Growth Rate Characteristics and Dry Matter Partitioning of Three Commercial Maize Genotypes Grown under Different Plant Densities

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Abstract

Maize genotypes respond differently to planting densities in their morpho-physiological characteristics. Studies were carried out during late and early rainy seasons at Ibadan, southwestern Nigeria to evaluate the morpho-physiological characteristics, dry matter accumulation and distribution and grain yield from different plant densities of maize genotypes. Each season's experiment was laid out as a factorial experiment in randomized complete block design with three replications. The treatments were three commercial maize genotypes single cross hybrid (Oba Super 1) and two open pollinated genotypes (Suwan-2 and Suwan-1) and four plant densities: 37,000, 53,333, 66,667 and 80,000 plants/ha. Results indicated no significant differences in plant height and number of leaves for genotypes and plant densities except in late season where significant difference was obtained in number of leaves. Plant density affected leaf area index (LAI), leaf area ratio (LAR), crop growth rate (CGR) and net assimilation rate (NAR) values which increased with increase in density. Dry matter (DM) production per unit area was significantly higher at 80,000 plants/ha. At final sampling, the percentage total DM increase of 80,000 plants/ha over the 66.667, 53,333 and 37,000 plants/ ha was 9, 29 and 61%, respectively for Oba Super 1, 27, 22 and 54%, respectively for Suwan-2 and 1, 19 and 35% for Suwan 1. Plant density significantly increased grain yield with the highest value at 80,000 plants/ha 6.2 and 6.1t/ha in early and late seasons respectively. The results obtained in this study confirmed the optimum density of 80,000 plants/ha recorded previously for maize genotypes in Nigeria but the yields here are higher than those previously recorded for maize at this density of planting.

Keywords: Commercial maize, Dry matter partitioning, Morpho-physiology, Plant density.

Introduction

Grain yield increase in maize has been attributed mainly to improve genetic gains, superior agronomic management and interaction among the two (Tollenaar and Lee 2002; Duvick, 2005; Lee and Tollenaar, 2007). One major agronomic practice that has led to this increase is the use of appropriate or optimum plant density. Porter *et al*, (1997) reported that wider plant spacing reduces plant competition for nutrients, water and light while Sangoi and Salvador, (1998) reported that higher planting densities ensure early crop cover which enhances soil protection and diminishes soil erosion.

In temperate zones, asymptotic relationship was reported between plant density and maize total dry matter yield (Adelana and Milbourn, 1972) along with a roughly-parabolic relationship between plant density and per-unit-area grain yield (Tokatlidis and Koutroubas, 2004). Increase in density above optimum results in intense intra-specific competition which generally leads to decrease in grain yield (Tollenaar and Wu, 1999; Olaniyan and Lucas, 2002; Boomsma *et al*., 2009). Allessi and Power (2004) revealed that maize cob weight decreased with increase in plant population and grain yield was reported to increase linearly with plant density until some competitive effects become apparent. Plant densities higher than critical levels affect grain yield, leaf size and leaf area index (LAI) negatively, and results in soil depletion (Wiyo *et al*., 1999). Boomsma *et al*. (2009) reported that without sufficient N at high plant densities, intra-specific competition for soil N is severe leading to reduced foliar N concentrations, earlier leaf senescence that limit total biomass and grain yield. It has also been reported that even when density-tolerant maize hybrids and N applied, high plant density can adversely affect overall grain yield as a result of increased plant variability and higher incidence of barrenness (Tokatlidis and Koutroubas, 2004). Use of optimum plant density in maize helps in proper utilization of solar radiation, which influences leaf area, and consequently maize dry matter and grain yield (Pepper, 1987; Boomsma *et al*., 2009). Previous studies reported improved morpho-physiological traits at high plant density among the modern maize genotypes in developed countries (Sangoi *et al*., 2002; Tollenaar and Lee, 2006; Hammer *et al*., 2009). Although maize farmers in Nigeria as well as many sub-Sahara African countries are adopting the use of hybrids at commercial level, however, majority of them still prefer the open pollinated genotypes especially the newly improved genotypes. As part of efforts to improve the output of the Nigerian farmers, experiments were set up to pinpoint the optimum density for cultivation of the commercial maize genotypes and recommend this to maize growers.

