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THE EFFECTS OF NITROGEN RATES ON PHENOLOGY AND YIELD COMPONENTS OF EARLY MATURING MAIZE CULTIVARS

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ABSTRACT

Two field experiments were conducted during the 1996 and 1998 cropping seasons to determine the effects of N stress levels on the phenology and yield components of early maturing maize cultivars. Seven early maize cultivars were tested against five N rates (0 30, 60, 90 and 120 kg N ha^{-1}). The N stress levels significantly affected phenological traits (days to 50% anthesis, silking and maturity, anthesis-silking interval (ASI) and grain filling period) and yield components (shelling percent, 1000 grain weight and harvest index) measured. For all these traits, there were better performances at 90 and 120 kg N ha^{-1}. Days to 50% anthesis decreased from 51 days at 0 kg N ha^{-1} to 48 days at 120 kg N ha^{-1} in 1996 season and from 54.5 to 46.2 at the same N levels in 1998 season. Maturity was delayed for 7.1 days at 0 kg N ha^{-1} compared to 120 kg N ha^{-1} in 1998 season. Grain yield increased with increased N rates with R2 values of 0.92 and 0.86 in 1996 and 1998 cropping seasons, respectively. The different cultivars reacted differently to the N rates factors for both the phenological traits and yield components. Such cultivars as TZECOMP4C2 and TZECOMP5C5 had the longest grain filling period in both seasons (43.2 and 34.8, respectively in 1998 season). In both seasons, EV89731-SR had the longest ASI. AC89DMRESRW and TZECOMP3C2 had the highest harvest index in both seasons with the highest values of 40.8 and 39.6, respectively in 1996 season.

KEYWORDS: Maize, nitrogen, phenology, yield, anthesis

INTRODUCTION

A primary factor affecting crop development is temperature as modulated by other factors including daylength, vernalization, heat and cold stresses, water and N stresses (Hodges 1991). The earlier research work on maize improvement was focused on better performance under optimum condition. Hence much of the studies on maize development have been under optimum nitrogen conditions, but the influence of N stress on the development of maize as expressed by phenological stages, dry matter production and grain yield still needs to be elucidated, especially with the recently developed maize varieties. In recent times, research focus on maize improvement has changed with emphasis on stress conditions. This is due to the realization that as a result of high poverty rates, farmers are often not able to afford the optimum conditions for maize production. With the changed focus in research, there is the need for more information on the performance of maize varieties under different stress factors.

Nitrogen is one of the most dynamic nutrient elements. It is usually the first limiting nutrient element as land use intensifies (Kang, 1989). It is taken up in the highest amount by crops (Dubei and Pessarakli, 1995) and its role in plants cannot be easily substituted (FAO, 1988). It is the most important factor limiting crop growth and yield (Dubei and Pessarakli, 1995). Increase in N supply within limits are associated with increase in leaf area and weight, carboxylases and chlorophyll content, all of which determine the photosynthetic activity of the leaf and ultimately dry matter production and allocation to the various organs of plant (Hageman, 1986). Photosynthetic rate, leaf surface area and sink size all increase with increase in nitrogen levels (Aluko and Fischer, 1987). According to Below *et al.* (1997), physiological processes limiting yield differ according to the level of N in the soil. This was confirmed by Dass *et al.* (1997) who found that days to 50% anthesis, 50% silking and ASI were reduced with N stress conditions. They reported up to 9 days delayed silking and increased ASI of 4 to 5 days and a direct correlation between ASI and maize grain yield. Sibale and Smith (1997) obtained a significant influence of N on number of kernels per ear.

Yield of maize grain involves the integrated effect of a large number of components and metabolic processes that act with varying intensity throughout the plant's life cycle. Nitrogen is involved in the establishment and maintenance of photosynthetic capacity, establishment of sink capacity (ear and kernel initiation) as well as ensuing maximum number and size of kernels (Hageman, 1986). Nitrogen plays a role in determining yield by influencing dry matter accumulation and partitioning to various plant organs (Anderson and Schomburg, 1986). Squire (1990) reported that an increased dose of nitrogen from 0 to 42 g m^{-2} more than doubled the dry matter of the plant, increased grain yield by about four folds and harvest index by 1.5 times. He observed a shorter vegetative phase with higher N application. He was of the view that the large effect of N on grain yields which he noticed was the result of both a longer period of grain filling and more rapid dry matter production as the level of N increased. He found that the number of grains per cob increased as N rates increased, and increased mass per grain from 200 to 270 mg with higher rates of N - a response attributed to the lengthening of the grain-filling period (Squire, 1990). N stress is therefore an important factor limiting maize growth and grain yield.

