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The Responses of Three Maize Varieties to Four Levels of Nitrogen in the Forest-transitional Zone of Ghana

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Abstract
Maize cultivation is one of the major farming activities in the forest-transition zone of Ghana. Maize is cultivated in the major and minor cropping seasons of the year. Hardly would any farmer harvest any produce without the application of fertilizer. Field trials were therefore conducted at the Crop Farm (Corn belt) of the University of Education, Winneba, Mampong Ashanti Campus in the minor cropping season (between August and January) and major cropping season (between April and July) to assess the responses of three varieties of maize to four different rates of nitrogen in the forest-transition of Ghana. The treatments were three varieties of quality protein maize. Obatanpa (V_1), Mamaba (V_2), Golden Jubilee (V_3) and four levels of nitrogen, 0Kg N/ha (N_0), 45kg N/ha (N_1), 60 Kg N/ha (N_2), 90Kg N/ha (N_3). The field trials were a 3 x 4 factorial experiment in a randomized complete block design (RCBD). Factor A was designated the maize varieties and factor B the rates of nitrogen fertilizer. The study showed that different application rate of nitrogen fertilizer significantly improved maize growth and grain yield. Growth and yield were more significantly ($P<0.05$) supported by 90 Kg N/ha and 60 Kg N/ha than 45 Kg and O Kg N/ha. The application rates of 90 Kg N/ha, 60 Kg and 45 Kg N/ ha led to significant ($P < 0.05$) increase in the yield of maize due to increases in yield components. In conclusion, it is recommended that farmers in the forest-transition zone, notably, Ashanti region, should plant Obatanpa and Golden Jubilee in both cropping seasons and Mamaba only in the major season.
Keywords: Maize, Nitrogen, Yield components, Grain yield

1. Introduction

Maize or corn (*Zea mays L)* is cultivated globally, being one of the most important cereal crops world-wide (IITA, 1991).It is grown by both peasant and commercial farmers (Onwueme & Sinha, 1991) and third in terms of production and consumption, following rice and wheat world–wide (Yayock *et al.*, 1988). In Ghana, it is the first among the cereal crops grown (Gounou *et al.,* 1994) and is cultivated in all the ecological zones. Ashanti region, which is within the forest-transition zone, is one of the leading regions where the crop is cultivated twice a year in the major (April – July) and the minor (August- November) seasons.

The crop is high yielding, easy to process, readily digested, and cheaper than other cereals. Every part of it has an economic value including the grain, leaves, stalk, tassel, and the cob which are used to produce a large variety of food and non- food products. In industrialized countries, maize is largely used as livestock feed and as raw material for industrial products while in developing countries it is mostly used for human consumption (IITA, 2007). World-wide, about 66% of maize produced is used for feeding livestock, 25% for human consumption and 9% for industrial and seed purposes (Romains, 2001). It is an important source of carbohydrate, protein, iron, vitamin B, and minerals. Green maize (fresh on the cob) may be eaten roasted or boiled. The grain is used to produce a variety of foodstuffs including corn flour, ground maize, cornflakes and corn oil (Yayock *et al.*, 1988). The crop residue is a source of fuel (Gibbon & Pain, 1985) and the grain is a major source of energy in non-ruminants. As food, it is prepared as *Banku, Kenkey, Akple* and *Tuo Zaafi* depending upon the locality while the husk is used locally to wrap kenkey and for making door mats (Awuku *et al.*, 1991).

Maize is cultivated by 1.75 million (about 64%) of the 2.74 million households operating farms in Ghana (MOFA, 2002). During the same period, average maize yield increased from 1.07 tones per hectare to 1.55 tones per hectare (PPMED 1991; 1998). Currently, total land area under cultivation is about 713, 300 hectares with yield of 5 metric tones per hectare (MOFA, 2002).

Several improved maize varieties with different maturity periods have been developed and released to farmers by the Crops Research Institute (CRI) of Council for Scientific and Industrial Research (CSIR), Ghana to meet the needs of growers in the different ecological zones of the country (Twumasi-Afriyie *et al.*, 1992, 1997). These varieties include Okomasa, Abeleehi, Obatanpa, Dadaba, Mamaba, CIDA–ba, and Golden Jubilee Maize. Dadaba, Dobidi, Mamaba, Golden Jubilee, CIDA–ba and Obatanpa are quality protein maize (QPM) varieties. (Asiedu *et al.*, 2001). Unlike normal maize, these QPM varieties have adequate amounts of lysine and tryptophan with their high yielding potential and high nutritive value making them the best varieties to boost maize production (Asiedu *et al.,* 2001).

Constraints to maize production include declining soil fertility, limited use of nitrogen fertilizers, and periodic drought caused by erratic rainfall distribution patterns. These factors reduce maize yields by amounts averaging 15% yearly (IITA, 2007).

Maize requires adequate supply of nutrients particularly nitrogen, phosphorus and potassium (NPK) for good growth and high yield. Nitrogen is key to increase in productivity, an integral component of many compounds essential for plant growth processes including chlorophyll and many enzymes (Sobulo, 1980). It also mediates the utilization of potassium, phosphorus and other elements in plants (Gibbon & Pain, 1985). Maize nitrogen requirement can be as high as 150 to 200 kg per hectare, with the recommended rate depending on soil type and cropping history of the field.

Nitrogen is a limiting factor in the forest-transition soils used for maize production in this zone. Hardly would farmers make harvest without the crops being fertilized. Field trials were conducted in the minor and major cropping seasons to assess the responses of three popular quality protein maize varieties to four levels of nitrogen fertilizer in the forest-transitional soil of the Ashanti region of Ghana.