Materials and Methods

The field trials were conducted in the early (May-August) and late (August-November) planting seasons at Ibadan, Nigeria (7^o 20'N, 3^o54'E). The experimental sites lies within derived savanna ecological zone (transition forest ecosystem of Nigeria). Generally, rainfall pattern is bimodal. Separate experimental fields were used for the study, in both seasons, the experimental field was cleared, ploughed and harrowed. Representative soil samples were taken at a depth of 0-15 cm from different parts of the field before planting. The soil samples were thoroughly mixed to form a composite sample, air-dried and passed through 2 and 0.5 mm sieve for soil physical and chemical analyses.

The experimental fields were laid out as a factorial in a randomized complete block design and replicated three times. The treatments consisted of three maize genotypes; single cross hybrid (Oba Super 1) and two open pollinated genotypes (Suwan-2 and Suwan-1) and four plant density levels: 37000 plants/ha (90 x 30cm), 53333 plants/ha (75 x 25cm), 66667 plants/ha (60 x 25cm) and 80000 plants/ha (50 x 25cm). The three maize genotypes are improved genotypes, readily available and commonly grown by farmers. The plot size per treatment was 6 x 4 m^2 and plots were separated from each other by distance of 1m. Seeds were treated with Cibaplus® (a seed treament insecticide + fungicide) before sowing.

Two seeds were sown per hole and later thinned to one plant per stand, five days after emergence. Weeds were controlled by application of Paraquat (1,1-dimethyl 1-4,-4-bipyridinum ion) at 0.56 kg/ha and supplemented manual weeding operation at five weeks after sowing. The experimental site in both seasons received inorganic fertilizer (side dressing) at the rate of 90 kgN, 60 kgP_20_5, and 60 kgK_20 per hectare. The entire dosage for phosphorus and potassium were applied two weeks after planting while nitrogen was split applied at two and four weeks after planting. For each experiment, samples were taken fortnightly starting from 5 weeks after sowing until plants reached physiological maturity (13 weeks after planting). On each sampling occasion, data on plant height, number of leaves per plant and leaf chlorophyll using SPAD were recorded for four sampled plants, after which the plants were uprooted. Plant parts were separated in the laboratory into leaves, stem, roots, tassel and ear depending on stage of growth for dry matter yield. Leaf area measurement was done using the LICOR 3000 leaf area meter, while dry weights were determined after the plant parts were dried for 48 hours at 75^{o}C in a force drought oven to constant weight. From the dry weight and the leaf area measurements, the growth analysis variables: leaf area index (LAI), leaf area duration (LAD), leaf area ratio (LAR) and crop growth rate (CGR) were computed.

Grain yield at maturity (98 days after planting) was determined by harvesting all the plants within one square meter. Components of yield which include cob diameter, cob length, kernels/ row, number of kernels/row and 100 kernel weight were subsequently determined. The data collected were analysed with Analysis of Variance (ANOVA) of statistical analysis system (SAS Institute, 2012). Significant means were separated by the Least Significant Difference (LSD) at 5% probability. Correlation coefficients were also determined among morpho-physiological parameters and among yield components.

Results

The result of soil analysis of the experimental field for the early and late seasons revealed that the soil is sandy loam, slightly acidic (pH (H_2O) 6.2 and 6.5) with low nitrogen content (0.04 and 0.06 %), respectively.

Plant height and number of leaves of maize genotypes under different plant densities

The effects of genotypes and plant population density on maximum plant height and number of leaves are shown in Table 1. Maximum values for both plant height and number of leaves were recorded nine weeks after planting. Results indicate that no significant differences were observed among genotypes and plant densities for maximum plant height in both early and late planting seasons. However, plant height values increased as density increased and significant ($P<0.05$) genotype by plant density interaction was observed in the early planting season. Suwan-1 had the highest number of leaves (12.9) in the early planting season while Suwan-2 had the lowest average number of leaves (Table 1). In the late season planting, plant density was significant ($p<0.05$) for maximum number of leaves per plant; plant density of 37,000 plants/ha produced the highest number of leaves per plant (12.9) similar to 53,333 plants/ha but different from other plant densities.

