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Yield Performance of Popcorn (*Zea mays* L. *everta*) under Lime and Nitrogen Fertilization on an Acid Soil

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Abstract

A two-year field experiment was carried out on the acidic coastal plain sands of South Eastern Nigeria during the year 2009 and 2010 planting seasons to study the effect of lime levels (L = 0, 500 and 1000 kg ha^{-1}) and nitrogen rates (N = 0, 40, 80 and 120 kg ha^{-1}) on -popcorn varieties (Yellow composite and Ashland). Results showed that N application resulted in significantly (p=0.05) higher grain yield at 80kg N ha^{-1} in 2010 than that obtained at 120 kg Nha^{-1} in 2009. Yield in 2010 outstripped yield in 2009 by 23.65%. Results also showed that lime at 500 kg ha^{-1} gave the highest popcorn yields in 2010, a yield increase of 18.03 % above control, whereas there was no yield response to lime in 2009. Based on the results obtained, it can be concluded that popcorn sown at 80 kg N ha^{-1} and 500 kg ha^{-1} rates of lime significantly increased the crop productivity compared to those sown at other N and lime rates. The study demonstrated the effect of lime amendment in reducing rates of inorganic N applied to popcorn especially with resource poor farmers who form the bulk of maize producers in Nigeria.

Keywords: popcorn, nitrogen, Lime, agronomic efficiency, acid soil

1. Introduction

Corn shows large responses to nitrogen (N) fertilizer application, depending on weather, soil characteristics, water supply, crop uniformity and the nutrient responses of the cultivated varieties (Nagy, 1997). However, concerns about N pollution of the environment, such as leaching of nitrates into ground water, nitrous oxide emission into the atmosphere and other forms of environmental degradation have stimulated interest in low-input strategies for N fertilization (Weisler et al., 2001; Sheng-wei et al., 2009). Nitrogen is vital for most plant metabolic activities and plays an important role in tillering, stalk elongation and photosynthesis (Koochekzadeh et al., 2009). Its deficiency results in leaf area reduction which causes decreased photosynthesis which in turn leads to suppression of yields and crop quality (Sreewarome et al., 2007).

Soil acidity is a major limitation to crop production in the humid tropics, which necessitates the use of liming for corrective purposes and amelioration of acidity. Soil acidity affects soil property and crop performance, causes deficiency of soil nutrients, depresses microbial growth and suppression of organic matter accumulation (Brady & Weil, 1999). The possibility of increasing yields through judicious fertilization and liming has been reported by several workers (Caires et al., 2007; Mullen et al., 2007; Hassan et al., 2007; Eze and Obi, 2008). Liming improves growth conditions for plants by increasing soil pH, availability of phosphorus and basic cations, resulting in increased nutrient uptake by plants (Brady & Weil, 1996; Halder et al., 2003). Eze and Obi (2008) obtained the highest pocorn yield of 1.58 t ha^{-1} at 0.5 t ha^{-1} lime rate while Hassan et al., 2007 recorded the highest yields of popcorn 4.32 t ha^{-1} with 0.25 t ha^{-1} lime rate. Oluwatoyinbo et al. (2005) obtained the highest fruit yield of okra 3.0 t ha^{-1} at 500 kg ha^{-1} lime.

Generally, yield response of corn grown on low fertility soils increases with increment in nitrogen uptake until yield is maximized, whereupon it decreases or becomes unresponsive to additional fertilizer rate increases (Nagy, 1997; Gokmen et al., 1999; Vasanthi & Kumaraswamy, 2000). In other words, yield response to larger N supply is positive until factors other than nitrogen limit higher yield. The positive response could be due to either a large amount of radiation intercepted over the crop growth period or higher average daily rate of photosynthesis (Vos et al., 2005), photo-assimilation (Melchiori & Caviglia, 2008) and nutrient partitioning (Sierra et al., 2006).

Corn grain yield is a product of yield components such as number of plants per unit area, number of ears per plant, number of kernels per ear, kernel weight, total dry matter and 1000-grain weight. Increasing the N rates increases the number of cobs per ear, number of grains per ear and other parameters associated with yield (Onasanya et al., 2009; Orosz et al., 2009; Akmal et al., 2010).

