Preziosi, "Improving maize production through nitrogen supply from ten rarely-used organic resources in Ghana," *Agroforestry Systems*, vol. 92, no. 2, pp. 375–387, 2016.

[4] C. Ragasa, A. Dankyi, P. Acheampong et al., "Patterns of adoption of improved rice technologies in Ghana," *International Food Policy Research Institute Working Paper*, vol. 35, pp. 6–8, 2013.

[5] H. Gul, S. Rahman, A. Shahzad et al., "Maize (*Zea mays* L.) productivity in response to nitrogen management in Pakistan," *American Journal of Plant Sciences*, vol. 12, no. 08, pp. 1173–1179, 2021.

[6] D. K. Asare, E. O. Ayeh, H. M. Amoatey, and J. O. Frimpong, "Biomass production by rainfed maize cultivars in a coastal savannah agro-ecological environment," *World Journal of Agricultural Sciences*, vol. 8, no. 3, pp. 286–292, 2012.

[7] FAO, "Analysis of price incentives for Maize in Ghana from 2005-2013," in *Technical Notes Series*, F. Angelucci, D. Modzakah, and L. Abusah, Eds., MAFAP, Rome, Italy, 2016.

[8] A. Kaur, S. Bedi, G. K. Gill, and M. Kumar, "Effect of nitrogen fertilizers on radiation use efficiency, crop growth and yield in some maize (*Zea mays* L) genotypes," *Maydica*, vol. 57, pp. 75–82, 2012.

[9] A. N. Shah, M. Tanveer, A. Abbas et al., "Combating dual challenges in maize under high planting density: stem lodging and kernel abortion," *Frontiers of Plant Science*, vol. 12, Article ID 699085, 2021.

[10] L. J. Šarčević-Todosijević, L. J. Živanović, S. Janjić et al., "The influence of nitrogen fertilizer on the total number of microorganisms and aminoautotroph dynamics under"ugar" and sown maize," *Journal of Agriculture and Forestry*, vol. 62, no. 3, pp. 185–196, 2016.

[11] K. Habtegebrial, B. R. Singh, and M. Haile, "Impact of tillage and nitrogen fertilization on yield, nitrogen use efficiency of tef (*Eragrostis tef* (Zucc.) Trotter) and soil properties," *Soil and Tillage Research*, vol. 94, no. 1, pp. 55–63, 2007.

[12] N. R. Abdelsalam, E. E. Kandil, M. A. F. Al-Msari et al., "Effect of foliar application of NPK nanoparticle fertilization on yield and genotoxicity in wheat (*Triticum aestivum* L.)," *The Science of the Total Environment*, vol. 653, pp. 1128–1139, 2019.

[13] S. Wei, X. Wang, G. Li, Y. Qin, D. Jiang, and S. Dong, "Plant density and nitrogen supply affect the grain-filling parameters of maize kernels located in different ear positions," *Frontiers of Plant Science*, vol. 10, p. 180, 2019.

[14] H. M. Hammad, M. S. Chawla, R. Jawad et al., "Evaluating the impact of nitrogen application on growth and productivity of maize under control conditions," *Frontiers of Plant Science*, vol. 13, Article ID 885479, 2022.

[15] A. Zhanbota, R. S. Noor, A. I. Khan et al., "A two-year study on yield and yield components of maize-white bean intercropping systems under different sowing techniques," *Agronomy*, vol. 12, no. 2, p. 240, 2022.

[16] S. A. Ojobor, C. N. Egbuchua, and R. A. Onoriasakpovwa, "Assessment of soil fertility status using nutrient index approach of Ovu Sub-Clan, Delta State," *Nigeria. Agricultural Science Digest*, vol. 41, no. 2, pp. 282–288, 2021.

[17] I. K. Amegbor, B. Badu-Apraku, and B. Annor, "Combining ability and heterotic pat- terns of extra-early maturing white maize inbreds with genes from *Zea diploperennis* under multiple environments," *Euphytica*, vol. 213, no. 1, Article ID 24, 2017.

[18] *Ghana Statistical Service and Meteorological Station, 2010 Population and Housing Census*, National Analytical Report, 2012.

[19] M. R. Motsara and R. N. Roy, "Guide to laboratory establishment for plant nutrient analysis," *Food and Agriculture Organization of the United Nations FAO Fertilizer and Plant Nutrition Bulletin No 19*, FAO of the United Nations, Rome, Italy, 2008.

[20] Kwame Nkrumah University of Science and Technology (Knust), *Kumasi*, Soil Science Laboratory, Ghana, 2019.

[21] *Meteorological Station*, Sunyani, Ghana, 2019.

[22] R. Payne, D. Murray, S. Harding, D. Bair, and D. Souter, *GenStat for Windows (12^{th} Edition) Introduction*, Hemel Hempstead: VSN International, UK, 2009.

[23] A. H. Mahdi and S. K. Ismail, "Maize productivity as affected by plant density and nitrogen fertilizer," *International Journal of Current Microbiology and Applied Sciences*, vol. 4, no. 6, pp. 870–877, 2015.

[24] M. Moraditochaee, M. K. Motamed, E. Azarpour, R. K. Danesh, and H. R. Bozorgi, "Effects of nitrogen fertilizer and plant density management in corn farming," *ARPN Journal of Agricultural and Biological Science*, vol. 7, no. 2, pp. 133–137, 2012.