Growth rates and SPAD readings of maize genotypes under different densities of planting

Plant density and genotypes were significant for maximum LAI which was obtained at 7 weeks after planting in both seasons. Plant density at 80,000 plants/ha produced significantly highest LAI in both seasons. Suwan-1 had highest LAI (3.8) similar to Oba super1 during the early season (Table 2).

Leaf area duration was significant among genotypes and plant density at both early and late planting season. In the early season, Suwan-1 had the highest LAD (52.2 days). Among plant density levels, 80,000plants/ha produced the LAD (61.5 days) which was significantly higher than LAD produced at other plant density levels ($p<0.05$). The same trend was observed in the late season (Table 2). There were significant ($p<0.05$) differences among genotypes and density levels for LAR; highest LAR was observed in Oba Super1 which was similar to Suwan-1 but significantly higher than Suwan-2 in both seasons.

There were significant differences observed among genotypes and plant density levels for CGR and NAR in both early and late seasons. Planting density level of 80,000plants/ha had highest CGR in the early season (31.2 g/m^2/day) and was statistically similar to the CGR obtained at 66,667 plants/ha (27.1g/m^2/ day). Also, in the late season, highest CGR rate was obtained at 80,000plants/ ha (23.8g/m^2/day) which was not different ($P<0.05$) from CGR obtained at 66,667plants/ha but higher than other densities of planting. The NAR was not significantly different among planting density during the early season but was significantly different for both plant densities and genotypes at the early and late seasons. Plant density level, 80,000 plants/ha had highest NAR in both seasons (21.0 and 14.8 g/m^2/day). Suwan-1 had highest NAR values for both season (21.7 and 10.4 g/m^2/day). Plant density and genotypes had no significant effect on SPAD values in both seasons (Table 2).

Table 1: Effects of genotype and plant density on maximum plant height (cm) and number of leaves/plant of maize grown at early and late planting seasons in Ibadan, Nigeria

Genotypes	Plant density (plants/ha)									
	Early season					Late season				
	37,000	53,333	66,667	80,000	Mean	37,000	53,333	66,667	80,000	Mean
	Maximum plant height (cm)									
Oba super 1	177.58	185.25	198.58	194.33	**188.93**	193.83	168.00	193.33	186.83	**185.50**
Suwan-2	179.08	173.08	185.42	191.50	**182.27**	175.33	181.67	198.83	198.83	**188.54**
Suwan-1	188.50	194.16	189.20	199.42	**192.82**	200.39	189.00	186.67	204.33	**195.08**
Mean	**181.72**	**184.17**	**191.06**	**195.08**		**179.56**	**189.83**	**192.78**	**196.67**	
LSD (5%)										
Genotypes (G)	ns					ns				
Plant Density(D)	ns					ns				
G x D	*					ns				
	Number of leaves/plant									
Oba super 1	12.00	11.67	11.17	11.67	**11.63**	12.00	12.00	11.33	11.67	**11.75**
Suwan-2	11.92	11.00	10.83	11.67	**11.35**	13.00	11.00	10.50	10.50	**11.25**
Suwan-1	13.50	12.75	11.75	11.58	**12.93**	13.67	12.17	11.33	11.33	**12.13**
Mean	**12.47**	**11.80**	**11.25**	**11.64**		**12.89**	**11.72**	**11.06**	**11.17**	
LSD (5%)										
Genotypes (G)	ns					ns				
Plant Density(D)	0.84					1.41				
G x D	ns		Ns							

ns: not significant, * Significant (p<0.05).

Table 2: Effects of genotype and plant density on growth parameters and SPAD Readings of maize grown at early and late planting seasons in Ibadan, Nigeria

