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POPCORN YIELD AND NUTRIENT COMPOSITION AS AFFECTED BY NITROGEN FERTILIZATION AND LIMING IN CALABAR, NIGERIA

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration between all authors. Author EBE designed the study, wrote the protocol and interpreted the data. Author EBE anchored the field study, gathered the initial data and performed preliminary data analysis. While authors ULU, NUN and CCO managed the literature searches and produced the initial draft. All authors read and approved the final manuscript.

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ABSTRACT

Zea mays L. everta (Popcorn) is a relatively new maize sub-species that is being introduced into the cropping system of arable crop farming in Calabar, Nigeria. Its productivity can, however, be impeded by low N concentration in the soil and high soil acidity that already affect the yield of conventional maize grown in the study area. Therefore, a two year trial was conducted at the Teaching and Research Farm of the University of Calabar, Nigeria to determine the effects of nitrogen and liming rates on growth, yield and nutrient composition of popcorn (*Zea mays* L. everta). A 3 x 4 factorial experiment in a randomized complete block design with three replication was used while treatments consisted of four levels of nitrogen (0, 40, 80 and 120 kg N ha^{-1}), applied as urea (46% N) and fitted in a factorial arrangement with three levels of lime (0, 500 and 1000 kg ha^{-1}) applied as calcium trioxocarbonate (iv) ($CaCO_3$). Results indicated that all plant parameters examined were significantly (p=0.05) higher with the application of 80 kg N ha^{-1} and 500 kg ha^{-1} lime rates than other N and lime rates. Grain yield performance was in the order 80 > 120 > 40 > 0 kg Nha^{-1}, which corresponded to 23.78, 33.55, 50.32% during 2009 and 15.14, 36.41 and 76.76% in 2010 above the 120, 40 and 0 kg N ha rates of N applied, respectively. Also, an increase of 20.0 and 24.83% in 2009, and 9.09 and 18.03% in 2010, in grain yield were observed when 500 kg ha^{-1} lime rates was applied and out-yielded both the 1000 kg ha^{-1} and control rates, respectively in both years. The application of lime at 1000 kg ha^{-1} resulted in significantly (p=0.05) higher N and Ca uptake in crop in both years. The P and Mg concentrations were highest from plants treated with 500 kg ha^{-1} lime. Effect of liming was not significant (p=0.05) in 2009, but was statistically at par at 0 and 500 $kgha^{-1}$ lime rates and significantly (p=0.05) higher than tissue K content at 1000 kg ha^{-1} liming rates in 2010. The effect of lime was not consistent in both years but N xLime (L) interaction was significant while 500 kg ha^{-1} liming rate was most promising. Maize grain yield performance was better and most rewarding with the application of 80 N ha^{-1} while grain yield was best when 500 kg ha^{-1} lime rates was applied, Therefore, application of 80 kg Nha^{-1} and 500 kg ha^{-1} of lime are recommended for a profitable popcorn production in Calabar, Nigeria.

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Keywords: Popcorn; nitrogen; liming; yield; nutrient composition.

1. INTRODUCTION

Zea mays L. *everta* (Popcorn) is a prominent cereal crop in the world and next to wheat and rice [1]. The grain is a major source of food for human beings and income for farmers while grains and the stovers serve as components of animal feed [2,3]. Among different income generating arable crops, maize has become an important "cash crop" to small holder farmers and constitutes a major source of calories for the poorer proportion of consumers who cannot afford more expensive foods like bread, milk and meat. Over 150 million people consume maize on average of 43 kg of maize per year [4,5]. With more than 50% of all households devoting over 50% of their total arable land to maize under various cropping systems, it remains one of the widely distributed and grown cereal crops in Nigeria [2]. Maize can therefore be said to be of strategic importance for food security and socio-economic stability of the country [6]. Despite the eminent role played by maize, its yield is still low particularly at peasant level thereby making it difficult to meet its demand. Several factors have been found to account for the low yield of maize one of which is low soil nutrient [7] and high soil acidity. Maize production, particularly among the smallholder farmers, have been found to be done mainly by depending on natural soil fertility recycling/improving strategies to boost maize yield. It is also imperative to state that currentlyfertilizer use by the farmers is not only haphazardly done but also adequate. Farmers depend on increasing fertilizer inputs to overcome yield deficits due to acid soil conditions with a pH being 5.0- 5.28 without conscious efforts of directly tackling the soil acidity. Hence, there is the need to explore alternative means of reducing acidity as a panacea to decrease fertilizer consumption and increasing maize yield. Liming has been used to ameliorate soil acidity and increased crop yield [8,9,10]. Against this background, there is need to use appropriate fertilizers such as nitrogen as well as adopt liming in order to boost maize production in Nigeria.

