Agronomic Responses of Maize (*Zea mays* L.) Hybrids of Different Maturity Classes to Variations in Split Proportion of Inorganic Nitrogen in a Derived Savanna

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Summary

Field experiments were conducted in 2017 and 2018 to evaluate the effect of split nitrogen (N) application in different proportions on the performance of maize hybrids of different maturity classes in a derived Savanna. Time of inorganic N application (⅓ at planting + ⅔ at anthesis, ⅔ at planting + ⅓ at anthesis) and hybrid maize of three maturity classes [(TZEE129 × TZEE121 (extra-early), TZE126 × TZE127 (early) and Oba super 2 (medium)] constituted the main plot and sub plot respectively in split plot arrangement fitted into randomised complete block design, replicated three times. Leaf area at 6 weeks after planting (WAP), plant height and stem girth at 9 WAP in the year 2017 were in the order Oba Super 2 > TZEE129 × TZEE121 > TZE126 × TZE127. A similar pattern was observed on fresh and dry cob weight, 100 grain weight, except shelling percentage that was significantly higher in other maize hybrids than Oba Super 2. A converse pattern was observed in the year 2018 which translated to significantly higher grain yield in earlier maturing hybrids maize than Oba Super 2. Leaf area at 6 WAP was more in maize hybrids sown when N was applied in the proportion ⅓ at planting + ⅔ anthesis than in ⅔ at planting + ⅓ anthesis in the year 2017. A converse pattern was observed in 2018. These data suggested that variations in the performance of maize hybrids of different maturity classes were mediated by the environment.

Key words

Days-to-flowering, grain-filling duration, Nitrogen management, SPAD meter reading, split N application

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Introduction

At a summit held in 2019 in Addis Ababa it was reported that among the biophysical constraints, nitrogen remains one of the limiting factors in crop production in sub-Sahara Africa (Stewart et al., 2020). This is more pronounced when examined within the context of myriad of factors that are responsible for the loss of N in this sub-region. Erratic rainfall pattern could predispose N to loss through leaching to the underground waters constituting environmental hazard in the long-run. Other sources of losses include volatilisation into the atmosphere when urea is not properly used. The cost of procurement of inorganic fertiliser is on the ascendency, hence the need for effective use of N at the right time, dosage and use of the right sources.

It had been reported that maize hybrids developed recently are more productive than the older hybrids (Tollenaar and Lee, 2006). The physiological basis for this was linked with the duration of their grain-filling period (Bolaños, 1995) and their tolerance to stress (Tollenaar and Lee, 2002). These hybrids with longer grain-filling period could accumulate more assimilates through increased carbon assimilation, considering the fact that grain yield formation in maize is most pronounced at the post-silking stage of growth. Morphologically, these new maize hybrids have smaller numbers of leaves with more dry matter and harvest index (Bolaños, 1995). They have also been reported to have shorter maturity period than the older hybrids (Bolaños, 1995). To sustain photosynthetic activity in hybrid maize they have been reported to have longer leaf area duration with reduced leaf senescence (Valentinuz and Tollenaar, 2004). It could be inferred that sustained photosynthetic activity could foster the uptake of mineral nutrients, especially N that is a major macronutrient on the activity of photosynthetic enzymes and components of photosynthetic apparatus. However, the uptake of macronutrients at the grain filling growth stage might not be sufficient to sustain photosynthetic activity. Crops are capable of recycling and remobilising assimilates and nutrients to meet the disequilibrium in the demand and supply of nutrients, especially at the grain-filling growth stage. Pre-anthesis accumulated N and assimilates could be remobilised from the source to the grain. This process could reduce leaf longevity and the duration of grain-filling period in maize. Compared to soybean and sunflower, maize (*Zea mays*) possesses lower assimilate remobilisation efficiency (Borrás et al., 2004). Few studies have paid attention to reconciling variations in the duration in the grain-filling period with pre-anthesis accumulation of assimilates under split application of N at varying proportion in a derived Savanna.