Growth Parameters	Plant Density (plants/ha)					Genotypes			
	37,000	53,333	66,667	80,000	LSD	Oba Super 1	Suwan-2	Suwan-1	LSD
				Early Season					
LAI	2.4	3.3	3.8	4.7	0.62	3.7	3.1	3.8	0.53
LAD (days)	31.4	44.7	52.8	61.5	4.40	48.8	41.9	52.2	3.81
LAR (cm^2/g)	46.9	47.1	49.2	54.2	9.10	53.3	42.6	52.2	7.88
CGR (g/m^2/day)	13.0	21.8	27.1	31.2	9.09	18.6	23.2	23.5	7.89
NAR (g/m^2/day)	18.0	18.6	20.2	21.0	3.42	18.6	17.9	21.7	2.96
SPAD readings	57.9	56.0	54.7	52.3	ns	54.1	55.9	55.5	ns
				Late season					
LAI	1.9	2.9	3.4	3.8	0.37	3.05	2.7	3.2	0.31
LAD (days)	26.8	40.0	48.2	56.8	3.90	44.1	37.3	47.5	2.76
LAR (cm^2/g)	21.9	23.3	23.7	23.9	2.89	24.7	20.2	24.3	2.50
CGR (g/m^2/day)	15.3	17.8	22.9	23.8	6.86	18.5	19.8	21.5	5.94
NAR (g/m^2/day)	8.8	10.5	11.7	14.8	1.50	9.83	8.71	10.4	1.29
SPAD readings	53.2	51.2	48.0	49.8	ns	49.3	51.2	51.2	ns

ns: not significant.

Table 3: Dry matter partitioning at harvest of maize varieties as influenced by different plant density levels during the early planting season in Ibadan, Nigeria

	Dry matter partitioning (g/m^2)							
Variables	Leaves	Stem	Root	Tassel	Husk	Rachis	Grain	Total Dry Weight(g /m^2)
Genotype (G)								
Oba Super 1	189.3	316.1	190.8	16.6	96.2	115.5	469.8	1394.3
Suwan-2	162.2	289.0	221.1	15.1	88.8	126.4	443.7	1346.3
Suwan-1	184.2	307.4	222.7	15.1	112.4	132.9	426.5	1401.2
LSD (5%)	25.50	ns	ns	Ns	22.9	ns	87.96	48.7
Plant Density (D) (plants/ ha)								
37,000	110.0	169.6	119.4	11.6	56.9	79.0	313.5	860.0
53,333	147.3	319.0	190.2	14.5	102.7	117.9	457.8	1349.0
66,667	199.5	334.6	235.9	15.6	103.7	128.3	548.0	1565.6
80,000	204.0	340.0	300.7	20.6	133.2	148.0	600.7	1747.2
LSD (5%)	44.46	70.96	56.16	3.4	26.44	25.31	101.57	216.64
G x D	ns	ns	ns	ns	ns	ns	ns	Ns

ns: not significant

Dry matter weights, partitioning and accumulation of maize genotypes under different densities of planting

Dry matter partitioning per unit area at harvest for early grown maize is presented in Table 3. Significant differences were observed among the genotypes for the leaves, husk, grain and total dry matter with Oba super1 and Suwan-1giving similar values which are significantly higher than values obtained from Suwan-2. The dry matter values for various plant parts and total dry weights per unit area increased as density of planting increased. Planting density at 80,000 plants/ha gave the highest values which were higher than other densities. The dry matter accumulation per unit area significantly increased with increase in densities for all the maize genotypes over the sampling periods. At 13 weeks after planting, the percentage total dry matter increase of 80,000 plants/ha over the 66,667, 53,333 and 37,000 plants/ ha are 8.8, 28.8 and 60.8%, respectively for Oba Super 1 and 27.3, 22.0 and 54.4% respectively, for Suwan-2 and corresponding increase for Suwan-1 are 1.0, 19.2 and 35.0% respectively (Figure 1).

Dry matter partitioning at 80,000 plants/ ha for the three maize genotypes is presented in Figure 2. At early stage of growth (5 weeks after planting) the proportion of dry matter partitioned to the stem were 36, 33 and 29% for Oba Super1, Suwan-2 and Suwan-1 respectively which later reduced to 21, 17 and 20% respectively at 13 weeks after planting. The proportion of dry matter partitioned to the grains at 13 weeks after planting were 33, 43 and 27% respectively for Oba Super 1, Suwan-2 and Suwan-1.