This work was therefore carried out to investigate the effects of varying N stress levels on phenology and grain yield of early maturing maize cultivars that have been developed under the tropical conditions.

MATERIALS AND METHODS

Field experiments were conducted during the 1996 and 1998 cropping seasons in Mokwa (latitude 9° 18' N and longitude 5° 04' E in the southern guinea savanna ecological zone of Nigeria. Mean monthly rainfall distribution, minimum and maximum temperatures, and solar radiation of Mokwa during the two seasons are presented in Table 1. The initial soil physical and chemical characteristics of the site during the two seasons are presented in Table 2. A split-plot design with

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four replications was adopted for the experiment. The five N rates used (0 30, 60, 90 and 120 kg N ha^{-1}) were assigned to the main plots while maize cultivars (AC90POOL16-DT, AC89DMRESRW, EV8731-SR, TZECOMP3C2, TZECOMP4C2, TZECOMP5C5 and DMR-ESRY) were assigned to the subplots. Each subplot was 5 m x 6 m with 8 rows per plot. In the first year, planting was done on 21st June while in the second year, it was done on 4th July based on when the rains were sufficient for planting. The inter-row spacing was 0.75 m while the intra-row spacing was 0.25 m, thus the plant population was 53,333 plants ha^{-1}

Table 1. Rainfall distribution during the 1996 and 1998 cropping seasons in the site

Month	1996 season				1998 season			
	SRAD (KJ)	TMAX (°C)	TMIN (°C)	RAIN (mm)	SRAD (KJ)	TMAX (°C)	TMIN (°C)	RAIN (mm)
January	14.3	35.2	16.9	0.0	14.9	35.1	15.6	0.0
February	17.5	38.6	21.2	0.8	17.4	37.5	21.1	0.0
March	18.0	39.5	23.4	0.0	17.9	38.3	23.9	0.0
April	18.3	38.5	26.8	38.0	18.0	38.6	25.1	39.0
May	16.9	34.4	24.5	178.0	16.8	34.2	23.2	153.0
June	16.1	33.6	23.7	230.0	15.1	32.4	22.4	334.0
July	12.9	31.6	23.5	174.0	13.8	31.3	22.8	203.0
August	12.5	30.5	23.6	262.0	12.6	30.3	22.3	64.0
September	14.4	31.3	23.5	151.5	15.1	31.4	21.4	318.0
October	18.1	33.1	23.5	27.8	17.7	33.0	21.1	117.0
November	18.0	35.8	20.5	0.0	18.8	35.1	16.0	0.0
December	15.0	34.8	17.3	0.0	17.0	37.0	16.9	0.0

SRAD = solar radiation, TMAX = maximum temperature and TMIN = minimum temperature

Table 2. Pre-planting chemical and physical soil characteristics of the site in 1996 and 1998 seasons

Properties	1996		1998	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm
pH (H_2O)	5.01	5.00	4.50	4.30
Organic carbon (g kg^{-1})	4.75	3.00	4.10	2.60
Total nitrogen (g kg^{-1})	0.38	0.26	0.35	0.25
C:N ratio	13.00	12.00	12.00	10.00
Available P (mg kg^{-1})	7.44	1.04	1.80	2.00
Exchangeable Mg (cmol kg^{-1})	0.50	0.35	0.30	0.20
Exchangeable K (cmol kg^{-1})	0.40	0.45	0.20	0.10
Exchangeable Ca (cmol kg^{-1})	2.20	1.60	1.70	1.20
Exchangeable Na (cmol kg^{-1}	0.30	0.30	0.40	0.30
Exchangeable Mn (cmol kg^{-1})	0.10	0.10	0.20	0.10
Exchangeable acid (cmol kg^{-1})	0.15	0.15	0.30	0.30
ECEC (cmol kg^{-1})	3.55	2.85	2.90	2.10
Sand (%)	78.00	76.00	80.00	74.00
Silt (%)	13.00	12.00	12.00	12.00
Clay (%)	9.00	12.00	8.00	14.00

The N rates were applied in 2 equal doses, one at 7 days after planting (DAP) and the other at 28 DAP. During the first N application, P and K were applied at the rates of 26.22 and 49.80 kg ha^{-1}, respectively. Dry matter accumulation was determined at 14 days intervals from 3 weeks after planting till maturity. Phenological data that were taken included days to 50% anthesis, days to 50% silking, anthesis-silking interval, grain filling period, and days to 50% physiological maturity.