The application of inorganic N fertiliser at the right dose and at the right time could provide alternative perspective on the sustenance of photosynthetic functions of hybrid maize especially at the grain-filling period. Split application of N is a common management practise not only to meet the N demand of hybrid maize but to foster environmental health. Furthermore, it had been reported that split application of N at different proportion affects canopy morphology and grain yield of maize (Amanullah et al., 2009). Less attention has been focused on the implication of variation in the proportion of N on the performance of maize hybrid of different maturity class in a derived Savanna of Nigeria. We tested the hypothesis that differences in maturity class of maize would determine their performance in a derived Savanna of Nigeria. In addition, we hypothesised that variations in the proportion of inorganic N applied at different times of growth would affect the performance of hybrid maize of different maturity classes in a derived Savanna.

Materials and Methods

Characterisation of the Location and Experimental Site

Field experiments were conducted at the Teaching and Research Farm of the Federal University of Agriculture, Abeokuta (Latitude 3°45'E, Longitude 7°23'N). The field experiments were conducted during the early raining seasons of 2017 and 2018. Agrometeorological data during the cropping seasons were sourced from the Department of Water Resources Management and Agro-meteorology, Federal University of Agriculture, Abeokuta. Pre-planting soil physico-chemical properties were determined at the depth of 0-15 cm. Bulked composite samples of the soil were randomly collected from the experimental sites in both years. Soil physico-chemical properties were determined as described by Sakariyawo et al., (2020).

Treatments and Design

Hybrid maize from different maturity classes [(TZEE129 × TZEE121, TZE126 × TZE127 and Oba super 2 (control)] and time of inorganic N application (⅓ at planting + ⅔ at 50% anthesis, ⅔ at planting + ⅓ at 50% anthesis) constituted the treatments. Split plot arrangement of the treatments fitted into randomised complete block design was implemented. The main plot consisted of the time of the application of inorganic N-fertiliser, while the sub plot was made of hybrid maize of different maturity classes. The treatments were replicated three times. The extra-early (80-85 days), early (90-95 days) and medium maturing (100-105 days at harvest) maize hybrids were TZEE129 × TZEE121, TZE126 × TZE127 and Oba super 2 respectively. The planting materials were sourced from the International Institute of Tropical Agriculture (IITA), Ibadan Station, Nigeria.

Cultural Practises

The field for the experiments was ploughed twice and harrowed once to ease the establishment of maize hybrids and reduce the incidence of weeds. The gross plot size was 5 × 4 m, while the net plot size was 4 × 3 cm. Planting was conducted on the 8th and 24th of June 2017 and 2018 respectively. The spacing was 75 × 25 cm. Two maize seeds were directly sown in a well-prepared land. The seedlings were later thinned to one plant per stand 2 weeks after sowing (WAS). The plant density was 106 stands per gross plot. Inorganic N was split applied at planting and at 50% anthesis at the rate of 120 kg N ha^{-1}. N was sourced from NPK 15:15:15 and urea (46% N). To implement ⅓ of split N application, 30 kg N ha^{-1} were sourced from N:P:K, while the outstanding 10 kg N ha^{-1} were sourced from urea. To achieve ⅔ of split N, 30 kg N ha^{-1} were sourced from N:P:K and the remaining 50 kg N ha^{-1} were sourced from urea. P and K were applied at planting at recommended rates (30 kg P_2O_5 and 30 kg K ha^{-1}). Weeding was conducted manually when due.

Sampling and Data Collection

Five plants were randomly sampled from the net plot for the determination of growth variables (plant height, above ground biomass mass, ear height, leaf area, stem girth, leaf area index) at 3, 6 and 9 WAS. From the sampled plants development variables (days-to-50% anthesis, days-to-50% silking and anthesis-silking interval) were determined. Grain yield ha^{-1} and yield components (cob fresh and dry weight, 100 grain weight and shelling) were determined at harvest maturity as described by Aderibigbe et al., (2017). This was determined when the grain moisture content was estimated to have attained 14%. Leaf area was determined as product of leaf length × leaf breath × 0.75 (Onasanya et al., 2009). SPAD meter reading was evaluated using SPAD (Minolta, Japan). Leaf Area Index (LAI) and leaf angle were measured using Ceptometer (AccuPAR model LP-80, Decagon Devices Incorporation).

Statistical Analysis

Data collected were subjected to Mixed Model Analysis of Variance. Significant treatment means were separated using Least Significant Difference (LSD) at $P \leq 0.05$ significance level. All discrete data were log-transformed prior to analysis. The statistical package used was GENSTAT 12th Edition (Payne et al., 2009).