2. Materials and methods

Field trials were conducted at the maize farm of the University of Education, Winneba, Mampong - Ashanti Campus. The first field trial was undertaken during the minor season (August to January) and the second field trial during the major season (April to July). Ashanti Mampong is situated on latitude 07^0 04'N and longitude 01^0 24'W at 137.3m above sea level (Asiedu *et al.*, 2001), about 55km north of Kumasi, along the Kumasi-Ejura road within the transitional zone between the rain forest of the south and Guinea savannah of the north.

The soil falls within the Bediesi series of the savannah ochrosol class, formed from Voltaian sandstone of the Afram Plains. It is deep, yellowish red, sandy loam and free from concretions and stones. It is well drained, with satisfactory moisture - holding capacity and a pH of 5.5 – 6.5 (Asiedu *et al.*, 2001). It is easy to cultivate by hand and machines and supports many crops such as cereals, legumes, root, and tuber crops.

The rainfall pattern of the area is bimodal. The major season starts from March and ends in July with the peak in June whilst the minor rains occur between September and November with a peak in October. The mean annual rainfall and temperature figures are 1094.2 mm and 30.8^0C, respectively (Asiedu *et al.*, 2001). The mean daily temperature ranges from 25°C to 37°C. (Asiedu *et al.*, 2001).

2.1 The experimental design and treatments

The experimental design was a 3 x 4 factorial fitted trial into a randomized complete block design (RCBD) with four (4) replications having net plot size of 10m x 4m. A total of 48 plots were used for the trial with 1.0m path between plots and between blocks. Twelve treatment combinations comprising three (3) varieties of maize (Obatanpa, Mamaba and Golden Jubilee) and four (4) nitrogen levels (0, 45, 60, and 90 kgN/ha) were randomized after the field had been laid out. Factor A represented the maize varieties and factor B the rates of nitrogen fertilizer.

2.2 Management practices

The experimental field was cleared, ploughed twice with tractor, leveled manually and divided into four (4) blocks and 48 plots before planting on a total land area measuring 87m x 29m (2523m^2) for the minor and major cropping seasons.

Before planting representative soil samples were taken with an augur at randomly selected sites on each treatment combination plot at a depth of 0-15cm. They were then mixed thoroughly, air-dried and sieved through 2mm and 0.5mm sieves for soil texture determination and chemical analysis. The soil samples were later sent to Soils Research Institute at Kwadaso- Kumasi for physico-chemical analysis. The three maize varieties (Obatanpa, Mamaba and Golden Jubilee, all QPM varieties) were obtained from the Crops Research Institute, Fumesua - Kumasi.

The seeds were sown manually on the flat land on 12th September during the minor cropping season and on 21st April for the major cropping season. Three seeds were sown per stand and thinned to two seedlings per stand two weeks after sowing. Seeds were sown at a planting distance of 75cm between rows and 40cm between plants at a depth of 3-5cm. Germination percentage was determined seven days after sowing for each treatment for both trials.

The traditional hoe as well as herbicide (Caliherb + Atrazine) was used to control weeds. The first and second weedings were carried out at three (3) weeks and six (6) weeks after seedlings emergence, respectively. Earthing up was carried out after the second weeding to provide support for plants against lodging.

A compound fertilizer 15-15-15 NPK was basally applied at the rate of 7.5g/hill to all treatments at two weeks after seedling emergence. It was applied by side placement of 11cm from the maize plants at a depth of 2-3cm. The test nitrogen in the form of sulphate of ammonia ($(NH_4)_2SO_4$) was applied as top dressing at the rates of 0gN (Okg N/ha), 7.5kg N (45 kgN/ha), 22.9kgN (60kgN/ha), and 53kgN (90kgN/ha). The nitrogen was applied at about 40 days after sowing during the minor season and at about 42 days during the major season.

Harvesting for both trials was done manually 15 weeks after sowing. The plants were harvested at physiological stage of maturity. Signs of maturity considered included toppling and drying of leaves and cobs. Yield components were taken from a quadrat of 2.1m x 1.2m (2.52m^2) within the harvestable area of each treatment plot. All the varieties were harvested 15 weeks after sowing (WAS).

2.3 Data collection

Plant Height: The heights of 10 randomly tagged plants were measured every two weeks from the ground level to the tip of the terminal leaf with the aid of a meter rule.

Plant Girth: The girth (diameter) of the plant stem was taken weekly at the base of each plant about 5cm above ground level with the aid of a Vernier calipers. Ten (10) plants were randomly tagged from the fourth week to the tenth week for the girth data.

Leaf Area Index: A quadrat of 2m^2 area was selected randomly at 8 WAS where optimum plant growth was achieved in both cropping seasons from each plot. The measurement of length and width at the broadcast point of each leaf in the quadrat was then taken. Each leaf area designated as A was estimated by the formula A= L x B x 0.75, where L is the length of the leaf, B is the maximum width of the leaf (cm) and 0.75 is the correction factor.

Days to 50% Tasselling and 50% Silking: The plants in the three middle rows in each plot were used to estimate days to 50% tasselling and 50% silking. At 6-8 weeks after seedling emergence, the number of maize plants which were completely tasseled and silked were counted and recorded on daily basis. The total number of plants recorded daily per plot was then converted into percentages. Mathematically, the total number of tasseled and silked plants (x) recorded was then divided by the total plant population (y) in the three middle rows and the results then multiplied by 100.

Cob length and cob diameter: The cob length was assessed by selecting ten (10) dehusked cobs at random from each harvested plot. The length of each cob was then carefully measured by means of a 50-meter measuring tape. The mean length of the ten dehusked cobs was then computed and recorded. Similarly, the mean cob diameter was assessed and recorded.

Number of Grains per Cob: Five (5) cobs were selected at random from each plot. The number of grains in 2-3 rows was then counted and the mean number calculated and multiplied by the number of rows on the cob. The mean number of grains per cob for each treatment was then computed.