Hamid and Nasab (2001) observed that both economic and biological yield, are positively correlated with vegetative and reproductive phase duration in maize. Leaf area influences interception and utilization of solar radiation by crop canopies, and consequently dry matter accumulation as well as economic yield. Valentinuz and Tollenaar (2006) reported that leaf area and yield increased with higher rates of N. According to Pandey et al. (2008), maize cultivars differ in their ability to maintain leaf area index (LAI), crop growth rate (CGR) and above ground dry matter biomass at different levels of water deficit and N supply (Dahmardeh, 2011).

Our objective was to assess the effects of nitrogen and efficacy of lime on the yield performance of two varieties of popcorn on an acid soil in south eastern rainforest agro-ecology of Nigeria.

2. Materials and Methods

2.1 Experiments, Crops and Management

Field experiments were conducted for two years at the Teaching and Research Farm of the University of Calabar in the south eastern rainforest zone of Nigeria (4.5^0 -5.2^0 N,8.0 – 8.3^0 E, 39m altitude) during the years 2009 and 2010 growing seasons.A different site was used each year of the experiment. The soil was an *Ultisol* under no till since 2002, organic matter contents were 1.0 and 3.18, total N 0.07 and 0.14 (g kg^{-1}) for plots in years 1 and 2 respectively, while P was 106.6 and 279.29(mg kg^{-1}). Previous crops were cocoyam and alley cropped cooking bananas in year 1 and 2 respectively. Treatments were laid out in a split-plot design with three replications and included a factorial combination of three factors- varieties (V1= Yellow composite and V2= Ashland), four nitrogen rates (0, 40, 80 and 120 kg ha^{-1}) and three rates of lime (0, 500 and 1000 kg ha^{-1}). The hybrid elite popcorn varieties- Yellow composite and Ashland were sown at a plant spacing of 0.75m x 0.25m, all the lime rates were soil incorporated one week before planting. Half of the nitrogen as urea (46% N), alongside basal single superphosphate (26 kg P ha^{-1}) and muriate of potash (50 kg K ha^{-1}) were ring applied by hand one week after emergence. The second half of N was side-dressed 6 weeks after sowing, at about 8 -10cm depth and a distance of 10cm away from the plants.

Relevant results of soil physico-chemical analyses and meteorological conditions of the experimental location during the seasons are presented in Tables 1 and 2 respectively. Crops were rain fed, therefore received varying amounts of water in the different years of the study. Sites were manually cleared, tilled and leveled to a fine tilled flat, before sowing on 18th April and 14th May for the 2009 and 2010 planting seasons respectively. Three seeds were sown per stand and the seedlings were later thinned to one per stand one week after sowing, giving a plant population of 53,333 plants per hectare at 0.75 m inter rows and 0.25 m intra-row spacing through out the experiment. Experiments were kept free of diseases and pests, while weeding was done by manual hand hoeing at 4 and 8 weeks after sowing (WAS). The ears were harvested on 4th July and 21st August in 2009 and 2010 seasons respectively and sun dried until 4 months later when the seeds attained more than 80% popping percentage.

Table 1. Mean monthly rainfall, average temperature, Humidity and photo-synthetically active radiation during the two experimental seasons

	Rainfall (mm)		Average Temp (^{0}C)		Humidity (%)		Sunshine (Hrs)	
	2009	2010	2009	2010	2009	2010	2009	2010
April	150.5	130.4	32.1	33.1	84	83	3.0	5.2
May	308.9	306.5	31.6	31.5	84	85	4.4	4.4
June	218.4	611.3	30.2	29.8	87	88	2.2	3.2
July	507.3	384.0	28.0	28.8	92	90	1.7	2.0
August	507.3	406.7	28.1	28.2	92	91	1.0	1.8

Source: Nigerian Meteorological Unit, Margaret Ekpo International Airport, Calabar.