Results

There was contrasting rainfall distribution in both years during the early cropping seasons of the year 2017 and 2018 (Table 1). In the early cropping season of the year 2017, the maximum rainfall (156.1 mm) was observed in July. Similar pattern was observed in the early cropping season of the year 2018 (221.1 mm), albeit with more precipitation than the previous year. The temperature range in the early season of 2017 was 27.80-25.30°C. The highest temperature (28°C) in the early cropping season of 2018 was observed in September, while the minimum 25°C was observed in July. In the year 2017 the soil pH was slightly acidic (5.69), with loamy sand texture (Table 2). The soil organic matter was 1.09%, with 24.54 mg kg^{-1} and 0.16% of available P and total N respectively. The pH (6.07) of the soil in 2018 was similar to the previous year and similar pattern was observed with regards to the soil texture in 2017. Soil organic matter (2.86%) was twice as obtained in the previous year and total N was in the same range as obtained in the previous year, while available P was four times lesser than the previous year.

In 2018 at 3 WAP hybrid maize sown with N in the proportion of ⅓ at planting + ⅔ anthesis was significantly taller (69 cm) than that sown with N in the proportion of ⅔ at planting + ⅓ anthesis (Table 3). In the year 2017, at 6 WAP leaf area (452.7 cm^2) of hybrid maize sown with N in the proportion ⅓ at planting + ⅔ anthesis was larger than that sown in the proportion ⅔ at planting + ⅓ anthesis (423.2 cm^2) (Table 4). In the following year a converse pattern on the leaf area at 6 WAP was observed. Similar pattern was observed on LAI at 9 WAP in hybrid maize in 2018 (Table 4). In the year 2017 at 3 and 6 WAP, stem girth of hybrid maize sown with N in the proportion of ⅓ at planting + ⅔ flowering was significantly higher than the one sown in the proportion of ⅔ at planting + ⅓ flowering (Table 5). In 2018 at 3 WAP similar pattern was observed on the number of leaves (Table 5) and SPAD meter reading at 6 WAP in 2017 (Table 6).

In 2017, varietal differences had significant effect on the plant height throughout the sampling periods (Table 3). At 3 WAP varietal differences on the plant height were in the order TZEE129 × TZEE121 > TZE126 × TZE127 > Oba Super 2. Similar pattern was observed in the 6 WAP. In the same year, plant height in the 9 WAP followed a reversed order of the earlier described response pattern. In the year 2018 varietal differences were observed on the plant height in the 3 and 6 WAP in the order TZE126 × TZE127 > TZEE129 × TZEE121 > Oba Super 2 (Table 3). In 2017 Oba Super 2 had significantly the broadest leaf area (474.9 cm^2) at 9 WAP, while the least leaf area (399.4 cm^2) was observed in TZEE129 × TZEE121 (Table 4). In the following year, varietal differences had no significant effect on the leaf area throughout the sampling periods. The stem girth response pattern of the maize hybrids at 9 WAP in 2017 was in the order Oba Super 2 > TZE126 × TZE127 > TZEE129 × TZEE121 (Table 5). Maize hybrid TZEE129 × TZEE121 had the highest number of leaves (6) with the least observed in Oba Super 2 (5.8) at 3 WAP in 2017 (Table 5). Similar pattern was observed on SPAD meter readings at 6 WAP in 2017 (Table 6).

Table 1. Weather data of the experimental location during the period of the experiment, 2017 and 2018

Months	Rainfall (mm)		Maximum temperature (°C)		Minimum temperature (°C)		Mean temperature (°C)		Relative humidity (%)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
May	146.00	152.20	32.40	31.90	23.16	22.18	27.80	25.50	80.80	84.00
June	111.00	172.90	31.43	30.33	23.05	22.66	27.50	27.00	83.50	84.00
July	156.10	221.10	29.16	28.50	22.80	23.02	26.00	25.00	85.50	84.00
August	90.50	161.80	28.18	29.09	22.45	23.34	25.30	26.00	83.70	88.00
September	50.00	270.00	30.02	30.17	22.12	22.22	25.50	28.00	79.20	64.00
October	92.20	173.40	31.94	30.82	23.30	22.69	27.60	27.50	82.40	70.00
Mean	107.63	191.90	30.33	30.14	22.88	22.69	26.61	26.50	82.50	79.00