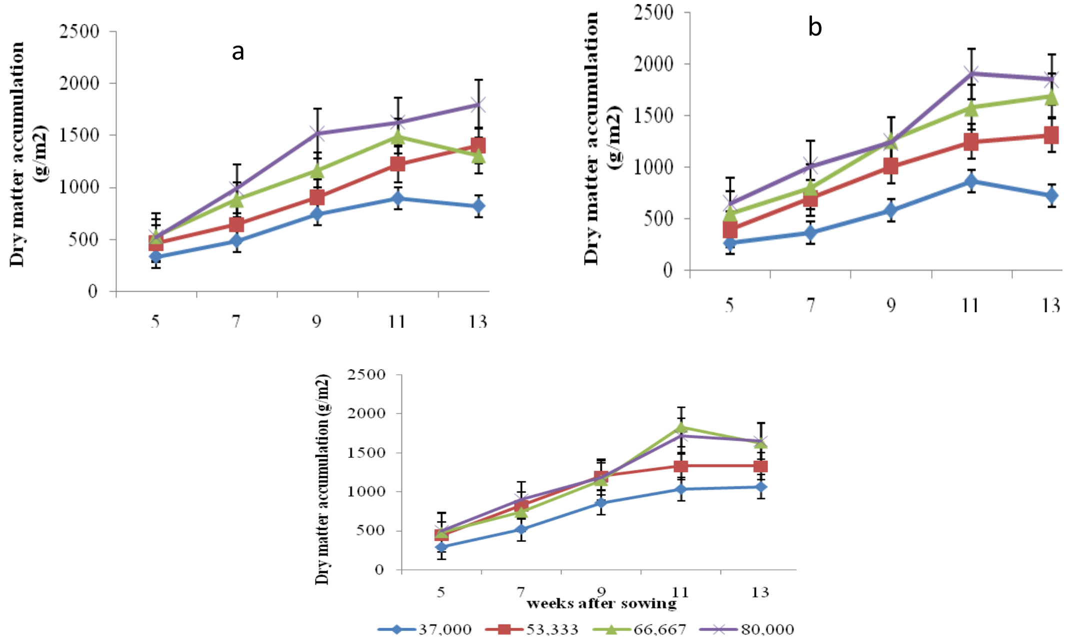

Figure 1. Dry matter accumulation of (a) Oba Super 1 (b) Suwan-2 and (c) Suwan-1 maize genotypes grown at different plant density levels in early season in Ibadan, Nigeria

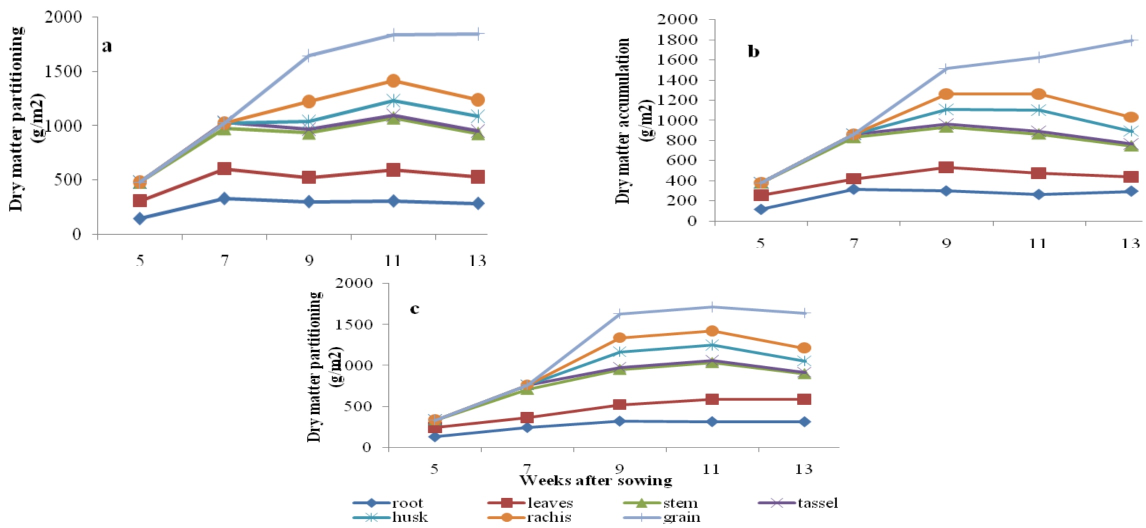

Figure 2: Dry matter partitioning of (a) Oba super-1, (b) Suwan-2 and (c) Suwan-1 maize genotypes at 80,000plants/ha in early season at Ibadan, Nigeria

