GREEN EAR YIELD POTENTIAL OF TROPICAL FIELD MAIZE AT TWO LEVELS OF NITROGEN FERTILISER APPLICATION IN IBADAN, NIGERIA

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Abstract

Green maize plays a significant role in the social and economic life of the peoples of the humid forest and derived savannah agro-ecologies of West and Central Africa. Appropriate strategies for its production would contribute significantly to sustainable agriculture. Fourteen tropical field maize genotypes, consisting of hybrids and open pollinated varieties (OPVs), were evaluated in field trials for green ear yield at two levels (30 and 60 kg ha^{-1}) of nitrogen fertilizer application during the main cropping seasons of 2012 and 2013. A factorial in a split plot design with three replications was used. Fertilizer levels were main plots and maize genotypes subplots. Highly significant genotype, N level and genotype × N level effects were observed for all traits considered. The range in yield of marketable cobs at 30 kg N ha^{-1} and 60 kg N ha^{-1} were 98.4% and 108.6% of the respective means. The number and yield of ears, yield of cobs and number and yield of marketable cobs were significantly reduced at 30 kg N ha^{-1}. The percentage reduction in yield of marketable cobs was 55.9%. Yield of marketable cobs and other measured green ear yield variables at 30 kg N ha^{-1} for OPVs were significantly higher than for the hybrids, while the differences were not signaficant at 60 kg N ha^{-1}. Suwan-1 STR produced the highest number and yield of marketable cobs per hectare both at 60 kg N ha^{-1} and across N levels. At 30 kg N ha^{-1}, the top yielding genotypes were ACR97 TZL COMP1 C2 (2.82 t ha^{-1}), TZE COMP3 C2 (2.71 t ha^{-1}) and 9044-27 STR (2.51 t ha^{-1}), while the best three genotypes at 60 kg N ha^{-1} were Suwan-1 (6.56 t ha^{-1}), AK96DMR-L-SR-W (5.91 t ha^{-1}) and 9144-4 (5.28 t ha^{-1}). Yield of marketable cobs in this study at 30 and 60 kg N ha^{-1} was 46.5 and 49.1% of the yield of ears ha^{-1}, respectively. Genetic variation for green ear yield was present among the maize genotypes studied and this was greatly influenced by the level of N fertiliser application.

Keywords: Green maize, Maize genotypes, N levels, *Zea mays* L.

Introduction

Maize (*Zea mays* L) is a cereal crop adapted to the agro-ecological zones with mono-modal rainfall distribution and 120 – 180 days growing period (Carsky and Iwuafor, 1999). It is one of the major crops in West and Central Africa where it provides up to 70% of the daily calorie intake (Martin *et al*., 2000; FAO, 2007) and a source of income for small-holder farmers (Smith *et al*., 1997; Fakorede *et al*., 2003). In Nigeria, maize is a major important cereal cultivated in the rainforest and the derived savannah zones (Iken and Amusa, 2004). Nigeria's annual grain maize production in 2012 was estimated at about 9.41 million tonnes from a land area of about 5.2 million hectares, with per hectare yield of 1.81 tonnes (FAO, 2013). A substantial fraction of the maize grown in Nigeria with early rains, particularly in the humid high rainfall agro-ecological zones of the south, is harvested and sold fresh as green maize. Green maize is maize harvested about 20 to 22 days after silking, when the grains in the ears are milky, with a moisture content of 70 to 80%. At this stage, the sugar content, succulence and tenderness of the kernel was highest (Osayintola *et al*., 1992). In this form, it is consumed in different

forms, roasted, boiled or steamed fresh on the cob for consumption or used in the preparation of typical local dishes and delicacies. This diversity of use has enhanced the popularity of green maize.

According to FAO statistics (FAO, 2013), average production of green maize in Nigeria in 2012 was 765,000 tonnes from a land area of 200,000 hectares. Most of this production comes from fadamas and the rainforest agroecology where the rainy season commences early and humidity too high for drying of grain. As other fresh staples are not readily available during this period, it is able to attract premium prices, leading to high profitability (Alimi and Alofe, 1993; Silva *et al*., 2006).