Source: Department of Water Resources Management and Agro-meteorology, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

Table 2. Pre-planting soil physico-chemical properties of location, 2017 and 2018

Soil properties	Values	
	2017	2018
pH	5.69	6.07
Sand (%)	85.80	82.20
Silt (%)	10.00	12.00
Clay (%)	4.20	5.80
Textural Class	Loamy sand	Loamy sand
Total Nitrogen (%)	0.16	0.15
Total Organic Carbon (%)	1.09	2.86
Available P (mg kg^{-1})	24.54	6.58
Ca (cmol kg^{-1})	3.41	4.05
Mg (cmol kg^{-1})	1.52	1.13
K (cmol kg^{-1})	0.41	0.26
Na (cmol kg^{-1})	0.65	0.54
Base Sat. (%)	98.52	98.52
H + Al (cmol kg^{-1})	0.09	0.09
ECEC (cmol)	6.08	6.07
Mn (mg kg^{-1})	42.55	52.43
Cu (mg kg^{-1})	3.54	1.76
Zn (mg kg^{-1})	3.64	6.43
Fe (mg kg^{-1})	5.55	0.55

In the following year at all sampling periods, SPAD meter reading was in the order TZEE129 × TZEE121 > TZE126 × TZE127 > Oba Super 2 (Table 6). In the year 2017, at 9 WAP varietal differences were observed on the leaf angle in the order Oba Super 2 > TZE126 × TZE127 > TZEE129 × TZEE121 (Table 6). This variable was not measured in the following year. In 2018, Oba Super 2 took longer days to attain 50% anthesis (61.17 days) and 50% silking (62 days) than other hybrid maize (Table 7). The least to attain anthesis and silking was observed in the hybrid maize TZEE129 × TZEE121 and TZE126 × TZE127 respectively. In the year 2018, above the ground dry matter at anthesis was in the order TZEE129 × TZEE121 > TZE126 × TZE127 > Oba Super 2. Similar pattern was observed on above the ground matter at harvest in the same year (Table 8). In 2018 ear height was in the order Oba Super 2 > TZE126 × TZE127 > TZEE129 × TZEE121. In the year 2017 Oba super 2 had the highest 100 grain weight (18.88 g) with the least observed in TZEE129 × TZEE121 (16.27), which was not significantly different from that of the TZE126 × TZE127 maize hybrid (Table 9). In the year 2018 a converse pattern was observed with hybrid maize TZEE129 × TZEE121 having the highest 100 grain weight (28.84 g) and the least was observed in hybrid maize Oba Super 2 (21.26 g). In the year 2017, cob fresh and dry weights were in the order Oba Super 2 > TZEE129 × TZEE121 > TZE126 × TZE127 (Table 9). In the year 2017 shelling percentage was the highest (77.70%) in TZEE129 × TZEE121 with the least observed in maize hybrid Oba Super 2 (61.50%). In the year 2018, hybrid maize cultivar TZE126 × TZE127 had the highest grain yield (3.24 t ha^{-1}), which was similar to the yield (3.08 t ha^{-1}) of TZEE129 × TZEE121, while the least was observed in Oba super 2 (2.11 t ha^{-1}) (Table 9).