Table 2. Physical and chemical properties of the soil from 0-20cm at the experimental sites during 2009 and 2010 planting seasons

	Year	
Physical Composition	2009	2010
Particle size analysis (g kg^{-1})		
Sand	772	801.3
Silt	119	96.5
Clay	109	102.2
Soil textural class	Sandy loam	Sandy loam
Chemical composition		
pH	5.30	5.25
Organic matter (g kg^{-1})	1.00	3.18
Total Nitrogen (g kg^{-1})	0.07	0.14
Available P (mg kg^{-1})	106.5	279.29
Na (cmolkg^{-1})	0.29	0.09
K "	0.14	0.12
Ca "	1.33	1.69
Mg "	0.23	0.66
ECEC "	4.80	3.06
Base Saturation (g kg^{-1})	50.41	52.56
Exchangeable Acidity	0.06	0.06

2.2 Measurements and Analysis of Data

For the collection of data, ten plants were randomly tagged two weeks after planting within the plots and the following parameters were measured;

Plant height: this was measured with a meter tape from the ground level to the collar of the tallest fully differentiated plants or the tips of tassels at last sampling and recorded in centimetres.

Leaf area index: This was computed by dividing the total area of leaves by the total ground area covered by the plant.

Number of days to 50% tasselling: By counting the number of days from sowing till half of the total number of plants per plot attained tasselling.

Total dry matter (g): This was determined by harvesting above ground portion of a plant in each plot every two weeks and oven drying to constant weight at 70^0C and the weights recorded.

Weight of ears per plant (g): Corn ears from plants in the net plot were weighed and averaged to represent mean ear weight per plant and recorded in grammes.

Number of kernels per ear: The number of ears on plants within the subplot were counted and the average taken as number of ears per plant.

Total grain yield: This was determined by oven drying the threshed seeds from each yield sample to a constant weight at 70^0C, weighing the sample and expressing the grain yield in t ha^{-1}.

Pooled yield of both seasons (t ha^{-1}) was calculated as the average yield in both years.

Agronomic efficiency of nitrogen was estimated by finding the yield difference in fertilized and unfertilized plots and dividing by the quantity of fertilizer nutrient applied.

All the data collected were subjected to analysis of variance using SAS version 9. ANOVA was carried out on the effects of nitrogen, lime, variety and their interactions on variables measured and mean separation was done using Student Newman Kuel's test ($P < 0.05$).

3. Results

3.1 Plant Height, Leaf Area Index and Number of Days to 50 Percent Tasselling

Increase in the rates of N from 0 – 120 kg N ha^{-1} significantly increased plant height and leaf area index (LAI) up to 120 kg N ha^{-1} in 2009 but not beyond 80 kg N ha^{-1} in 2010. Lower N rates resulted in significantly longer number of days to 50% tasselling in both seasons (Table 3). There was no significant difference in plant height at 0 and 1000 kg ha^{-1} lime rates in 2009, but at 500 kg ha^{-1} in the second season, lime application resulted in significantly taller plants. Statistically similar LAI was observed at 500 and 1000 kg ha^{-1} lime rates in 2009, while LAI was not significant in 2010. Similarly, the number of days to 50% tasselling was not significant in both seasons. The variety effect on plant height and LAI was non significant in the first season. In the second season however, Yellow Composite had significantly taller plants and higher leaf area index than Ashland variety (Table 3). In the second season also, Yellow composite took significantly longer number of days to attain fifty percent tasselling than Ashland, compared to 2009 when there was no significant effect of variety.

Table 3. Plant height, leaf area index and number of days to 50% tasselling

Treatment	Plant height (cm)		Leaf area index		Days to 50% tasselling	
N (kg N ha^{-1})	2009	2010	2009	2010	2009	2010
0	173.45c	182.81d	1.82d	2.18d	9.66a	51.39a
40	199.31b	217.30c	3.06c	3.10c	8.33b	48.72b
80	203.04b	257.01a	4.78a	4.21a	7.16c	46.11c
120	220.57a	233.92b	4.78a	3.95b	6.50d	44.61d
SE±	4.087	3.984	0.071	0.063	0.372	0.401
Lime (Kg ha^{1})						
0	202.64a	208.39c	3.17b	3.10a	7.95a	47.21a
500	189.80b	231.28a	3.71a	3.49a	7.58a	47.08a
1000	204.84a	228.61b	3.51a	3.49a	8.20a	48.88a
SE±	3.543	3.450	0.061	0.055	0.144	0.347
Variety						
Yellow Composite	200.91a	225.88a	3.35a	3.40a	7.91a	48.06a
Ashland	197.28a	219.64a	3.35a	3.32b	7.91a	47.36b
SE±	3.147	1.959	0.044	0.023	.228	0.136

Means followed by the same letter(s) within a column are not significantly different at 5 percent level using SNK.