At maturity, the number of plants from the two middle rows in each plot were counted and harvested (excluding two plants at both ends of each row). The number of ears were counted and weighed. Soon after harvesting, the ears were shelled to determine the moisture content using a Dickey-John moisture tester. The readings of the moisture tester were converted to percentage moisture using a chart on the moisture tester.

Ten ears were randomly sampled per plot for the determination of ear diameter and length using vernier calipers (model Baty) and a measuring tape, respectively. The number of rows per ear and the number of kernels per row were also determined from each of the ten ears and the means obtained. The ears were shelled and the grains and cobs weighed, after which the grains were cleaned and 400 grains sub-sampled and weighed using a top loading Mettler balance to determine unit grain weight.

All the ears harvested were shelled and used for the determination of grain yield. These were adjusted to 15% moisture content using the values of the moisture content from each plot. Shelling percentage was computed from the grain weight and cob while harvest index was computed from the grain yield and the dry matter yield.

Statistical analysis

Data collected were subjected to analysis of variance using the Mixed Model Procedure of Statistical Analysis System (SAS) (1994) and means were compared with LSD at P=0.05

RESULTS

There were no significant N rates x cultivar interactions for all the parameters, so only the results of the main effects were presented.

Phenological traits

Days to 50% anthesis, days to 50% silking, anthesis-silking interval and length of grain filling period varied significantly among N rates at P<0.01 (Table 3) in both seasons. However, days to maturity significantly differed at P<0.05 in 1998 season but not in 1996 season. There was a decrease in days to 50% anthesis with increase in N rates from 51 days at 0 kg N ha^{-1} to 48 days at 120 kg N ha^{-1} in 1996 season and from 54.5 to 46.2 days at the same N levels in 1998. Similarly, days to 50% silking decreased with increase in N levels from 60 days at 0 kg N ha^{-1} to 51 days at 90 kg N

ha^{-1} in 1996 and the same trend was observed in 1998 The 60, 90, and 120 kg N ha^{-1} were not significantly different at P<0.01 for both seasons (Table 3). The same trend was observed for anthesis-silking interval.

Grain filling period was longest at 90 and 120 kg N ha^{-1} with means of 31 days for both N rates in 1996, and 35.8 and 36.1 days for 90 and 120 kg N ha^{-1}, respectively in 1998. The shortest mean grain-filling period of 25.2 and 29.8 days were obtained from 0 kg N ha^{-1} in the two seasons. There was a significant delay in maturity of 1.5 days at 0 kg N ha^{-1} compared to 120 kg N ha^{-1} in 1996 and 7.1 days in the 1998 season. However, there was no difference between 120 kg N ha^{-1} and the other N rates except the 0 kg N ha^{-1} for both seasons (Table 3).

Table 3: Phenological parameters of early maturing maize cultivars at five N rates in 1996 and 1998 planting seasons and expressed in days.