Discussion

In 2017 Oba Super 2 had shorter canopy (plant height at 3 WAP) with smaller number of leaves at 6 WAP than obtained in the succeeding year. This could be attributed to the prevailing environmental condition in that year with comparatively less rainfall than in 2018. Tollenaar and Lee, (2002) reported that hybrids released recently are more tolerant to stress than those released in the earlier periods. Despite this fact, a variation was observed in their canopy architecture in both years, which could be ascribed not only to differences in rainfall intensity but also to differences in their maturity classes. In the same year, the comparatively larger leaf area of Oba Super 2 than other hybrid maize of different maturity classes and its planophile leaf orientation could have predisposed it to mutual shading and water loss when examined within the context of comparatively reduced water availability in 2017. However, higher stem girth at 9 WAP in Oba Super 2 than other hybrids of different maturity classes could have suggested the maintenance of the function of the photosynthetic apparatus. Furthermore, Ouattar et al., (1987) posited that reserve of assimilates in the stem could buffer shortage of it during photosynthesis especially at the silking growth stage. The maintenance of photosynthetic activities in Oba Super 2 was evidenced by the higher SPAD meter readings at 8 WAP than the other hybrid maize of different maturity classes. It could be inferred that the observed higher fresh and dry weight of cob together with the observed higher 100 grain weight in Oba Super 2 than other hybrid maize could be attributed to the aforementioned physiological attributes. Taken together, the yield components discussed earlier with respect to Oba Super 2 could have explained the observed pattern of grain yield at harvest, though similar, among the investigated maize cultivars. The weight of reproductive structures was reported to be more conserved when crops are subjected to environmental stress. Speculatively, it could be inferred that the number of reproductive structure could have displayed phenotypic plasticity to accommodate the prevailing environmental condition in the year 2017 with a trade-off on kernel weight and subsequently on the yield. The contribution of the number of kernel in this context could be inferred from the shelling percentage pattern observed, giving credence to the aforementioned mechanism with regards to yield formation among the maize cultivars of different maturity classes in that year.

Under comparatively favourable rainfall distribution in 2018 the above ground biomass at anthesis and harvest were significantly higher in earlier maturing maize hybrid (TZEE129 × TZEE121, TZE126 × TZE127) than Oba Super 2.

Table 3. Effects of variation in the proportion of inorganic nitrogen (N) applied at different time on the plant height (2017 and 2018) of hybrid maize of different maturity classes in a derived Savanna

Time of inorganic N fertiliser application (N)	Plant height (cm)					
	3 WAP		6 WAP		9 WAP	
	2017	2018	2017	2018	2017	2018
⅓ at planting + ⅔ at 50% anthesis	63.30	69.00	137.40	173.40	170.40	214.10
⅔ at planting + ⅓ at 50% anthesis	58.14	66.70	131.2	174.40	165.00	212.30
LSD	ns	1.85*	ns	ns	ns	ns
Variety (V)						
TZEE129 × TZEE121	66.43	67.90	145.40	175.30	172.30	208.10
TZE126 × TZE127	59.73	74.30	128.70	185.60	155.30	215.30
Oba Super 2	56.01	61.20	128.90	160.80	175.60	217.90
LSD	6.79*	7.44**	13.34*	11.11**	16.22*	ns
Interaction						
F × V	ns	ns	ns	ns	ns	ns

Note: WAP = Weeks After Planting, LSD = Least Significant Difference, * = significant at $P \leq 0.05$ level, ns= not significant

Table 4. Effects of variation in the proportion of inorganic nitrogen (N) applied at different time on the leaf area (2017 and 2018) and leaf area index (2018) of hybrid maize of different maturity classes in a derived Savanna

Time of application of inorganic N fertilizer (F)	Leaf area (cm^2)						Leaf area index		
	3 WAP		6 WAP		9 WAP		3 WAP	6 WAP	9 WAP
	2017	2018	2017	2018	2017	2018			
⅓ at planting + ⅔ at 50% anthesis	136.2	203.1	452.7	512.0	439.0	549	0.479	0.786	1.507
⅔ at planting + ⅓ at 50% anthesis	115.2	176.9	423.2	552.0	424.6	571	0.454	0.697	1.858
LSD	ns	ns	0.023*	39.4*	ns	ns	ns	ns	0.17**
Variety (V)									
TZEE129 × TZEE121	136.3	198.9	440.6	571	399.4	545	0.472	0.795	1.68
TZE126 × TZE127	128.6	207.3	449.5	520	421.2	545	0.51	0.752	1.765
Oba Super 2	112.3	163.6	423.9	505	474.9	591	0.418	0.677	1.602
LSD	ns	ns	ns	ns	43.25**	ns	ns	ns	ns
F × V	ns	ns	ns	ns	ns	ns	ns	ns	ns

Note: WAP = Weeks After Planting, LSD = Least Significant Difference, * = significant at $P \leq 0.05$ level, ns= not significant

Table 5. Effects of variation in the proportion of inorganic nitrogen (N) applied at different time on the stem girth and number of leaves of hybrid maize of different maturity classes in a derived Savanna, 2017 and 2018