[25] M. E. El-Naggar, N. R. Abdelsalam, M. M. Fouda et al., "Soil application of nano silica on maize yield and its insecticidal activity against some stored insects after the Post-Harvest," *Nanomaterials*, vol. 10, no. 4, p. 739, 2020.

[26] D. R. Dawadi and S. K. Sah, "Growth and yield of hybrid maize (*Zea mays* L.) in relation to planting density and nitrogen levels during winter season in Nepal," *Tropical Agriculture Research Series*, vol. 23, no. 3, pp. 218–227, 2012.

[27] F. Hu, Y. Tan, A. Yu et al., "Optimizing the split of N fertilizer application over time increases grain yield of maize-pea intercropping in arid areas," *European Journal of Agronomy*, vol. 119, Article ID 126117, 2020.

[28] P. Adhikari, B. R. Baral, and J. Shrestha, "Maize response to time of nitrogen application and planting seasons," *Journal of Maize Research and Development*, vol. 2, no. 1, pp. 83–93, 2016.

[29] A. E. Coelho, L. Sangoi, A. A. Balbinot, H. F. Kuneski, and M. C. Martins, "Nitrogen use efficiency and grain yield of corn hybrids as affected by nitrogen rates and sowing dates in subtropical environment," *Revista Brasileira de Ciência do Solo*, vol. 46, Article ID e0210087, 2022.

[30] E. M. S. Gheith, O. Z. El-Badry, S. F. Lamlom et al., "Maize (*Zea mays* L.) Productivity and nitrogen use efficiency in response to nitrogen application levels and time," *Frontiers of Plant Science*, vol. 13, Article ID 941343, 2022.

[31] R. K. Srivastava, R. K. Panda, A. Chakraborty, and D. Halder, "Enhancing grain yield, biomass and nitrogen use efficiency of maize by varying sowing dates and nitrogen rate under rainfed and irrigated conditions," *Field Crops Research*, vol. 221, pp. 339–349, 2018.

[32] J. R. Lawrence, Q. M. Ketterings, and J. H. Cherney, "Effect of nitrogen application on yield and quality of silage corn after forage legume-grass," *Agronomy Journal*, vol. 100, no. 1, pp. 73–79, 2008.

[33] H. J. Earl and R. F. Davis, "Effect of drought stress on leaf and whole canopy radiation use efficiency and yield of maize," *Agronomy Journal*, vol. 95, no. 3, pp. 688–696, 2003.

[34] J. A. Roth, I. A. Ciampitti, and T. J. Vyn, "Physiological evaluations of recent drought-tolerant maize hybrids at varying stress levels," *Agronomy Journal*, vol. 105, no. 4, pp. 1129–1141, 2013.

[35] M. E. Westgate, "Water status and development of the maize endosperm and embryo during drought," *Crop Science*, vol. 34, no. 1, pp. 76–83, 1994.

[36] M. I. Ahmad, A. N. Shah, J. Sun, and Y. Song, "Comparative study on leaf gas exchange, growth, grain yield, and water use efficiency under irrigation regimes for two maize hybrids," *Agriculture*, vol. 10, no. 9, p. 369, 2020.

[37] A. Noor Shah, Y. Wu, J. Iqbal et al., "Nitrogen and plant density effects on growth, yield performance of two different cotton cultivars from different origin," *Journal of King Saud University Science*, vol. 33, no. 6, Article ID 101512, 2021b.

[38] A. D. Halvorson, B. J. Wienhold, and A. L. Black, "Tillage and nitrogen fertilization influence grain and soil nitrogen in an annual cropping system," *Agronomy Journal*, vol. 93, no. 4, pp. 836–841, 2001.

[39] B. L. Ma, K. D. Subedi, and C. Costa, "Comparison of crop-based indicators with soil nitrate test for corn nitrogen requirement," *Agronomy Journal*, vol. 97, no. 2, pp. 462–471, 2005.

[40] M. Asif, M. F. Saleem, S. A. Anjum, M. A. Wahid, and M. F. Bilal, "Effect of nitrogen and zinc sulphate on growth and yield of maize (*Zea mays* L.)," *Journal of Agricultural Research*, vol. 51, pp. 455–464, 2013.

[41] A. Wasaya, M. Tahir, H. Ali et al., "Influence of varying tillage systems and nitrogen application on crop allometry, chlorophyll contents, biomass production and net returns of maize (*Zea mays* L.)," *Soil and Tillage Research*, vol. 170, pp. 18–26, 2017.

[42] P. H. Zaidi, S. Rafique, P. Rai, N. N. Singh, and G. Srinivasan, "Tolerance to excess moisture in maize (*Zea mays* L.): susceptible crop stages and identification of tolerant genotypes," *Field Crops Research*, vol. 90, no. 2-3, pp. 189–202, 2004.

[43] Y. Alemayehu and M. Shewarega, "Growth and yield responses of maize (*Zea mays* L.) to different nitrogen rates under rain-fed condition in Dilla area, southern Ethiopia," *Journal of Natural Sciences Research*, vol. 5, pp. 40–44, 2015.