Treatment	DAT		SILK		DM		ASI (days)		GFP (days)	
N rates (kg ha^{-1})	1996	1998	1996	1998	1996	1998	1996	1998	1996	1998
0	51.0	54.5	59.6	61.6	84.5	85.1	8.6	7.0	25.2	29.8
30	48.9	53.4	54.9	55.7	82.9	83.6	5.9	5.0	28.0	31.3
60	48.6	52.5	52.3	52.7	82.4	84.0	3.7	2.7	30.1	33.9
90	48.2	47.4	51.4	51.5	83.1	84.1	3.0	2.6	31.2	35.8
120	48.2	46.2	51.8	51.3	83.0	84.1	3.5	2.0	31.2	36.1
Means	49.0	50.8	54.0	54.6	83.2	84.2	4.9	3.9	3.9	33.4
S.E.D	0.76	0.37	1.90	0.27	0.37	0.30	0.41	0.13	0.65	0.31
Prob. of F	0.01	0.01	0.01	0.01	ns	0.05	0.01	0.01	0.01	0.01
LSD	0.57	1.39	1.65	1.02	0.64	0.83	1.54	0.47	1.78	1.17
Cultivars										
TZECOMP4C2	48.9	50.7	54.2	54.7	84.2	84.7	5.3	4.0	30.1	34.2
AC89DMRESRW	49.5	51.5	53.9	54.5	83.4	83.4	4.4	3.7	29.5	32.6
TZECOMP5C5	49.2	50.2	54.1	54.4	84.5	85.0	4.9	3.9	30.5	34.8
EV8731-SR	49.4	50.8	55.6	56.2	83.5	85.0	6.2	4.4	28.3	33.3
AC90POOL16-DT	48.6	51.8	52.5	53.5	81.6	84.3	3.8	3.7	29.1	31.9
TZECOMP3C2	48.5	50.2	52.9	53.5	82.6	83.5	4.4	4.0	29.7	33.8
DMR-ESRY	49.2	50.6	54.6	55.3	82.2	83.6	5.4	3.6	27.7	33.2
Means	49.0	50.8	54.0	54.6	83.1	84.2	4.9	3.9	29.3	33.4
S.E.D	0.25	0.44	0.65	0.32	0.42	0.35	0.49	0.15	0.72	0.37
Prob. of F	0.01	ns	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.01
LSD	0.67	1.64	1.95	1.21	1.0	1.31	1.82	0.56	2.1	1.39

DAT = Days to 50% anthesis, SILK = Days to 50% silking, DM = Days to maturity, ASI = Anthesis-silking interval, GRP = Grain filling period and ns = not significantly different at P=0.05. S.E.D. = *Standard error of difference*, LSD = Least significant difference.

In 1996 season, the shortest period to 50% *anthesis* among the cultivars was recorded from TZECOMP3C2 (48.5 days) and AC90POOL16-DT (48.6 days). In 1998 season however, there were *no significant differences* (P<0.05) *among* the cultivars for days to 50% anthesis. In both seasons, TZECOMP3C2 and AC90POOL16-DT attained silking earliest (52.5 and 52.9 days, respectively) while EV8731-SR and DMR-ESRY were the last to attain silking stage (P<0.01). DMR-ESRY and EV8731-SR had the shortest grain filling period (28 days) in 1996 (P<0.01) while in the 1998, AC90POOL16-DT had the shortest period (P<0.05). On the other hand, TZECOMP4C2 and TZECOMP5C5 had the longest grain filling period in both seasons. AC90POOL16-DT had the shortest anthesis-silking interval of 3.8 days (P<0.01) in 1996 as compared to EV8731-SR, which had the longest period (6.2 and 4.4 days) in both seasons. Days to maturity was significantly different among the cultivars where TZECOMP4C2 and TZECOMP5C5 had longer period to maturity in both seasons (P<0.01), while DMR-ESRY and AC90POOL16-DT *on the other hand had the shortest period* to maturity in both seasons (Table 3).

Yield components

Among the yield components measured, ear diameter (1998), ear length, number of rows per ear, number of kernels per row, shelling percentage (1996) and HI (1998) significantly increased with increased N rates at P<0.01. The rest of the traits significantly increased at P<0.05 while shelling percentage (1998) and HI (1998) followed the same trend but were not significantly different at P<0.05 (Table 4). The highest ear diameter values were obtained from the 120 kg N ha^{-1} in both seasons (43.2 cm and 39.9 cm, respectively) while the lowest values were recorded from the 0 kg N ha^{-1} (39.6 cm and 33.9 cm, respectively). The 120 kg N ha^{-1} had the highest ear length in both seasons (13.1 and 11.5, respectively). Number of kernels per row of harvested ears and the number of kernels per row on the ears were highest at the 120 kg N ha^{-1}. The lowest shelling percentage were recorded from the 0 kg N ha^{-1} (83.8 and 83.5, respectively). In 1998, the lowest 1000 grain value was recorded from 0 kg N ha^{-1} while the highest value (221.1) was recorded at 120 kg N ha^{-1}. In 1996, the lowest HI value was 32.4% (at 0 kg N ha^{-1}) while the highest value was 41.7 (at 90 kg N ha^{-1}). In 1998, the same trend was observed as recorded in 1996. For most of the traits measured, there were no differences observed between 60, 90 and 120 kg N ha^{-1}. The lowest values of *the yield components* measured were recorded from 0 kg N ha^{-1}. This was followed by the 30 kg N ha^{-1}. Except for shelling percentage, the means of *all* the *yield components* were lower in the 1998 season compared to means in the 1996 (Table 4). Grain yield significantly (P<0.01) increased with increased N rates *although there were no significant differences* between 90 and 120 kg N ha^{-1} in both seasons.