Time of application of inorganic N fertilizer (F)	Stem girth (cm)						Number of leaves					
	3 WAP		6 WAP		9 WAP		3 WAP		6 WAP		9 WAP	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
⅓ at planting + ⅔ at 50% anthesis	3.318	13.93	6.167	20.38	5.113	20.82	6.556	8.58	10.00	12.34	10.00	11.82
⅔ at planting + ⅓ at 50% anthesis	2.948	12.89	5.950	22.17	4.963	20.6	5.556	8.13	9.50	12.24	10.33	12.27
LSD	0.3181**	ns	0.1985*	ns	ns	ns	ns	0.51*	ns	ns	ns	ns
Variety (V)												
TZEE129 × TZEE121	3.271	14.12	5.967	20.02	4.687	19.6	6.250	8.5	10.42	12.03	10.00	11.43
TZE126 × TZE127	3.163	13.8	5.950	21.18	4.923	19.72	6.083	8.57	9.75	12.82	9.25	12.1
Oba Super 2	3.018	12.32	6.258	22.62	5.325	22.82	5.834	8	9.08	12.03	11.25	12.6
LSD	ns	ns	ns	ns	0.1586**	ns	0.6125*	ns	ns	ns	ns	ns
F × V	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Note: WAP = Weeks After Planting, LSD = Least Significant Difference, * = significant at $P \leq 0.05$ level, ns= not significant

Table 6. Effects of variation in the proportion of inorganic nitrogen (N) applied at different time on the SPAD meter reading, and leaf angle of hybrid maize of different maturity classes in a derived Savanna, 2017 and 2018

Time of application of inorganic N fertilizer (F)	SPAD meter reading					Leaf angle
	3 WAP		6 WAP		9 WAP	9 WAP
	2017	2018	2017	2018	2018	2017
⅓ at planting + ⅔ at 50% anthesis	77.70	37.53	72.10	52.57	52.88	44.78
⅔ at planting + ⅓ at 50% anthesis	67.20	36.67	60.90	52.44	48.32	44.44
LSD	ns	ns	10.63*	ns	ns	ns
Variety (V)						
TZEE129 × TZEE121	76.80	38.75	72.10	53.30	46.65	36.58
TZE126 × TZE127	63.20	37.2	53.30	53.25	49.8	37.17
Oba Super 2	77.30	35.35	74.30	50.97	53.35	60.08
LSD	ns	2.24*	14.56*	1.94*	3.45*	7.92**
F × V	ns	ns		ns	ns	ns

Note: WAP = Weeks After Planting, LSD = Least Significant Difference, * = significant at $P \leq 0.05$ level, ns= not significant

Table 7. Effects of variation in the proportion of inorganic nitrogen (N) applied at different time on the developmental variables of hybrid maize of different maturity classes in a derived Savanna, 2017 and 2018

Time of application of inorganic N fertilizer (F)	Days to 50% anthesis		Days to 50% silking		Anthesis-silking interval (days)	
	2017	2018	2017	2018	2017	2018
⅓ at planting + ⅔ at 50% anthesis	54.20	54.33	59.0	55.11	4.78	0.92
⅔ at planting + ⅓ at 50% anthesis	54.90	54.67	59.30	55.44	4.45	0.89
LSD	ns	ns	ns	ns	ns	ns
Variety (V)						
TZEE129 × TZEE121	54.70	50.50	59.70	52.17	4.83	1.50
TZE126 × TZE127	56.70	51.83	61.70	51.67	5.33	0.38
Oba Super 2	52.30	61.17	56.0	62.00	3.67	0.83
LSD	ns	0.94**	ns	1.29**	ns	ns
F × V	ns	ns	ns	ns	ns	ns

Note: WAP = Weeks After planting, LSD = Least Significant Difference, * = significant at $P \leq 0.05$ level, **= Significant at $P \leq 0.01$ level, ns= not significant

Table 8. Effects of variation in the proportion of inorganic nitrogen (N) applied at different time on the aboveground dry weights and ear height of hybrid maize of different maturity classes in a derived Savanna, 2018