Although green maize is a major component of the diet of the peoples of Nigeria and other countries of West and Central Africa, only few attempts had been made to evaluate available field maize cultivars for their green ear yield in Nigeria. For example, in a study in which twelve maize cultivars were evaluated under three levels of nitrogen fertiliser application at two locations in south-western Nigeria, Kim *et al.* (2007) reported a mean yield of 5.51 t ha^{-1} marketable cobs at 60 kg N ha^{-1}.
Elsewhere, Silva *et al*. (2005), working in Brazil, evaluated three field maize cultivars for green ear yield after cowpea incorporation. They reported a mean yield of marketable husked ear of 7.35 t ha^{-1}. The N fertilizer recommendation for the forest and derived savannah agro-ecologies of Nigeria for maize production is 60 kg N ha^{-1} (Akintunde *et al*., 1993). Giving that green maize is harvested 34 to 43 days (depending on maturity) before physiological maturity, the possibility of a reduction in the quantity of applied fertiliser N would not only enhance farmer's income but also be beneficial to the environment. Several genotypes, hybrids and open pollinated varieties (OPVs), are available to farmers for the production of grain maize. These same cultivars, though not specifically developed for direct human consumption as green maize (Ogunbodede, 1999), are used for the production of fresh green maize. This study was therefore conducted to (i) assess the green ear yield potential of 14 tropical normal endosperm field maize genotypes and (ii) determine the effects of N fertiliser application on the green ear yield of the genotypes.

Materials and Methods.

Field experiments were conducted at the Teaching and Research Farm of the University of Ibadan, in Ibadan, Nigeria (7°26' N, 3°54' E), during the main cropping seasons of the 2012 and 2013. The field was manually cleared. Soil samples were collected and analysed for chemical and physical properties.
Selected chemical and physical properties of the field prior to land preparation in each cropping season, as well as precipitation and atmospheric temperature during the growing seasons at the location are presented in Table 1. Fourteen normal endosperm tropical field maize genotypes, comprising of eight single cross hybrids and six OPVs, developed by the International Institute of Tropical Agriculture (IITA), Ibadan, were used for the study. Treatments consisted of the factorial combination of the 14 maize genotypes and two fertiliser application levels (30 and 60 kg N ha^{-1}) arranged in a split plot design with three replications.
Nitrogen levels were assigned to the main plots while the maize genotypes were assigned to the subplots. The subplot units consisted of 2-row plots

that were 5.0 m long spaced 0.75 m between rows and 0.25 m within rows. Planting was done on ridges. Two seeds were planted per hill and later thinned to one to give a plant population density of approximately 53,333 plants per hectare. The fertiliser treatments were hand applied in two equal split doses at two weeks after planting using NPK 15-15-15 and five weeks after planting using urea. Plots were kept weed free with herbicide application complemented with hand weeding.

Harvesting for green ear yield was carried out 23 days after mid-silking. Data collected for green ear yield included: number of ears (fresh ears with husk), yield of ears, yield of cobs (husked fresh ears), number of marketable cobs (cobs with at least 250 filled kernels), and yield of marketable cobs. Data were subjected to analysis of variance using the proc. GLM procedures in SAS (SAS Institute Inc., 2003). Analyses were performed for each N level and later for the N levels combined. A mixed model was assumed for the experiment with

Table 1: Selected chemical and physical properties of the soil prior to land preparation and precipitation and temperature at the experimental site

	Soil test value	
Parameter	2012	2013
pH (1:1 H_2O)	6.0	6.1
Organic C (g kg^{-1})	8.1	8.0
Total N (g kg^{-1})	1.02	0.98
Available P (Bray-1)(mg kg^{-1})	20.32	14.79
K (cmol kg^{-1})	0.23	0.25
Exchangeable acidity (cmol kg^{-1})	0.13	0.12
Exchangeable CEC (cmol kg^{-1})	5.32	5.25
Mechanical analysis		
Sand (g kg^{-1})	830	712
Silt (g kg^{-1})	70	134
Clay (g kg^{-1})	100	154
Textural class (USDA)	Sandy-loam	Sandy-loam
Total precipitation (mm) (March – July)		
2012	833.2	
2013	779.6	
Minimum temperature (°C) (March – July)		
2012	22.7	
2013	23.9	
Maximum temperature (°C) (March – July)		
2012	31.4	
2013	31.3	

genotype and N level fixed and replication and its interaction with N level random. Since the effects of years and its interaction with genotype and N level were not significant, data was pooled for years to allow a better visualization of the effect of N. Means were separated using Least Significant Difference (LSD) at p = 0.05. Comparison between hybrids and OPVs was done using a one degree of freedom orthogonal contrast.