Yield and components of yield of maize genotypes under different planting densities

Yield components of maize grown during the early season in Ibadan are shown in Table 4**.** Genotype had no significant effect for any of the yield components except 100 kernel weight (P<0.05). Suwan-2 had the highest 100 kernel weight (26.8g) which was not significantly different from Oba Super1 (24.9g) and Suwan-1(26.6g). Density was significant for all yield traits (P<0.05). For Oba super 1, 53,333 plants/ha produced the highest value for cob diameter (4.7cm) and was significantly higher than cob diameter value at 80,000 plants/ha (3.5cm). Longest cobs were observed at 37,000 plants/ha (15.3cm) while the shortest cobs were obtained at 80,000 plants/ha (13.3cm) across genotypes. The same trend was observed in kernel rows, number of kernels per row and 100 kernel weight. There was a significant (P<0.01) genotype x plant density interaction for kernel rows.

In the late season planting, among genotypes, significant differences were observed for cob length and 100 kernel weight (P<0.05). Suwan-1 had the longest cobs (15.9cm) while the shortest cobs were observed in Oba Super 1(13.5cm). Suwan-2 had the highest value for 100 kernel weight (24.8g) while Oba Super 1 had the lowest 100 kernel weight (22.4g). However no significant differences was observed for yield components with regard to plant density (Table 5). Grain yield was highest at 80,000 plants/ha (6.2t/ha) though only significantly higher than grain yield obtained at 37,000 plants/ha (3.9t//ha) while in the late season after planting, similar result was obtained. Density of 80,000 plants/ha gave the highest grain yield of 6.1t/ha which was significantly higher (P<0.05) than grain yield obtained at 53,333 plants/ha (4.4t/ha) and 37,000plants/ha (2.6 t/ha) (Table 6).

In the combined analysis of variance (ANOVA) for grain yield and yield components of maize genotypes evaluated under varying plant density levels in both early and late planting seasons (Table 7), cob diameter, kernel rows, number of kernels per row and grain yield were significant for seasons and plant density (P<0.05) while cob length and 100 kernel weight were significant for genotype (P<0.01).Season x genotype x density interaction was not significant for any trait (Table 7). However, there was a significant season x density interaction for kernel rows and number of kernels per row (P<0.05). Genotype x season interaction was significant for cob diameter and cob length (P<0.05). Genotype x density interaction was significant for kernel rows, number of kernels per row (P<0.01) and cob diameter (P<0.05).

Table 4: Effects of genotypes and plant density levels on grain yield components of maize grown at early season in Ibadan, Nigeria

Genotype	Density (plants/ha)	Cob diameter (cm)	Cob length (cm)	Kernel rows	No. of Kernels/row	100 Kernel Weight (g)
Oba Super 1	37,000	4.67	14.29	14.05	28.92	28.47
	53.333	4.71	14.49	14.80	30.61	23.97
	66,667	4.45	13.38	13.73	28.79	24.50
	80,000	3.46	12.94	14.13	25.83	22.63
	Mean	**4.32**	**13.78**	**14.18**	**28.54**	**24.89**
Suwan-2	37,000	4.62	15.05	13.74	30.40	26.93
	53.333	4.59	13.64	14.07	28.55	27.03
	66,667	4.52	13.16	13.77	24.60	28.30
	80,000	4.41	13.64	13.80	25.27	24.73
	Mean	**4.54**	**13.87**	**13.844**	**27.21**	**26.75**
Suwan-1	37,000	4.88	16.54	15.33	29.97	28.90
	53.333	4.84	15.00	15.29	26.06	26.17
	66,667	4.96	13.47	14.39	25.40	26.80
	80,000	4.27	13.33	12.80	23.60	24.33
	Mean	**4.74**	**14.59**	**14.45**	**26.26**	**26.55**
	LSD(0.05)					
	Genotype (G)	Ns	ns	ns	ns	2.04
	Density (D)	0.32	0.65	0.57	2.41	2.36
	G x D	Ns	ns	**	ns	ns

ns = not significant; ** =significant

Table 5: Effects of genotypes and plant density levels on yield components of maize grown at late season in Ibadan, Nigeria