The cultivars varied significantly (P<0.01) for ear diameter in the 1996 (Table 4). In the 1998, there were no significant differences observed among the early cultivars for ear diameter, however, the same trend was observed as in 1996. AC90POOL16-DT, TZECOMP4C2 and AC89DMRESRW had the highest ear diameter. AC90POOL16-DT had significantly lower ear length than the rest of the cultivars in both seasons (P<0.01) while TZECOMP5C5, TZECOMP3C2 and AC90POOL16-DT had the longest ears. TZECOMP3C2 and AC89DMRESRW had more number of rows per ear (greater than 14 in 1996 and greater than 13 in 1998) at P<0.01. EV8731-SR *and* DMR-ESRY on other hand had the lowest number of rows per ears in both seasons.

In 1996 TZECOMP5C5 *and* AC89DMRESRW had the highest number of kernels per row while in the 1998, TZECOMP3C2 and TZECOMP5C5 had significantly (P<0.05) higher kernel number per row with means greater than 23. In 1996, the highest shelling percentage of 84.9 was recorded in TZECOMP5C5 and AC90POOL16-DT while AC89DMRESRW, AC90POOL16-DT and TZECOMP3C2 had the highest shelling percentage of about 85% in the 1998. In both seasons, EV8731-SR and DMR-ESRY had the lowest shelling percentage. TZECOMP4C2 and TZECOMP5C5 had the highest and lowest 1000-grain weight, respectively in the two seasons. AC89DMRESRW and TZECOMP3C2 had the highest HI in both seasons (Table 4). TZECOMP3C2 and AC89DMRESRW had the highest grain yield in both seasons ($P<0.05$) while TZECOMP4C2 and AC90POOL16-DT were among the cultivars that had the lowest grain yield in both seasons.

The response curve between grain yield and N rates was a linear relationship in both seasons (Figure 1). The R^2 values obtained were 0.93 and 0.86 for 1996 and 1998, respectively.

Table 4: Yield and yield parameters of early maturing maize cultivars at five N rates in the 1996 and 1998 planting seasons

Treatment	CDIA (cm)		CLEN (cm)		NRPC		KPR		SHLL		1000SW (g)		HI (%)		Grain yield (kg/ha)	
N rates (kg ha^{-1})	1996	1998	1996	1998	1996	1998	1996	1998	1996	1998	1996	1998	1996	1998	1996	1998
0	39.6	33.9	10.3	7.4	13.3	11.03	24.8	15.3	83.8	83.5	240.6	192.9	32.4	14.0	2500.4	486.2
30	40.8	37.6	11.4	9.9	14.4	13.4	27.0	21.0	83.8	84.6	237.6	206.7	35.1	24.5	2950.5	1331.3
60	41.4	39.3	12.2	10.9	13.9	13.4	29.4	23.7	83.3	84.9	241.1	214.0	37.1	33.5	3786.6	2032.4
90	42.8	39.2	13.1	11.1	14.1	13.6	31.7	23.8	85.1	84.5	266.0	216.3	41.7	34.3	4979.6	2244.0
120	43.2	39.9	13.1	11.5	14.5	13.4	31.6	25.5	84.1	84.9	255.3	221.1	40.8	38.7	4907.0	2276.4
Means	41.6	38.0	12.0	10.1	14.0	13.0	28.9	21.9	84.0	84.5	248.1	210.2	37.4	29.0	3824.8	1674.0
S.E.D	0.39	1.00	0.48	0.38	0.24	0.42	1.12	1.89	0.45	0.36	8.8	3.15	2.30	2.56	103.83	158.03
Prob. of F	0.05	0.01	0.01	0.01	0.05	0.01	0.01	0.01	0.01	ns	0.05	0.01	0.05	0.01	0.01	0.01
LSD	0.99	2.18	0.89	0.82	0.49	0.91	2.21	4.11	0.84	1.08	27.79	11.78	5.10	7.21	588.12	386.42
Cultivars																
TZECOMP4C2	42.4	38.2	11.3	10.0	13.6	12.9	28.3	22.5	84.2	84.8	263.0	224.7	31.0	27.4	3631.0	1485.9
AC89DMRESRW	41.8	38.3	12.3	10.0	14.3	13.3	30.6	21.5	83.9	85.3	243.0	208.3	40.8	31.2	4009.7	1856.3
TZECOMP5C5	41.0	37.4	12.9	10.6	14.3	12.8	30.7	23.1	84.9	85.0	237.0	199.2	39.1	29.2	3913.6	1651.2
EV8731-SR	41.5	37.2	12.0	9.8	13.6	12.7	27.8	21.3	83.1	83.9	257.0	203.2	35.6	31.3	3584.1	1784.9
AC90POOL16-DT	42.6	38.9	11.1	9.4	14.1	12.8	26.9	19.2	84.9	85.5	255.0	219.6	37.7	26.7	3665.7	1433.8
TZECOMP3C2	41.1	37.1	12.2	10.5	14.5	13.6	29.0	23.1	84.1	85.9	240.0	201.9	39.6	30.8	4178.4	1855.1
DMR-ESR	40.4	37.7	12.4	10.7	14.0	12.7	29.1	22.0	83.2	83.2	241.0	214.6	37.6	26.4	3791.3	1651.2
Means	41.5	37.8	12.0	10.1	14.1	13.0	28.9	21.8	84.0	84.8	248.0	210.2	37.4	29.0	3824.8	1674.0
S.E.D	0.47	0.75	0.27	0.35	0.20	0.38	0.67	1.08	0.49	0.44	8.4	3.72	2.60	3.03	122.86	186.98
Prob. of F	0.01	ns	0.01	0.01	0.01	ns	0.05	0.01	0.01	0.01	0.01	0.01	0.05	ns	0.05	0.05
LSD	1.55	1.50	1.05	0.70	0.77	0.76	1.97	2.15	1.33	1.65	19.85	13.94	6.04	8.53	525.34	345.17