3.2 Total Dry Matter, Weight of Ears per Plant and Number of Kernels per Ear

Increase in nitrogen rates significantly increased TDM from 0 up to 120 kg N ha^{-1} in 2009 and not beyond 80 kg N ha^{-1} in 2010 by 59.80 % and 77.73 % respectively. Weight of ears per plant was statistically similar at 40-120 kg N ha^{-1} and higher than control in 2009, and significantly higher at 80 kg N ha^{-1} in 2010 (Table 4). Increasing rates of N significantly increased the number of kernels per ear up to 80 kg N ha^{-1} beyond which it decreased in both seasons.

Table 4. Total dry matter, weight of ears per plant, number of kernels per ear

Treatment	Total dry matter (g)		Weight of ears per plant (g)		No. of kernels per ear	
N (kg N ha^{-1})	2009	2010	2009	2010	2009	2010
0	120.67d	120.35d	67.25b	59.19d	256.64d	250.05d
40	142.11c	159.82c	75.05a	70.63c	377.12c	362.35c
80	158.01b	213.90a	75.50a	75.58a	450.06a	451.07a
120	192.83a	199.89b	78.05a	74.06b	410.46b	391.97b
SE±	3.422	7.015	3.742	1.363	11.483	14.841
Lime (Kg ha^{1})						
0	159.23a	154.86c	75.00a	66.09c	343.05b	328.90c
500	151.65b	171.08b	78.33a	73.96a	397.25a	392.74a
1000	149.33c	194.54a	75.25a	69.55b	384.91a	369.99b
SE±	2.963	6.075	3.241	1.181	9.945	12.853
Variety						
Yellow Composite	149.33a	179.85a	78.07a	70.52a	379.90a	367.25a
Ashland	157.48a	167.13b	78.35a	69.21a	370.24a	360.49a
SE±	0.825	4.958	1.712	0.085	9.432	11.064

Means followed by the same letter(s) within a column are not significantly different at 5 percent level using SNK.

There was no significant increase in total dry matter (TDM) due to application of lime in 2009, whereas in 2010, TDM increased with increase in lime rates up to 1000 kg ha^{-1}. The effect of N on the weight of ears per plant was not significant in 2009. In the second season however as well as in both seasons, the weight of ears per plant and number of kernels per ear respectively were significantly higher at 80 kg N ha^{-1} than at all other rates of N. Except for TDM in 2010, when Yellow Composite had significantly higher TDM than Ashland, there was no significant effect of variety among all the parameters measured (Table 4).

3.3 Total Grain Yield, Combined Yield Analysis (t ha^{-1}) and Agronomic Efficiency of N

The total grain yield significantly increased with increasing N rates in 2009 up to 120 kg N ha^{-1} but not beyond 80 kg N ha^{-1} in 2010. At 40, 80 and 120 kg N ha^{-1}, nitrogen gave a yield increase of 12.6, 21.5, 50.4% as well as 29.6, 76.8 and 53.2% above control in both seasons respectively. The pooled data showed that grain yield increased significantly up to 120 kg N ha^{-1} (Table 5). Although the 80 and 120 kg N ha^{-1} rates were statistically similar, 120 kg N ha^{-1} gave a yield increase of 52.17% above control. The agronomic use efficiency of N was significantly higher at 40 kg N ha^{-1} in 2009 and at 80 kg N ha^{-1} in 2010.

Table 5. Effect of nitrogen, lime and variety on total grain yield, combined yield analysis (t ha^{-1}) and agronomic efficiency of N in 2009 and 2010

Treatment	Total grain yield (t ha^{-1})		Combined yield (tha^{-1})	Agronomic Use efficiency of N	
Nitrogen (kg N ha^{-1})	**2009**	**2010**		**2009**	**2010**
0	1.35c	1.42d	1.38c	0.00b	0.00c
40	1.52b	1.84c	1.68b	7.11a	12.85a
80	1.64b	2.51a	2.07a	4.38a	14.29a
120	2.03a	2.18b	2.10a	6.0a	6.86b
SE±	0.074	0.104	0.141	1.365	1.815
Lime (Kg ha^{-1})					
0	1.86a	1.83b	1.85a	2.14b	6.40b
500	1.49b	2.16a	1.82a	6.29a	12.14a
1000	1.55b	1.98b	1.77a	4.68ab	6.96b
SE±	0.064	0.090	0.122	1.182	1.572
Variety					
Yellow Composite	1.62a	2.03a	1.83a	3.72a	9.33a
Ashland	1.65a	1.95a	1.80a	5.02a	7.67a
SE±	0.053	0.080	0.066	1.312	0.742

Means followed by the same letter(s) within a column are not significantly different at 5 percent level using SNK.