Genotype	Density (plants/ha)	Cob diameter (cm)	Cob length (cm)	Kernel rows	No. of kernels per row	100 Kernel Weight (g)
Oba Super 1	37,000	4.21	13.89	14.07	27.55	24.27
	53.333	4.29	13.24	13.10	28.46	23.07
	66,667	4.21	13.64	13.53	29.07	20.97
	80,000	4.26	13.35	14.30	29.36	21.36
	Mean	**4.23**	**13.53**	**13.75**	**28.61**	**22.41**
Suwan-2	37,000	4.40	15.08	14.01	31.75	22.53
	53.333	4.28	14.81	12.70	30.70	25.80
	66,667	4.63	15.58	13.80	31.82	25.84
	80,000	4.33	14.89	13.32	28.65	25.03
	Mean	**4.41**	**15.09**	**13.45**	**30.73**	**24.80**
Suwan-1	37,000	4.55	17.03	13.97	31.38	25.80
	53.333	4.35	15.52	13.47	30.85	24.17
	66,667	4.05	15.43	13.47	28.96	23.03
	80,000	4.19	15.66	12.73	29.63	25.03
	Mean	**4.28**	**15.91**	**13.42**	**30.20**	**24.51**
	LSD(0.05)					
	Genotype(G)	ns	0.81	ns	ns	1.20
	Density (D)	ns	ns	ns	ns	ns
	G x D	ns	ns	ns	ns	ns

ns: not significant.

Table 6. Effects of genotypes and plant density levels on grain yield (tonnes/ha) of maize grown at early and late planting season in Ibadan

Genotype	Plant Density (plants/ha)									
	Early season					Late season				
	37,000	53,333	66,667	80,000	**Mean**	37,000	53,333	66,667	80,000	**Mean**
Oba super 1	3.93	5.66	5.73	6.45	**5.44**	2.41	4.01	5.34	6.25	**4.50**
Suwan-2	3.77	5.15	5.86	5.94	**5.18**	3.21	4.46	4.79	5.89	**4.59**
Suwan-1	3.95	5.26	5.84	6.09	**5.29**	2.18	4.75	5.15	6.08	**4.54**
Mean	**3.88**	**5.36**	**5.81**	**6.16**		**2.60**	**4.41**	**5.09**	**6.07**	
LSD (5%)										
Genotypes (G)	ns					ns				
Plant density (D)	0.91					1.48				
G x D	ns					ns				

Table 7: Mean squares from combined ANOVA of yield components and grain yield of maize genotypes evaluated under varying planting density in both early and late planting seasons in Ibadan, Nigeria

Source of variation	df	Cob Diameter (cm)	Cob length (cm)	Kernel Rows	No. of kernels per row	100 Kernel Weight (g)	Grain Yield (Mg/ha)
Rep	2	0.52ns	0.66ns	0.41ns	7.33ns	2.62ns	2.35ns
Season (S)	1	10.18***	10.84ns	6.56**	22.61***	77.10**	8.30n*
Genotype (G)	2	0.32ns	14.87***	0.56ns	4.22ns	32.20**	2.40ns
Density (D)	3	1.73**	5.91**	1.24ns	27.40**	15.05ns	26.06***
S*D	3	0.71ns	2.78ns	2.07**	14.98*	12.64ns	1.74ns
G*S	2	1.43*	4.74*	0.92ns	5.98ns	0.57ns	1.10ns
G*D	6	1.05*	1.21ns	1.62**	27.86**	11.29ns	0.99ns
S*G*D	6	0.37ns	0.51ns	0.36ns	5.99ns	1.06ns	0.78ns
Error	46	0.36	1.02	0.38	5.07	6.07	1.59

*,**, ***: significant at 0.05, 0.01, 0.001 probability levels, respectively; ns: not significant.