CDIA = Ear diameter, CLEN = Ear length, NRPC = Number of rows per ear, KPR = Number of kernels per row,
SHLL = Shelling percentage, 1000SW = 1000 grain weight, HI = Harvest index and ns = not significantly different at P=0.05

DISCUSSION

The delay in anthesis and maturity and the increased length of anthesis-silking interval at lower N rates suggests that N stress, apart from delaying maize growth, also delays maize development. This is contrary to the view of Coelho and Dale (1980) and Kiniry *et al.* (1983) who were of the view that maize development is a function of temperature, radiation, day length and water stress, but did not consider N stress as an important factor in maize development. The longer delay in silking and maturity noticed in 1998 could be due to the additional stress introduced by drought spell experienced in that planting season thus confirming the work of Coelho and Dale (1980), Kiniry *et al.* (1983) and Shaw (1988) that water stress delays silking and maturity in maize. The water stress might have caused the applied nitrogen not to be available to the plants. This shows that the expression of some phenological traits in maize could be further complicated by other stress factors that will inhibit N uptake and then lead to poor performance of the crops. Nitrogen interacts with other factors to produce some effects on the phenological traits. Therefore, in addressing the problem of stress in maize, N should not be considered alone. The result agrees with the report of Dass *et al.* (1997) who found increased days to 50% silking and ASI with N stress. They reported up to 9 days delayed silking and increased ASI of 4 to 5 days with N stress. The increase in ASI is an indication that low N increases the chances of having more abortions of the ears and spikelets and thus having more barrenness and fewer grains per ear (Edmeades *et al.*, 1993). This leads to low grain yields as there is reduction in number of grains per plant (Edmeades *et al.*, 1993). The result further shows that with higher N, there will be more synchrony in flowering, thus reducing the rate of barrenness during the grain filling period.

Length of grain filling period was increased by about 6 days at 90 and 120 kg N ha^{-1} (both seasons). This is in agreement with the findings of Squire (1990) who also obtained longer grain filling periods with increased N rates. Higher N application will result in longer grain filling periods thus enabling the plants to have better filled grains and thus higher grain yields. Also with less leaf senescence which normally characterizes higher N, there could be more leaves for energy capture and utilization at the grain filling stage. Aluko and Fischer (1987) reported that the amount of light intercepted and therefore the photosynthate produced by the plant during flowering is the dominant factor determining final kernel number. The results show that N hastens growth and development and reduces maturity period. For most of the traits, there was no advantage of 120 kg N ha^{-1} over 90 kg N ha^{-1} indicating that for economic production of maize, 90 kg N ha^{-1} could be applied thus reducing the cost of fertilizer application. This shows that most of these cultivars can perform well at a nitrogen level that is below the recommended optimum in this region.