Time of application of inorganic N fertilizer (F)	Aboveground dry weights at anthesis (kg)	Aboveground dry weights at harvest (kg)	Ear height (cm)
⅓ at planting + ⅔ at 50% anthesis	85.6	70.7	87.0
⅔ at planting + ⅓ at 50% anthesis	99.6	84.6	92.6
LSD	ns	ns	ns
Variety (V)			
TZEE129 × TZEE121	106.6	92.0	82.1
TZE126 × TZE127	97.7	81.5	92.5
Oba Super 2	73.5	59.3	94.7
LSD	24.0*	15.5**	6.9**
F × V	ns	ns	ns

Note: WAP = Weeks After Planting, LSD = Least Significant Difference, * = significant at $P \leq 0.05$ level, **= Significant at $P \leq 0.01$ level, ns= not significant

Table 9. Effects of variation in the proportion of inorganic nitrogen (N) applied at different time on the yield components and yield of hybrid maize of different maturity classes in a derived Savanna, 2017 and 2018

Time of application of inorganic N fertilizer (F)	100 grain weight (g)		Fresh cob weight (g)	Dry cob weight (g)	Shelling percentage (%)	Cob diameter (cm)	Grain yield (t ha^{-1})	
	2017	2018	(2017)	(2017)	(2017)	(2017)	2017	2018
⅓ at planting + ⅔ at 50% anthesis	17.32	26.08	74.40	61.80	71.97	3.64	1.5	2.72
⅔ at planting + ⅓ at 50% anthesis	17.09	25.13	74.60	62.60	71.23	3.66	1.53	2.9
LSD	ns	ns	ns	ns	ns	ns	ns	ns
Variety (V)								
TZEE129 × TZEE121	16.27	28.84	69.10	58.00	77.70	3.65	1.5	3.08
TZE126 × TZE127	16.47	26.72	64.10	53.10	75.50	3.56	1.3	3.24
Oba Super 2	18.88	21.26	90.20	75.60	61.50	3.73	1.7	2.11
LSD	2.239*	2.91**	10.60*	8.09*	8.81*	ns	ns	0.83*
F × V	ns	ns	ns	ns	ns	ns	ns	ns

Note: WAP = weeks after planting, LSD = Least Significant Differences, * = 5% significant level, ns= not significant, **= Significance at $P \leq 0.01$

Pandey and Gardner, (1992) reported that the yield of tropical maize was associated with high harvest index, changes in dry matter distribution and ear growth rate at silking (Bolaños, 1995). Photosynthetic apparatus was maintained in all the hybrid maize in both years through the stability of chlorophyll as evidenced by their SPAD meter readings. This could have supported photosynthesis and the accumulation of the above ground biomass at anthesis and harvest. Yuan et al., (2010) report that plant and ear heights are affected by the genetics of the cultivar and environmental factors. Despite the fact that the plant height of early maturing maize hybrids (TZEE129 × TZEE121 and TZE126 × TZE127) was significantly higher than Oba Super 2 at 3 and 6 WAP, Oba Super 2 had the highest ear height in 2018. This could have suggested that comparatively earlier maturing maize hybrids (TZEE129 × TZEE121 and TZE126 × TZE127) would be less prone to lodging in that year. Landi et al., (1998) also reported correlation of ear height with plant height. The correlation was reported to be negative by Pandey and Gardner, (1992) with lower leaf size. Lübberstedt et al., (1998) observed that increased plant and ear height could reduce grain yield of maize due to their susceptibility to lodging.

In similar vein, Beavis et al., (1991) indicated that with reduced ear height maize was capable of having improved root system for increased nutrient uptake. Both, days to anthesis and silking were observed to be longer in Oba Super 2 than in earlier maturing maize hybrids, which could have suggested reduced grain-filling duration. Bolaños, (1995) posited that the increased grain filling duration in maize had a positive effect on the grain yield. Furthermore, he indicated that grain filling duration was negatively associated with days to maturity. He also observed that morphologically such varieties of maize had lesser number of leaves than those with short grain filling period. Though the last observation was not empirically validated in this experiment in 2018, the 100 grain weight was observed to be higher in comparatively earlier maturing maize hybrids (TZEE129 × TZEE121 and TZE126 × TZE127) than in Oba super 2 in 2018. It could be inferred that the significantly higher grain yield in these maturity classes maize hybrid (TZEE129 × TZEE121 and TZE126 × TZE127) could be attributed to its significantly higher 100 grain weight and above ground biomass accumulation at anthesis and harvest than Oba Super 2 in 2018. Other studies attributed this to their grain-filling period and other yield components. Bolaños, (1995) reported that additional days to the grain filling period increased grain yield by 90 and 110 kg ha^{-1} in OPV and hybrid maize respectively. Milander et al., (2017) attributed the improved performance of early maturing hybrid maize to more kernel m^{-2}, ear length and number of kernel ear^{-1} than other maturity classes.