Discussion

Planting crops at optimum density is a necessity to obtain maximum yield of the crop. In this study, the optimum yield of the commercial maize genotypes were obtained at density of 80,000 plants/ha. This is in conformity with results obtained from previous related studies on maize in Nigeria (Lucas, 1986; Akintoye *et al*., 1997; Olaniyan and Lucas, 2002). Plants in plots of 80,000 plants/ha were taller than plants in other population densities, although, the difference was not statistically significant. This is consistent with results obtained by Remison and Lucas (1984) who reported that density had no effect on most of the morphological traits measured in their study. Monueke *et al*. (2007) also reported no significant effect of plant density on plant height of maize at any age of the maize plants. Plants at high density were taller than those at low density similar to findings of Enujeke (2013) in his study. The difference was no doubt due to the fact that a high density led to increased competition for space, light and available nutrients. In the early planting season, genotype was significant for maximum number of leaves per plant. This result is consistent with report by Sajjan *et al*. (2002) who also reported genotypic differences for number of leaves per plant. Higher density planting resulted in significantly lower number of leaves compared to low plant density. This contradicts Enujeke (2013) who reported that increase in number of leaves per plant as plant density increased could be linked to increased growth rate in search of space, sunlight and environmental resources.

Leaf area index (LAI) is defined as the functional leaf area over a unit of land area and represents the leafiness of the maize plant in relation to land area. Leaf area duration (LAD) is a measure of leaf area index integrated over time. It takes into account both the magnitude of leaf area and its persistence in time. There was increase in LAI with increased plant population per unit area which presumably resulted in greater photosynthetic activity and consequently the accumulation of dry matter. Bavec and Bavec (2002) also reported that LAI increased with increasing plant population from 4.5 to 13 plants/m^2.Crop growth rate and net assimilation ratio also increased with increased plant density at both early and late planting seasons. Generally, plants under 80,000 plants/ ha performed better in growth rates as indicated by LAI, LAD, LAR, CGR, and NAR; these values increased with increase in density of planting similar to previous reports (Adelana and Milbourn, 1972, Lucas, 1986, Valadabadi and Farahani, 2010 Sharfi and Zadeh, 2012).

With regards to components of yield, the number of kernel rows per cob was highest at 53,333 plants/ha and decreased at higher densities. The high stand density reduced ear shoot growth, which resulted in fewer spikelet primordial transformed into functional florets by the time of flowering. This result agrees with Abuzar *et al*. (2011) who also reported that number or kernel rows/cob decreased as plant population density increased. Cob length decreased with increase in plant density and was lowest at 80,000 plants/ha. This result is consistent with the observations of Shafi *et al*. (2012) who reported that high plant population had a negative impact on ear length. According to the authors observed trend may be due to the fact that available nutrients, moisture, space and light become limited under high plant population due to high competition of soil resources among plants.100-grain weight was significantly affected by genotype and plant density. Highest mean grain weight was produced at 37,000 plants/ha while the lowest was obtained at 80,000 plants/ha. Zamir *et al*., (2011) obtained similar results and explained that low grain weight at high plant density was probably due to the availability of less photosynthate for grain development on account of high intra-specific competition which resulted in low rate of photosynthesis and high rate of respiration, as a result of enhanced mutual shading.

The study on dry matter partitioning gave an indication of possible remobilization of stem assimilate to the grain towards the grain fill period. In this study, at early stage of growth the proportion of dry matter partition to the stem in the three maize genotypes are 36, 33 and 29% and this was later reduced to 21, 17 and 20% respectively at the final harvest. As this reduction was taking place in the stem, the proportion of assimilate to the grain also increased to 33, 43 and 27% respectively for Oba super 1, Suwan -2 and Suwan-1. Mobilization of stem assimilate to the grain is a phenomenon that has been well documented for maize both in the temperate region and in the tropics (Adelana and Milbourn, 1972, Tollenaar, 1977 and Lucas, 1981).

Grain yield increased by 37% when plant density increased from 37,000 to 80,000 plants/ha and 13% from 53,333 to 80,000 plants/ha in the early season and corresponding increase in late season was 57 and 27%, respectively. The conclusion one can draw from this study is that the maize genotypes used gave their optimum yield at 80,000 plants/ha plant and this yield is mediated through improve growth rates.

Acknowledgements

The author wishes to thank Miss Enobong Udo of Maize Improvement Program, IITA, for her help in the field, laboratory and statistical analysis. The editorial assistance of Prof E.O. Lucas of Department of Agronomy, Faculty of Agriculture and Forestry is highly appreciated.

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