Shelling percentage: Ten (10) cobs selected at random from each plot were weighed. These were shelled and the grains weighed. The weights obtained were then used to compute the shelling percentage.

1000-grain weight: Thousand grains from each plot were weighed by the use of the electronic balance at moisture content of 13 to14% and the treatment mean computed.

Grain yield (kg) per hectare: The grain yield from each plot harvested from cobs in the harvestable rows was calculated and the results were used to compute the yield per hectare.

Harvest Index: The harvest index was calculated as follows. One plant per hill was selected randomly from each treatment plot and the shoot with roots and the cob weighed. The cob was then removed and weighed alone. The harvest index was then computed as the ratio of the cob (c) weight to the weight of the shoot (s) plus the cob.

2.4 Data analysis

The data collected were subjected to the analysis of variance (ANOVA) using SAS-GLM procedures (SAS Institute, 1990). The treatment means were separated by the least significant difference (LSD).

3. Results

During the minor season, significant ($P<0.05$) differences were observed between the three maize varieties on the seedling emergence or establishment. Maximum germination was recorded in Mamaba that was statistically at par with that of Golden Jubilee while minimum percent germination was recorded in Obatanpa but differences were not significant ($P>0.05$).

In the major season no significant ($P>0.05$) differences were observed but maximum percent germination was recorded in Golden Jubilee whereas minimum germination was observed in Obatanpa. No significant ($P>0.05$) differences were recorded between the levels of nitrogen applied to the varieties in the minor and major cropping seasons. The interaction between maize varieties and the levels of nitrogen did show significant ($P<0.05$) differences in both cropping seasons.

3.1 Growth components in three varieties of maize during the minor and major cropping seasons

3.1.1 Plant height

The data recorded (Figure 1) showed that plant height increased across the treatments at all stages of growth. At weeks 4 and 6 after planting (WAP), the varieties of maize did not show any significant ($P>0.05$) differences in plant height in the treatments (treatment combinations) during the minor season.

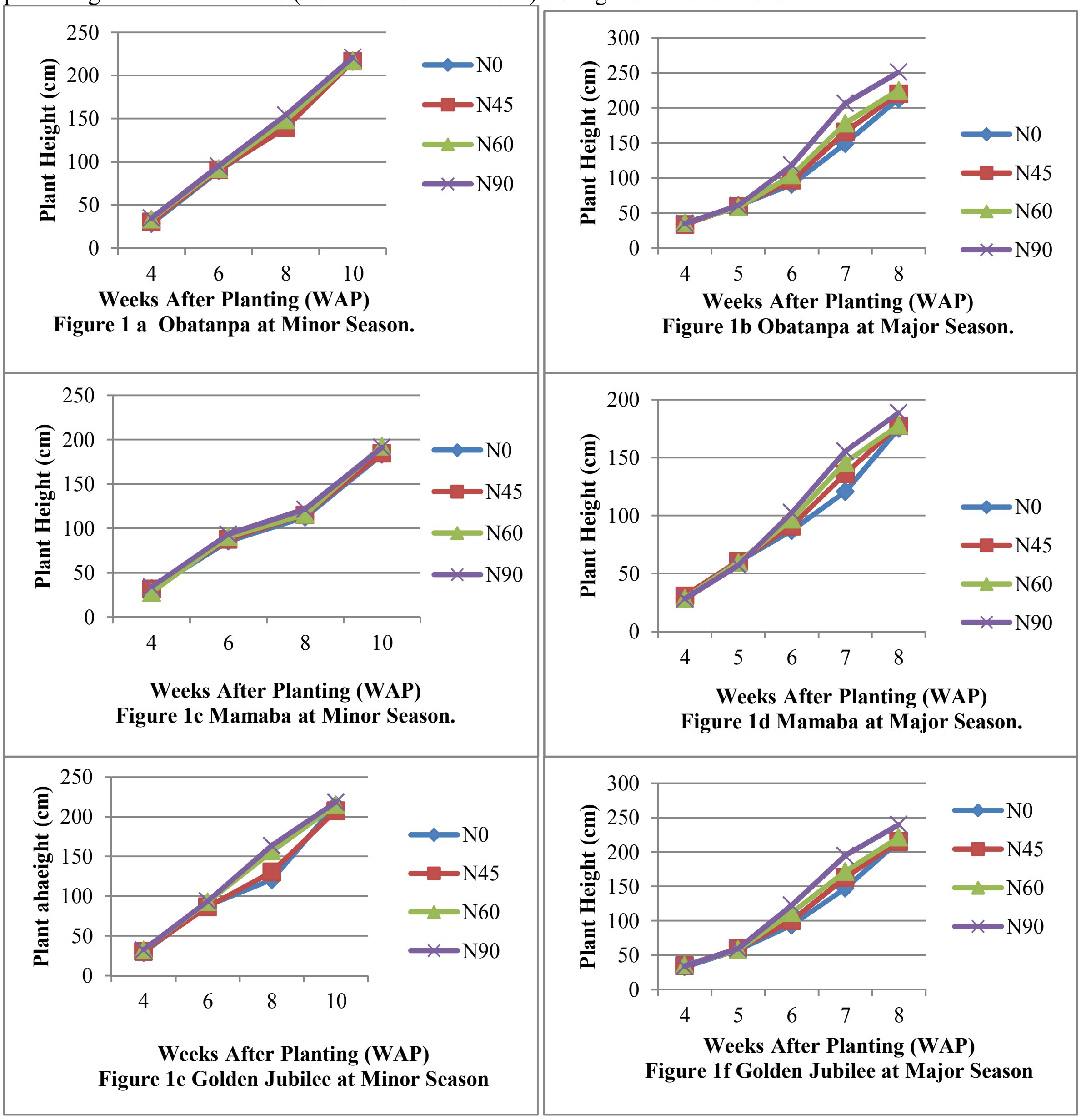

Figure 1: The effect of rates of nitrogen on plant height in the three varieties of maize.