Results and Discussion

There were highly significant (p = 0.01) variation among the genotypes for the main effects (genotype, N level and genotype × N level interaction) for all the variables measured (Table 2). For each N level, significant variation was found among the genotypes for all the variables measured (Table 2). This indicates that the maize genotypes responded differently to N fertilizer, consistent with results reported earlier on grain yield for tropical maize (Agrama *et al*., 1999; Worku *et al*., 2007; Abe *et al*., 2013) which revealed significant genotype × N level interaction. It is however instructive to note that while green maize is harvested at the milk stage (Kling, 1996), grain maize is harvested after physiological maturity.

The range in yield of marketable cobs at 60 kg N ha^{-1} from the lowest value (1.89 t ha^{-1}) to the highest value (6.56 t ha^{-1}) was 108.6% of the yield of marketable cobs. Similarly, at 30 kg N ha^{-1}, the range from the lowest value (0.93 t ha^{-1}) to the highest value (2.82 t ha^{-1}) was 98.4% of the yield of marketable cobs (Table 2).

Percentage decrease in yield of marketable cobs observed by reducing the level of fertilizer application from 60 to 30 kg N ha^{-1} ranged from 20.0% to 82.3% among the genotypes. Across genotypes, the reduction observed was 55.9% (Table 3). This is in agreement with the results reported by Kim *et al.* (2007) of a 52% reduction in yield of marketable ears due to N stress. Bänziger *et al.* (1999) and Abe *et al.* (2013) reported that low N accounts for more than 40% yield reduction in maize. The significantly higher genotypic yields of marketable cobs at 60 kg N ha^{-1} over 30 kg N ha^{-1} is in line with previous reports (Worku *et al*., 2007; Abe *et al*., 2013) for grain yield and (Kim *et al*., 2007; Freire *et al*., 2010) for green ear yield in maize.

This is explained by the enhanced leaf area development and increase in the leaf's photosynthetic activity with nitrogen application (Sallah, *et al*., 1998) which is associated with an increase in number of ears per plant as the level of N increases (Kamprath *et al*., 1982). The significant reduction in number and yield of marketable cobs at 30 kg N ha^{-1} could also be as a result of the asynchrony in flowering observed in the genotypes. Carcovas and Otegui (2001) reported that

Table 2: Means of green ear yield and its components averaged across two years of 14 tropical field maize genotypes at two levels of nitrogen fertiliser application across two years in Ibadan, southwest Nigeria

Genotype	Number of ears per hectare ($\times 10^2$)		Yield of ears (t ha^{-1})		Yield of cobs (t ha^{-1})		Number of marketable cobs per hectare ($\times 10^2$)		Yield of marketable cobs (t ha^{-1})	
	30 kg N ha^{-1}	60 kg N ha^{-1}	30 kg N ha^{-1}	60 kg N ha^{-1}	30 kg N ha^{-1}	60 kg N ha^{-1}	30 kg N ha^{-1}	60 kg N ha^{-1}	30 kg N ha^{-1}	60 kg N ha^{-1}
Hybrids										
9021-18	269.35	407.40	4.89	8.95	2.91	5.56	104.22	282.88	2.03	4.74
8644-31	270.70	460.19	4.37	8.73	2.84	5.55	121.82	333.86	2.07	4.20
9144-4	216.55	490.13	3.56	10.15	1.26	6.16	108.28	324.84	1.66	5.28
9143-20	234.15	433.12	4.32	9.54	2.84	5.08	117.76	324.84	2.14	4.74
9044-27 STR	314.01	485.90	4.83	9.35	3.19	6.02	143.13	289.65	2.51	4.29
8338-1	250.39	243.63	3.65	5.59	2.34	2.77	101.51	121.82	1.52	1.89
9022-13 STR	162.42	297.77	2.17	5.96	1.62	3.72	67.67	121.82	1.08	2.23
8425-8 STR	175.96	458.83	1.69	10.22	1.45	6.97	60.88	307.24	0.93	5.22
Open Pollinated Varieties (OPVs)										
AK96 DMR-L-SR-W	235.51	496.73	4.56	10.41	2.91	6.86	138.06	337.02	2.14	5.91
ACR97 TZL COMP4 C2	208.44	365.44	3.27	6.90	1.95	4.20	69.03	203.03	1.18	3.39
BR9943 DMRSR	250.40	485.90	3.76	11.17	2.50	6.47	125.87	349.20	1.75	4.68
TZE COMP3 C2	324.84	422.80	5.96	7.48	3.72	5.02	189.49	211.23	2.71	3.43
ACR97 TZL COMP1 C1	378.13	433.12	5.96	8.80	4.13	5.48	175.96	284.23	2.82	4.40
ACR91 SUWAN1-SRC1	297.09	446.65	4.87	10.83	3.45	7.17	154.30	378.97	2.31	6.56
Mean	256.28	423.40	4.13	8.86	2.65	5.50	119.85	276.47	1.92	4.35
CV (%)	11.9	11.6	12.5	14.3	13.1	15.7	16.9	19.6	16.2	21.4
LSD (0.05)	35.34	55.75	0.60	1.45	0.40	0.99	23.49	61.86	0.36	1.07
Genotype × N level	***		***		***		***		***	
	Probability > *F*									
Contrast: *Hybrids versus OPVs*	0.0008	0.4196	0.0002	0.3909	< 0.0001	0.1842	< 0.0001	0.2900	0.0033	0.1245