Grain yield decreased significantly with increase in lime rates in 2009, but increased significantly at 500 kg ha^{-1} more than other lime rates in 2010. The mean differences for pooled grain yield indicated non significant lime effect. The agronomic use efficiency of N was significantly higher at 500 kg ha^{-1} of lime in both seasons (Table 5).

4. Discussion

The results obtained from this study showed that different application rates of nitrogen and lime significantly improved grain yield and performance of popcorn. Growth was mostly supported by the application of Nitrogen at 120 kg N ha^{-1} and 80 kg N ha^{-1} in 2009 and 2010 respectively. This was evident in the plant height, and total dry matter. The above mentioned parameters tended to increase up to 120 kg N ha^{-1} in 2009 and not beyond 80 kg N ha^{-1} in 2010. This can be attributed to the fact that nitrogen promoted vegetative growth in maize (Paradker & Sharma, 1996; Dahmardeh, 2011). LAI was also affected by the rates of nitrogen application. There was increase in LAI until the plants achieved maximum attainment at 80 kg N ha^{-1}, at which point it ceased to increase. This is in agreement with the findings of Cox et al., (1993) that higher rates of nitrogen promote leaf area during vegetative development and also maintain functional leaf area during the growth period. Nitrogen is essential for the establishment of the photosynthetic structure for efficient light interception and increased photosynthesis. Mulebo et al. (1983) achieved maximum LAI of 4.4 with tropical maize, whereas in this study the highest LAI was 4.78 at 80 – 120 kg N ha $^{-1}$ rates (Table 3).

Yield components such as weight of ears per plant and number of grains per ear were significantly increased by application of N up to 80 kg ha^{-1}. Total grain yield was significantly (p=0.05) increased by N at 120 kg ha^{-1} in 2009 but not beyond 80 kg ha^{-1} in 2010. All the treatments had significant improvement over control, signifying the importance of fertilization in maize production. The favourable response also confirmed the essentiality of N in plant growth and development (Brady & Weil, 1996; Mengel & Kirkby, 2001). The positive increase in yield components demonstrates that N increased assimilates supply for component development and yield set (Akmal et al., 2010). According to Lizaso et al. (2003) and Melchiori and Caviglia (2005), positive increase in yield has been linked to kernel weight development during the grain filling stage, when moisture is not limiting. Total rainfall in 2009 was higher than that recorded in 2010 especially during the last two months which coincided with the grain filling stage and maturity period of the crop (Table 2). This could be the reason for the yield differences observed between the two seasons.The 120 kg N ha^{-1} rate gave a yield increase of 23.78% over the 80 kg N ha^{-1} rate, and a further increase of 50.37% above the control in 2009. On the other hand, the 80 kg N ha^{-1} rate increased yield by 15.14% in 2010 over the 120 kg N ha^{-1} rate and a further increase of 76.76% over the control. The relationship among the treatments was of the order 120 > 80 > 40 > 0 and 80 > 120 > 40 > 0 in seasons 1 and 2, respectively. The pooled yield however showed that the 80 and 120 kg N ha^{-1} were statistically at par (p=0.05), but significantly higher than other rates.

Considering the agronomic use efficiency (AUE) of N, in 2010, the order of relationship was of the magnitude 80 > 40 >120 kg N ha^{-1} which explained that there was greater gain from the N applied than in 2009 with a relationship order of 40 > 120 > 80 kg N ha^{-1}. At the 80 kg N ha^{-1}, grain yield in 2010 was 150% higher than that recorded in 2009, indicating that there was better utilization of N which coincided with maximum yields obtained.This observation is in agreement with reports by Abbas et al. (2003) and Akmal et al. (2010). The situation in 2010 was ideal for crop production, giving maximum yield increase for fertilizer inputs, and was more desirable because of its potential for cleaner production and higher yields at the same time. This is so because farmers will not sacrifice crop yields for higher agronomic efficiency level that is not commensurate with yield as was observed in 2009 (Table 5).The difference in N consumption in the two seasons could be due to native N as well as prevailing climatic conditions in the two seasons. Agronomic efficiency of N was significantly higher at 80 kg N ha^{-1} which corresponded with the highest yield recorded in 2010.