However, at 50% tasselling at 8WAP and 10WAP, plant height in the maize varieties differed significantly ($P < 0.05$). Maximum plant height was recorded in Obatanpa 10 WAP during the minor season. The height was not significantly ($P>0.05$) different from Golden Jubilee but higher ($P<0.05$) than Mamaba variety.

Plots fertilized with 90kgN/ha produced maximum plant height which was also, statistically ($P>0.05$) similar to plots fertilized with 60kgN/ha. The least plant height was recorded on plots fertilized with 45kgN/ha and 0kgN/ha.

3.1.2 Plant stem girth

Figure 2 shows the effect of nitrogen application on the girth of maize varieties at various growth stages after planting. In the minor cropping season, there were no significant ($P>0.05$) differences in plant girth between Obatanpa and Golden Jubilee varieties.

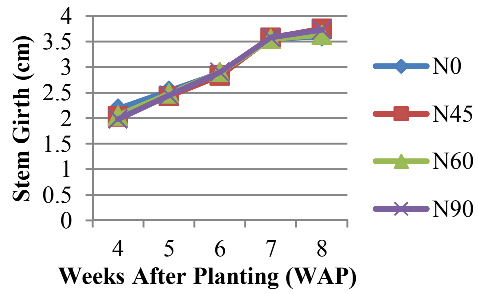

Figure 2a Obatanpa at Minor Season.

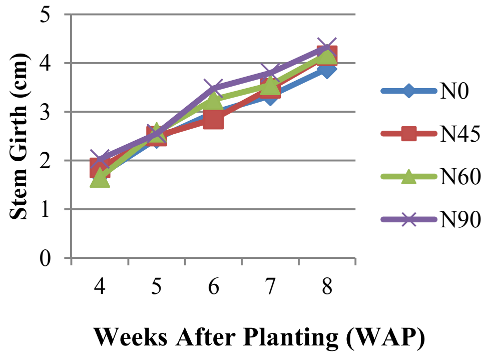

Figure 2b Obatanpa at Major Season.

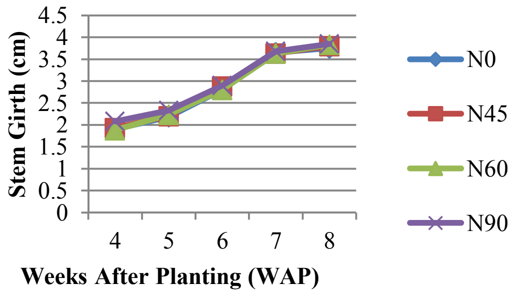

Figure 2c Mamaba at Minor Season.

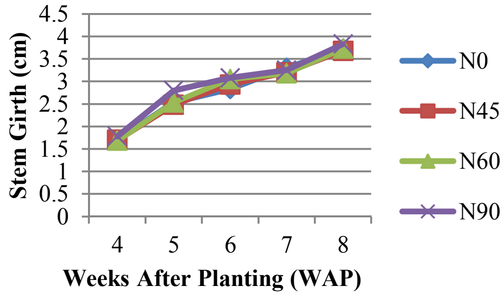

Figure 2d Mamaba at Major Season

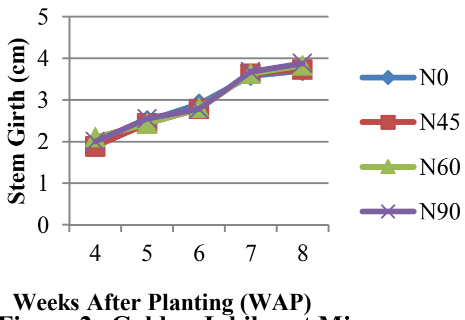

Figure 2e Golden Jubilee at Minor Season.

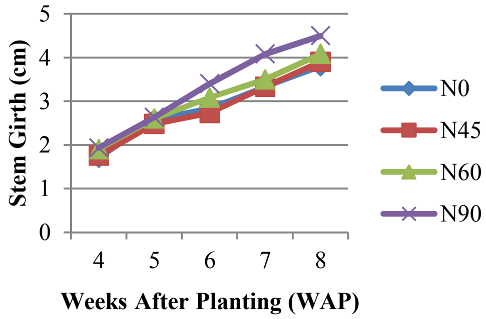

Figure 2f Golden Jubilee at Major Season.

Figure 2: Effects of rates of nitrogen on stem girth in three maize varieties.

However, significant (P<0.05) bigger girths were observed in the Obatanpa and Golden Jubilee than Mamaba. No significant (P>0.05) differences were observed between the various nitrogen levels applied during the season, except at 8WAP. The interaction between varieties and nitrogen levels on plant girth showed significant (P<0.05) differences at 5 and 8WAP.Nitrogen applied at 90kgN/ha produced the biggest plant girth in Golden Jubilee while 0kgN/ha produced the smallest plant girth in Mamaba.

During the major season, maize varieties did not show significant (P>0.05) differences in plant girth at 6, 7 and 8WAP. The biggest stem girth was recorded in Obatanpa maize and the smallest stem girth was observed in the Mamaba maize. With regards to the various nitrogen levels, significant (P<0.05) differences in plant girth occurred during 4 and 5 WAP. The interaction between nitrogen and the varieties of maize significantly (P<0.05) affected plant girth. Plots which received 90kgN/ha produced the biggest plant girth followed by plots which received 60kgN/ha, 45kgN/ha and 0kgN/ha in that order (Figure 2).