Split application of N in different proportions has been reported to modify canopy morphology (leaf area/plant, plant and ear height) and biomass accumulation compared with equal proportion of N in split (Amanullah et al., 2009). In both years leaf area at 6 WAP was affected by the variations in the proportion of N applied at planting and anthesis. While maize hybrids of different maturity classes sown with N applied in the proportion ⅓ at planting + ⅔ anthesis favoured more leaf area in 2017, a converse pattern was observed in 2018, which could have been associated with variations in weather in both years. Despite the higher soil P concentration in 2017 than in 2018, synergistic relationship between N and P could be compromised probably due to reduced intensity of precipitation during the cropping season compared to 2018. However, Scharf et al., (2002) indicate that delayed N application did not lead to substantial yield loss provided the growing season is long. The observed pattern of leaf area at 6 WAP in the year 2017 could have aided the interception of light and water loss through transpiration. The former could have assisted carbon assimilation as evidenced in the high stem girth observed in maize hybrids of different maturity classes under that condition in that year. SPAD meter readings at 6 WAP in maize hybrids sown when N was applied in the proportion ⅓ at planting + ⅔ anthesis in 2017 could have suggested its role in leaf chlorophyll formation (Chapman and Barreto, 1997). SPAD was reported to correlate with grain yield at R4 and R5 rather than at V6 growth stages. However, this pattern is contingent on the genotype, leaf position and growth stage (Peng et al., 1993). In the year 2018, taller and more leaves were observed when maize hybrids were sown in plots with N split applied in the proportion ⅓ at planting + ⅔ anthesis. Amanullah et al., (2009) attributed more numbers of leaves in their study to leaf expansion. The rainfall pattern could provide the basis for the volumetric change in the leaf cell in a particular year. How variations in weather in both years could have affected leaf area expansion could not be ascertained, since leaf area expansion in this study was associated with maize cultivars sown when N was applied in split in the proportion ⅔ at planting + ⅓ anthesis and not in the proportion ⅓ at planting + ⅔ anthesis. Plant height at 3 WAP and the number of leaves were better developed in maize hybrids sown with split N application in the proportion ⅓ at planting + ⅔ anthesis than ⅔ at planting + ⅓ anthesis. It was reported that yield components of maize were developed at different growth stages. Ear plant^{-1}, kernel ear^{-1} and kernel weight were determined at early (Evans et al., 2003), mid (Abendroth et al., 2011) and late growing stages (Novacek et al., 2013) respectively. It could be inferred that the variations in the N proportion in split application on maize cultivars would vary the growth of these sinks provided the source is not compromised. These observations could not be ascertained in this study since maize hybrids used had similar grain yield with split application of N in different proportions.

In conclusion, in 2017 Oba Super 2 had better growth (leaf area, stem girth and plant height at 9 WAP) than other earlier maturing maize hybrids (TZEE129 × TZEE121 and TZE126 × TZE127). Better growth of Oba Super 2 was more reflected in yield components (fresh and dry cob weight, 100 grain weight) than in other earlier maturing maize hybrids, except shelling percentage that was significantly higher in comparatively earlier maturing maize hybrids than in Oba Super 2. A converse pattern was observed in the year 2018, which translated to significantly higher grain yield in earlier maturing maize hybrids than Oba Super 2. This could have suggested that apart from genetic differences and maturity classes, differences in rainfall pattern could have explained the observed pattern in their performances. Split application of N in different proportions resulted in variations in canopy morphology and SPAD meter readings in 2017 and 2018. This was further mediated by variations in weather and the soil P availability in both years. In 2017 leaf area at 6 WAP was more in maize hybrids sown when N was split applied in the proportion ⅓ at planting + ⅔ anthesis than when sown in the proportion ⅔ at planting + ⅓ anthesis. A converse pattern was observed in 2018.

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