The earliest time taken by TZECOMP3C2 and AC90POOL16-DT to attain 50% anthesis and silking compared to most other cultivars in both seasons suggests that they may be good cultivars for areas with a short growing period due to limited water supply. The earliest maturity and the shortest ASI from AC90POOL16-DT and TZECOMP3C2 show that they could withstand the effects of N stress on development more than the other cultivars. This shows that under N and other stress factors it will pay to plant these cultivars so as to escape some of the stress factors. Also these cultivars have the tendency for less ear barrenness and better grain filling. TZECOMP4C2, TZECOMP3C2 and TZECOMP5C5 had the longest grain filling period compare to the other cultivars showing that they have the tendency for better energy capture and utilisation and better filled grains.

The significant increases in yield components with increased N rates might be due to higher N uptake with higher N rates which facilitated more photosynthetic activity and more partitioning of dry matter to the ears (Lemcoff and Loomis, 1986). Other studies by Ogunlela *et al.* (1988) and Heuberger (1998) also showed differences in yield components with higher N levels in Mokwa. The differences noticed in the yield components among different cultivars show the higher yield potentials of some cultivars. Heuberger (1998) also obtained differences in yield components among cultivars. This might be due to the varietal differences in N uptake, translocation, photosynthesis and partitioning of dry matter.

With increased N stress, there were significant reductions in yield components such as ear diameter, ear length, number of kernel rows per ear, kernels per row, and shelling percentage. This forms the basis for low yield under low N situations. This agrees with the report of Lemcoff and Loomis (1986) that variations in the supply of C and N substrates affect the growth of plants and may lead to changes in the components of grain yield such as grain weight and number.

The increase in shelling percentage, 1000-grain weight and HI with increased N rates, agrees with the findings of Hageman (1986) that N influences sink capacity in maize. Squire (1990) also reported higher 1000-grain weight and HI with higher N. The variability of HI with N rates and cultivars agrees with the report of Tollenaar (1986) that dry matter harvest index is influenced by both environmental and genetic factors. Aluko and Fischer (1987) noted that low sink size reduces HI in tropical maize. They were of the view that both dry matter production and assimilate allocation to the grains affect HI. The highest shelling percentage obtained from TZECOMP5C5 and TZECOMP3C2 shows that they were more efficient in dry matter partitioning to the grains. It also shows that they had less barren ears and better grain filling compared to other cultivars. The highest 1000-grain weight obtained from TZECOMP4C2 and TZB-SR shows that they have the biggest grains. The low grain yield at lower N observed among the cultivars was earlier explained by Squire (1990) that when environmental constraints reduce the number of reproductive units well below the potential size, the small size of the resulting sink itself limits the fraction of the dry matter allocation to the structure (in this case grains). Under such condition, partitioning factor is usually proportional to the size of the sink. Aluko and Fischer (1987) also noted that partitioning of assimilate depends on the sink size. The highest grain yield obtained from TZECOMP3C2 and AC89DMRESRW can be attributed the higher performance of these cultivars in most of the yield components measured such as ear diameter, ear length, number of rows per ear and number of kernels per row.

The linear response curve between grain yield and N rates shows that there could be higher grain yield with higher N rates. The high R^2 value shows that there is a high linear association between grain yields and increasing N rates. Elsewhere, Simonis (1988) also obtained a linear relationship with N rates even beyond 120 kg N ha^{-1}. This shows that there will be higher grain yield with higher N application. The high slope shows that a slight change in N will result in a high change in grain yield.

CONCLUSIONS

In order to determine the effects of N stress factor on the phenology and yield components of early maturing maize cultivars, seven early maize cultivars were tested against five N rates. It was observed that the N stress levels significantly affected all the phenological traits measured. Similarly, yield components were also affected by N rates. For all these traits, there were better performances at 90 and 120 kg N ha^{-1}. Similarly, the different cultivars reacted differently to the N stress factors for both the phenological traits and yield components. Such cultivars as TZECOMP3C2, TZECOMP4C2 and DMR-ESRY performed better than most of the cultivars for most of the traits that were measured. Apart from the higher yields associated with high N levels, maize phenology can also be hastened by the application of higher N levels.

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