3.1.3 Leaf area index

No significant (P>0.05) differences in leaf area index were observed among the maize varieties during the minor season (Table 1) but in the major season, the largest leaf area index was significant (P<0.05) in Obatanpa (3.38). In both cropping seasons the maize varieties which received 90kgN/ha, 60kgN/ha and 45kgN/ha showed significantly higher (P<0.05) leaf area indices.

The various levels of nitrogen significantly (P < 0.05) affected leaf area index in both cropping seasons. As the level of nitrogen was increased leaf area index also increased (Table 1), with higher doses of N (90kg /ha) and 60kg/ha) being significantly (P<0.05) different from the plots with the lower doses of N (45kg/ha) and 0kg/ha) applied in both minor and major cropping seasons. Analysis of the data also showed that interaction between nitrogen levels and varieties of maize was significant (P<0.05) in both cropping seasons. The leaf area index observed in the maize varieties was highest at the application rate of 90kgN/ha.

Table 1: Levels of Nitrogen on Leaf Area Index and Phenology in Three Varieties of Maize during Minor and Major Seasons.

TREATMENT	Minor season			Major season		
	Leaf Area Index 8WAP	Days to 50% tasselling	Days to 50% silking	Leaf Area Index 8WAP	Days to 50% tasselling	Days to 50% silking
Variety X Nitrogen						
Obatanpa						
N0	2.57	49.75	51.00	2.62	47.50	51.25
N45	3.05	49.75	50.75	3.09	48.75	51.00
N60	3.46	49.75	50.50	3.84	49.00	50.25
N90	3.60	50.00	50.75	3.96	48.50	50.75
Mamaba						
N0	2.53	48.25	51.00	2.46	48.25	50.75
N45	2.87	48.25	50.50	2.69	48.00	50.25
N60	3.14	48.00	50.5	3.19	48.00	50.25
N90	3.53	48.25	50.25	3.48	48.25	50.50
Golden Jubilee						
N0	2.50	48.25	51.00	2.39	48.75	50.75
N45	2.84	48.75	50.25	2.93	48.75	51.00
N60	3.30	48.75	50.75	3.51	48.50	50.50
N90	3.72	49.25	50.25	3.88	48.75	51.00
LSD Variety	NS	0.43*	NS	0.19*	NS	0.37*
LSD Nitrogen	0.24*	NS	0.47*	0.22*	NS	0.42*
LSD Var. x N.	0.42*	0.86*	NS	0.38*	0.93*	0.73*

* = significant at 5% probability level NS= not significant at 5% probability level

3.2 Yield and yield components of maize

3.2.1 Cob length

The results on cob length for the minor season are indicated in Figure 3. There were significant (P<0.05) differences in cob lengths among the three maize varieties. The mean highest cob length was recorded in the Golden Jubilee variety.

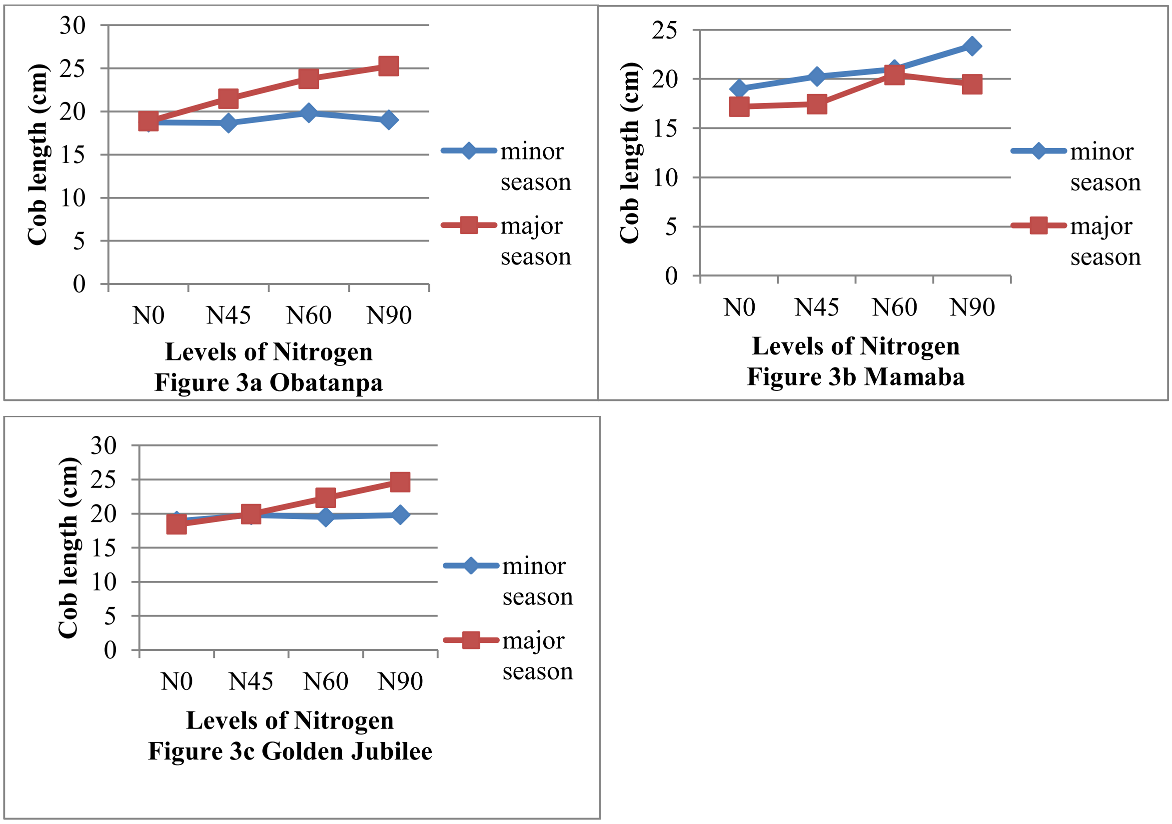

Figure 3: Different Levels of Nitrogen on Cob Length in Three Varieties of Maize during Minor and Major Seasons.