***: significant at 0.001 probability levels

Table 3: Effects of nitrogen fertiliser on green ear yield and its components of 14 tropical field maize genotypes at two levels of nitrogen fertiliserapplication across two years in Ibadan, southwest Nigeria

Traits	Nitrogen level				LSD	%
	30 kg N ha^{-1}		60 kg N ha^{-1}		(0.05)	reduction
	mean	se	mean	se		
Number of ears per hectare ($\times 10^2$)	256.28	6.80	423.40	9.59	11.13	39.5
Yield of ears (t ha^{-1})	4.13	0.14	8.86	0.24	0.26	53.4
Yield of cobs (t ha^{-1})	2.65	0.10	5.50	0.16	0.17	51.2
number of marketable cobs per hectare ($\times 10^2$)	119.86	4.56	276.47	10.29	10.99	56.6
Yield of marketable cobs (t ha^{-1})	1.92	0.07	4.35	0.17	0.19	55.9

asynchrony of flowering can limit grain production per ear due to lack of pollen, loss of silk receptivity or early kernel abortion. N stress has also been shown to result in barrenness in maize. At both N levels, number of ears per plant was less than one, consistent with previous findings (Abe *et al.,* 2013). The yield of marketable cobs obtained in this study represented 46.5 and 49.1% of the yield of ears, as well as 72.5 and 79.1% of the yield of cobs at 30 and 60 kg N ha^{-1} respectively.

In this study, orthogonal comparison revealed significant differences between the hybrids and the OPVs for all green ear yield traits at 30 kg N ha^{-1} with the OPVs being superior to hybrids (Table 2). At 60 kg N ha^{-1} however, differences between hybrids and OPVs were not significant. This finding which is suggestive of a better performance of OPVs under suboptimal N fertiliser application could be one of the reasons for the preference of OPVs over hybrids by smallholder farmers. Although maize hybrids are known to require high doses of fertiliser for optimum yields (Gardner *et al.*, 1990; Killorn and Zourarakis, 1992), fertilizer use by smallholder farmers in Africa is known to be very low, an average of 8 kg ha^{-1} (Heisey *et al.*, 2007). The result of this study contradicts earlier report (Kim *et al.*, 2007) of superior green ear yield of hybrids over OPVs even at suboptimal N levels. These contradictory results could be a consequence of differences in the N-use efficiency of the genotypes included in the two studies.

The genotype ACR91 SUWAN-1 SR C1 had the highest yield of marketable cobs of 6.56 t ha^{-1} at 60 kg N ha^{-1}, while genotype 8338-1 had the lowest at the same level of fertiliser application. At 30 kg N ha^{-1}, genotype ACR97 TZL COMP1-C1 recorded the highest yield of marketable cobs of 2.82 t ha^{-1} while genotype 8425-8 STR had the least (0.93 t ha^{-1}). Only four genotypes (two open pollinated varieties and two hybrids) had yield of marketable cobs greater than 5.00 t ha^{-1} at 60 kg N ha^{-1}. On the other hand, three genotypes (one hybrid and two open pollinated varieties) which did not include the top yielding ones at 60 kg N ha^{-1} had yields of marketable cobs greater than 2.50 t ha^{-1} at 30 kg N ha^{-1}.

This result suggests that the field maize genotypes included in this study differ in both their green ear yield potential and in their linear response to nitrogen fertiliser application.

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