The significant effect (p=0.05) of lime on plant height, leaf area index (Table 3) and total dry matter (Table 4) could be attributed to the positive influence of liming in soil acidity neutralization. Such positive effect according to Halder et al. (2003), results in increased uptake of nutrient elements by the plants. This increased uptake and an enhanced leaf canopy obviously strengthened the plants photosynthetic structure, thus increasing assimilate production and total dry matter accumulation. These findings are in consonance with those of Oluwatoyinbo et al. (2003), and Akmal et al. (2010).

Lime at 500 kg ha^{-1} rate also significantly (p=0.05) increased the weight of ears per plant by 11.98% in 2010, and number of kernels per ear by 15.8 and 19.41% compared to their respective controls in both seasons (Table 5). This increase resulted from partitioning and storage of increased assimilates produced as a result of the effective photosynthetic structure created due to the improvement in the plants physical structure. This is in agreement with Abbas et al. (2003), Oluwatoyinbo et al. (2003), Vos et al. (2005), Sierra et al. (2006) and Melchiori and Caviglia (2008).

In 2010, application of lime at 500 and 1000 kg ha^{-1} rates increased the grain yield by 18.03 and 9.09% respectively above the control (Table 5). In spite of the favourable effects of lime in improving soil physico-chemical properties, the total dry matter and grain yield in 2009 did not respond positively to application of lime compared to 2010. The poor yield response to lime is attributable to the low organic matter and low inherent fertility status of the experimental plots in 2009 compared to 2010 (Table 1), a situation which may have increased the crops demand for N. With the depression of biological activity and suppression of organic matter accumulation, plants performance in 2009 was lower than in 2010. This is in agreement with Brady and Weil (1996). Very low organic matter status and low soil fertility levels in 2009 resulted in ineffectiveness of lime applied. According to Baquerol and Rojas (2001), organic matter increases the availability and uptake of mineral nutrient elements by plants. This could not be achieved in 2009 due to low organic matter content of soil, which accelerated the rapid leaching of calcium ions deeper into the soil profile thus curtailing plant productivity. Similarly, the ineffectiveness of lime could have led to phosphate deficiency as a result of the non release of PO^{3+} ions to the plants even though relatively high P levels were reported from the soil tests (Table 2). This further supports the essentiality of P as another limiting element in maize production under acidic soil conditions. This may have contributed to reduction in leaf area expansion and surface area limitation, as well as reduced kernel number and size which transcended into lower grain yields recorded in 2009 as was observed in our experiment. These findings are in agreement with Onansanya et al. (2009).

The varietal differences observed among the parameters measured were not consistent, although Yellow Composite had significantly higher mean total dry matter in 2010 and tasselled later than Ashland variety. This could merely be chance occurrence and not due to inherent differences or environmental factors, as both varieties are said to be relatively stable in given environment (Amusa et al., 2005) According to Pandey et al. (2000), maize cultivars differ in their ability to maintain LAI, CGR and above ground biomass under different water deficit levels and N supply rates. But our findings proved otherwise.

5. Conclusion

From the study, the useful rate of lime and nitrogen for optimum popcorn production was 80 kg N ha^{-1} and 500 kg ha^{-1} lime rates which gave maximum yields. Above this rate of lime, there was decrease in yield. In the presence of liming therefore, inputs of inorganic N can be greatly reduced. This will enhance higher agricultural productivity but with reduced adverse effects on the environment. These findings have significant implication for farmers in this agro-ecology to enhance crop production that is not deleterious to the environment. Therefore the 80 kg N ha^{-1} in combination with lime at 500 kg ha^{-1} lime rate which had a good efficiency index is recommended. There might be need for further assessment of different organic materials and lime as sole sources of fertilization for popcorn on acid soils.

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