The various levels of nitrogen also significantly (P <0.05) affected the cob lengths. The interaction between the levels of nitrogen and maize varieties significantly (P <0.05) affected the cob length. The plots with nitrogen level of 0kgN/ha produced the lowest cob length.

During the major season, cob lengths recorded in the maize varieties again, showed significant (P<0.05) differences, with Obatanpa maize cob being the longest. Similarly, the various levels of nitrogen significantly (P<0.05) affected maize cob length. Plots which received nitrogen level of 90kgN/ha produced the highest cob length. The interaction between nitrogen and maize varieties significantly (P<0.05) affected cob length. Plots with nitrogen level of 0kgN/ha had the lowest cob length (Figure 3).

3.2.2 Cob width

In both cropping seasons, significant (P<0.05) differences were observed in cob width for the maize varieties with the biggest cob width (P<0.05) found in the Obatanpa maize variety. Cob widths in Mamaba and Golden Jubilee were statistically similar (P>0.05). No significant (P>0.05) differences in cob width were observed for levels of nitrogen applied during the minor season. The interaction between the nitrogen levels and maize varieties did not show any difference in cob width (P >0.05).

During the major season, the cob width recorded in the maize varieties and the nitrogen levels showed significant (P<0.05) differences. The biggest cob width was observed in the Obatanpa maize variety followed by Golden Jubilee with Mamaba recording the smallest cob width. With nitrogen application, the biggest cob width was from plots that received 90kgN/ha and this was followed by nitrogen levels of 60kgN/ha, 45kgN/ha and 0kgN/ha in that significant (P<0.05) order. The interaction between nitrogen levels and maize varieties also significantly (P<0.05) affected maize cob width.

3.2.3 Harvest index

Data analysed for the minor cropping season indicated no significant (P>0.05) effect on the harvest index between maize varieties. The different levels of nitrogen significantly (P<0.05) affected the harvest index. The plots fertilized with 90kgN/ha significantly (P<0.05) produced higher harvest index than that on the plots which received 0kgN/ha. No significant (P>0.05) differences in harvest index were observed between 90kgN/ha, 60kgN/ha and 45kgN/ha. However, the interaction between nitrogen and maize varieties significantly (P<0.05) affected the harvest index.

In the major cropping season, the harvest index of the maize varieties, the levels of nitrogen applied and the interaction showed significant (P<0.05) effect. The harvest index was highest in Obatanpa followed by Golden Jubilee and Mamaba in that significant (P<0.05) order.

In the case of nitrogen levels, 90kgN/ha produced the highest harvest index that was statistically similar (P<0.05) to 60kgN/ha. The treatment which was not fertilized (OkgN/ha) produced the lowest harvest index.

3.2.4 Shelling percentage

During the minor cropping season, the shelling percentage in the maize varieties did not show significant (P>0.05) differences. However, Golden Jubilee maize showed the highest shelling percentage closely followed by Mamaba and Obatanpa produced the least. With regard to the nitrogen levels, shelling percentage was significantly (P<0.05) high with the 90kg N/ha treatment and significantly (P<0.05) low with 0kgN/ha treatment. The interaction between nitrogen and maize varieties significantly (P<0.05) affected shelling percentage in both cropping seasons.

In the major cropping season, the varieties of maize and the levels of nitrogen significantly (P<0.05) affected shelling percentage. Significantly high (P<0.05) shelling percentage was recorded in the Obatanpa variety and the least in the Mamaba maize variety. The plots which received 90kgN/ha had significantly (P<0.05) higher shelling percentage than plots treated with 45kgN/ha and 0kgN/ha.

3.2.5 Maize grain yield

The seed grains realized from the trials during the two seasons are shown in Table 2. During the minor cropping season, the responses of the maize varieties to the nitrogen levels on grain yield were significant (P<0.05). The Obatanpa maize variety produced the highest grain yield per hectare which was significantly (P<0.05) similar to the yield of the Golden Jubilee maize. The lowest (P<0.05) grain yield (t/ha) was obtained from Mamaba. Maize grain yield increased significantly (P<0.05) within crease in the nitrogen level up to 90kg N/ha. The highest (P<0.05) grain yield was obtained from the plots fertilized with 90kgN/ha and the lowest (P<0.05) yield from the plots which received 0kgN/ha. The interaction between the maize varieties and the nitrogen levels was found to have significant (P<0.05) effect on grain yield.

Again, in the major cropping season, the three maize varieties and the nitrogen levels had significant (P<0.05) effects on mean grain yield (Table 2). Obatanpa maize variety produced significantly (P<0.05) high grain yield followed by Golden jubilee and Mamaba in that order. Maize grain yield was significantly (P<0.05) higher on plots fertilized with higher nitrogen levels. The interaction between the maize varieties and the nitrogen levels significantly (P<0.05) affected grain yield. The highest (P<0.05) grain yield was obtained from plots which received the nitrogen dose of 90kgN/ha and the lowest (P<0.05) yield from plots of 0kgN/ha (Table 2).

Table 2: Levels of Nitrogen on Yield and Yield Components in Three Varieties of Maize

	Minor Season						
TREATMENT	Harvest Index (%)	Cob length (cm)	Cob diameter	No. of grains per cob	Shelling Percentage	1000 Grain Weight (g)	Grains yield (t/ha)
			Nitrogen X Variety				
Obatanpa							
N0	52.0	18.8	5.0	549.9	72.0	272.0	4.68
N45	49.5	18.7	5.2	553.3	72.0	293.5	5.50
N60	53.0	19.8	5.1	577.7	74.3	314.5	6.50
N90	55.0	19.0	5.2	593.0	74.8	311.0	7.70
Mamaba							
N0	51.0	17.2	4.5	526.4	73.0	264.0	3.85
N45	53.8	17.5	4.6	529.5	73.0	271.8	4.48
N60	50.8	20.4	4.7	591.4	73.3	297.0	4.93
N90	55.5	19.5	4.8	537.5	74.0	290.0	5.93
Golden Jubilee							
N0	37.8	18.9	4.8	547.8	73.5	277.0	5.03
N45	45.3	19.8	4.9	549.8	74.8	287.3	5.70
N60	47.0	19.5	4.8	561.4	75.0	309.0	6.00
N90	51.0	19.8	4.9	561.2	76.3	310.0	6.70
LSD Variety	NS	0.97*	0.13*	NS	NS	NS	0.52*
LSD Nitrogen	5.50*	1.12*	NS	NS	2.01*	21.52*	0.60*
LSD Var x N.	9.52*	1.95*	NS	NS	3.49*	37.27*	1.04*

* = significant at 5% probability level NS= not significant at 5% probability level

Table 2 continuation

TREATMENT	Major Season						
	Harvest Index (%)	Cob length (cm)	Cob diameter	No. of grains per cob	Shelling Percentage	1000 Grain Weight (g)	Grains yield (t/ha)
				Nitrogen X Variety			
Obatanpa							
N0	47.0	18.9	4.7	504.7	70.5	271.5	4.73
N45	50.6	21.5	5.1	549.7	72.3	293.5	5.63
N60	53.8	23.8	5.5	610.2	78.5	314.5	6.70
N90	63.8	25.3	6.8	627.0	89.0	315.3	8.23
Mamaba							
N0	47.5	19.0	4.7	499.5	46.5	264.0	3.95
N45	47.9	20.3	5.2	545.8	61.7	271.8	4.18
N60	50.0	21.0	5.1	602.7	69.0	309.3	5.30
N90	53.2	23.4	5.4	672.0	74.5	325.5	6.00
Golden Jubilee							
N0	46.2	18.4	4.7	499.7	65.3	269.8	4.28
N45	47.0	19.9	5.0	552.0	71.3	292.8	4.90
N60	50.6	22.3	5.1	606.6	77.0	314.8	6.13
N90	57.9	24.6	5.7	658.1	85.5	325.5	6.63
LSD Variety	2.69*	0.76*	0.42*	NS	4.14*	NS	0.31*
LSD Nitrogen	3.10*	0.89*	0.48*	28.33*	4.78*	16.77*	0.35*
LSD Var x N.	5.38*	1.51*	0.83*	49.06*	8.28*	29.04*	0.62*

* = significant at 5% probability level NS= not significant at 5% probability level

3.2.6 1000-Grain weight

The analyses of the data on the 1000-grain weight for the minor and major cropping seasons are summarized in Table 2. No significant ($P>0.05$) differences were observed in the maize varieties in both seasons. Generally, 1000-grain weight was higher in the Obatanpa variety followed by Golden Jubilee variety and Mamaba variety. With regard to the nitrogen rates, significant ($P<0.05$) effect was recorded in both cropping seasons. Significantly ($P<0.05$) higher 1000-grain weight was recorded from plots fertilized with 60kgN/ha and 90kgN/ha than plots fertilized with 45kgN/ha and 0kgN/ha during the minor and the major cropping seasons. Significant ($P<0.05$) weight differences were also observed in the interaction between the maize varieties and the levels of nitrogen applied in both cropping seasons. Minimum 1000-grain weight produced from plots with 45kgN/ha was statistically similar to the treatment of 0kgN/ha.

3.2.7 Number of grains per cob

The results in Table 2 show the effect of different rates of nitrogen on the number of grains per cob for the minor cropping season. No significant ($P>0.05$) differences between the maize varieties were observed. Obatanpa varieties, however, produced the highest number of grains per cob followed by Golden Jubilee and Mamaba varieties. The various nitrogen levels as well as the interaction between the levels of nitrogen and maize varieties did not show any significant ($P>0.05$) differences in the number of grains per cob.

In the major cropping season, however, significant ($P<0.05$) effect on the number of grains per cob was observed in the use of different levels of nitrogen as well as the interaction between maize varieties and the levels of nitrogen. (Table 2). Plots fertilized with 90kgN/ha produced the highest number of grains per cob followed by plots with 60kgN/ha, 45kgN/ha, and 0kgN/ha. The varieties of maize did not show significant ($P>0.05$) differences between them on the number of grains per cob.

4. Discussion

4.1 The rates of nitrogen applied and crop growth

The results of the study showed that the tallest plant height was produced with the application rate of 90kgN/ha and the shortest being the application rate of 0kgN/ha. This observation can be attributed to the fact that higher levels of nitrogen fertilizer promote vegetative growth in the maize. Generally, there were increases in leaf area and plant height with increasing rate of nitrogen fertilizer. These results agree with the previous findings of Roth and Fox (1990) that higher rate of nitrogen promotes growth and leaf area during vegetative development and also helps maintain functional leaf area during the growth period. The highest plant height was observed in Obatanpa maize variety at 10WAP and 8WAP during the minor and major seasons, respectively. This was followed by Golden Jubilee and Mamaba varieties.

The results in maize varieties (Figure 2) indicated that significant differences in plant girth occurred at 6, 7 and 8WAP during the major season. The biggest plant girth was recorded in Golden Jubilee which was statistically similar to Obatanpa at 8WAP whiles the smallest stem girth was recorded in Mamaba. Application of 90kgN/ha significantly enhanced maize plant girth followed by 60kgN/ha and 45kgN/ha more than 0kgN/ha. The smallest plant girth observed at 0kgN/ha might be explained by the fact that nitrogen promotes growth and development of maize plant. This observation confirms the work done by Tweneboah (2000) who reported that nitrogen deficiency retarded growth of maize and caused stunted growth and poor root development. The trend observed in the growth of stem girth is similar to that observed in plant height.

The study showed that the largest leaf area was recorded in Obatanpa variety in both cropping seasons. This was followed by Golden Jubilee and Mamaba. Plots fertilized with 90kgN/ha, 60kgN/ha and 45kgN/ha produced the largest leaf area in that order. It is known that nitrogen plays important roles in plant growth and development. The observation in this study totally agrees with the findings of Raven *et al*. (1999) that nitrogen is a component of a number of compounds (proteins, nucleic acids, chlorophyll) and has an important role in many plant physiological processes.

With regard to the number of days to 50% tasselling and 50% silking, the least number of days to 50% tasselling occurred in Mamaba in the minor cropping season (Table1). In the major season, however, the least number of days to 50% tasselling occurred in Obatanpa. On the number of days to 50% silking, the maize varieties did not show any significant differences in the minor season. However, in the major season, Mamaba showed the least significant number of days to 50% silking than Golden Jubilee and Obatanpa. In both seasons, the varieties of maize which received 0kgN/ha significantly resulted in the highest number of days to 50% silking. The differences observed could be attributed to the rates of nitrogen applied and the varietal differences which existed between them. Obatanpa is an open pollinated maize variety while Mamaba and Golden Jubilee are hybrid maize varieties. The genetic attributes possibly influenced these varieties as to their tasseling and silking stages.

4.2 The different rates of nitrogen and yield components and grain yield

The Golden Jubilee produced the largest number of cobs per plant as compared to Obatanpa and Mamaba. The differences were, however, not significant in the minor season but the differences were significant in the major season. This might be due to Golden Jubilee being a hybrid maize variety, the genetic make up of the variety, and the fact that the rates of nitrogen applied could influence the production of cobs. It was also noted during the study that the number of cobs per plant did not increase with increase in nitrogen in the minor season but significant differences were observed during the major season. This observation confirms the earlier findings of Bangarwa *et al.* (1988) and Khan *et al.* (1999) that the number of cobs per plant did not increase with the increase in nitrogen rates.

Analyses of the data in Table 2 revealed significant differences in cob length and cob diameter in both cropping seasons between the maize varieties. Obatanpa showed a marginal increase over Golden Jubilee and Mamaba in the major season.

The high harvest index(%) observed in Mamaba was statistically similar to that of Obatanpa maize variety in the minor season. On the contrary, Obatanpa in the major season showed the highest harvest index followed by Mamaba and Golden Jubilee. The results suggest that the supply of 90kgN/ha and 60kgN/ha are essential for favourable partitioning of dry matter between grain and other parts of maize plant. The higher the efficiency of converting dry matter into economic yield, the higher the value of harvest index (%). Other workers such as Bangarwa *et al.* (1988) and Sabir *et al.* (2000) have reported similar results. Application of nitrogen at 0kgN/ha produced the lowest harvest index per plot.

The shelling percentage (%), 1000-grain weight, and the maize grain yield (t/ha) all increased significantly with increasing nitrogen level. Maximum yield and yield components were achieved with the application rate of 90kgN/ha. Fertilizer rate of 60kgN/ha and 45kgN/ha also supported maize grain yield compared to the 0kgN/ha. Thousand (1000)-grain weight of Obatanpa was slightly higher than that of Golden Jubilee and Mamaba in the minor season (Table 2). In the major season, however, Golden Jubilee recorded the highest 1000-grain weight. This observation could be attributed to the fact that Golden Jubilee is the yellow version of Obatanpa and that they share some traits. The results obtained in this study differ from the results obtained at the Crops Research Institute, Kumasi by Asiedu *et al.* (2003) that the 1000-grain weight in Mamaba was heavier than that in Obatanpa. The 1000-grain weight values of Obatanpa and Golden Jubilee being higher than Mamaba were influenced by the nature of their seeds which makes it compact and heavier than other maize varieties. Besides, it could also be due to differences in grain filling period (partition factor).

Table 2 showed no significant differences in the number of grains per cob observed between the maize varieties in the minor season. Similarly, no significant differences were observed in both the nitrogen applied and the interaction between the nitrogen and the maize varieties during the minor season. However, significantly higher number of grains per cob and grain yield per hectare were observed in the maize varieties during the major season than in the minor season. This observation could be attributed to the fact that the minor season showed significantly heavier stem borer infestation than the major season.

Generally, the highest number of grains per cob and grain yield were observed in Obatanpa maize variety in the minor season. This was followed by Golden Jubilee and Mamaba in that order. This could partially be due to the good climatic conditions recorded throughout growing the period.

During the major season, however, Obatanpa maize showed the lowest number of grains per cob with Mamaba showing the highest which was followed by Golden Jubilee maize variety. The differences observed, however, were not significant. Again, higher number of grains per cob and grain yield were observed on plots fertilized with 90kgN/ha, 60kgN/ha and 45kgN/ha than the plots fertilized with 0kgN/ha when the maize varieties was assessed (Table 2). With regard to the level of N needed for maize production the result obtained in the study confirmed the previous results of Lucas (1986) that the yield response of maize to N fertilizers could be obtained up to 150 kg N/ha. This study therefore shows that yield response of various maize varieties to different rates of nitrogen follow the same trend (Table 2). The increase in grain yield with an increased in the rates of nitrogen was also observed by Luchsinger *et al.* (1999), Sabir *et al.* (2000) and Younas and Hayder (2002), in their investigations on nitrogen levels and maize grain yield.

From the present study, it is concluded that cultivation of Obatanpa or Golden Jubilee maize variety would produce good grain yield in the major season and Mamaba variety in the minor season for the farmers in the forest-transition ecological zone.

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