Nitrogen is essential for many plant metabolic processes as it plays vital roles in photosynthesis, leaf formation, tillering, stalk elongation, disease resistance, health and general well-being of plants [11,12]. Nitrogen deficiency has been reported that N deficiency in the soil led to inefficient utilization of optimum amounts of other available nutrient elements [13,14]. This implies that plant would remain poor in status, pale in appearance and unable to effectively photosynthesize. It also leads to restriction of root growth that directly impairs the source and sinks relationship and thus lowers yields [13]. Nitrogen is ultimately responsible for the buildup of leaves and other tissue in plants, has an exceptional importance in plant life [15] and is the most limiting nutrient in crop production. Insufficient N in soil and within plants has disastrous consequences, directly inhibiting photosynthesis and curtailing assimilates partitioning to the detriment of economic yields. Due to high precipitation and low organic matter status of soils in the humid tropics, there is attendant leaching and extensive weathering of soil bound mineral fractions which pose grave acidity problems for crop production [14]. Soil acidity exacerbates nutrient fixation, especially P by the Fe and Al oxides forming insoluble complexes in water [16], thus limiting its availability to plants. Aluminium, hydrogen and manganese are injurious to roots, affecting uptake of important mineral nutrient elements from the soil solution which ultimately affects growth and yield performance of crops. Matsumoto [17] and Onyekwere et al. [18] reported that there is poor bacterial growth that could lead to reduced N transformation in the soil. Soil acidity problems are however commonly ameliorated by the application of lime and some types of ashes [8,10,9,19]. Application of lime not only reduces soil acidity but also promotes availability and utilization of essential nutrients, symbiotic fixation of atmospheric N, decrease toxic levels of Al and Mn; and enhances the effectiveness of applied fertilizers [1].

Popcorn (*Zea mays* L. *everta*) like other related maize varieties requires enriched soil conditions and carefully managed environment for profitable production and high yield. Popcorn which is currently growing in importance as a snack food and economic crop all over the world [20,21] is also growing in demand in Nigeria [22,23]. However, its yields on peasant farmer fields have remained relatively low, rarely up to 1000 kg ha^{-1} [24] and may very well be considered a neglected maize type in Nigeria. However, there is possibility of yield increase through judicious fertilization and liming [25]. Uwah et al. [26] obtained the highest yield of 2.5 t ha^{-1} of popcorn with 80 kg N ha^{-1}, Eze and Obi [27] recorded the highest yields of "*Nsukka* white" popcorn variety (1.58 t ha^{-1}) at 0.5 tha^{-1} lime rate while Hassan et al. [25] reported yield of 4.32 t ha^{-1} with application of 0.25 t ha^{-1} lime. Sharifa et al. [3] recommended 82 kg N ha^{-1} in combination with 1.91 t ha^{-1} of poultry manure at 25 cm inter-row spacing for extra early maize variety in Zaria, Nigeria. Therefore, with these conflicting findings and paucity of research generated information on the yield performance of popcorn in south eastern rainforest agro-ecology of Nigeria. This study was conducted to assess the effects of nitrogen and liming rates on growth and yield performances and nutrient composition of popcorn in Calabar, a rainforest agro-ecology in Nigeria.

2. MATERIALS AND METHODS

The study was conducted at the Teaching and Research Farm of the University of Calabar (4.5°-5.2° N, 8.0°-8.3°E, 39 m ASL) during the first cropping seasons (between April and August) of 2009 and 2010. Calabar has a bi-modal rainfall pattern with annual amount ranging from 3000–3500 mm and a temperature range of 27 - 35°C. The popcorn used was the Yellow composite popcorn hybrid.Treatments consisted of four levels of nitrogen (0, 40, 80 and 120 kg N ha^{-1}), applied as Urea (46% N) and three levels of lime (0, 500 and 1000 $kgha^{-1}$) applied as calcium trioxocarbonate (iv) ($CaCO_3$. These treatments were combined in a factorial arrangement, laid on a randomized complete block design and replicated three times. The fertilizer and liming rates were selected based on soil analysis. Each gross plot measured 3.0 x 2.8 m^2, while net plots were 1.0 x 1.5 m^2 from which growth and yield parameters were estimated. Replications were separated by 1.5m pathways, while plots within replicates were separated by 1.0 m pathways. Soil was sampled at 0-20 cm depth prior to treatments application and analyzed for some physico- chemical properties using standard procedures as outlined by IITA [28]. The soil physico-chemical properties of the experimental sites are presented in Table 1. Sites were manually cleared, tilled and leveled to fine tilled flats before planting on 18th April and 14th May in 2009 and 2010 seasons, respectively. The difference in planting time between 2009 and 2010 was influenced by time rainfall stabilized in the area for planting operation. Plants were spaced at 25 x 75 cm^2 with three seeds per hole but later thinned to one per hole at five days after emergence, with a resultant plant population of 53,333 plants per hectare. Lime was incorporated into the soil one week before planting while half of the nitrogen, alongside basal single super-phosphate (26 kg P ha^{-1}) and muriate of potash (50 kg K ha^{-1}) were applied a week after emergence by ring method. The second half of N was top-dressed at 6 weeks after planting (WAP) about 8 cm deep and 8 -10 cm away from maize and covered with soil. N was split applied first to cater for first phase, which is vegetative, and critical yield phase as maize displays. Moreover, the nature of rainfall pattern and intensity in the area requires a split application of fertilizer to prevent the fertilizer from being leached and washed away by runoff water when rain falls.

Table 1. Physical and chemical properties of the soil from 0-20cm at the experimental sites during 2009 and 2010

Physical Composition	Year	
	2009	2010
Particle size analysis		
Sand (g/kg)	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)	1.00	3.18
Total nitrogen (g/kg)	0.07	0.14
Available P (mg/kg)	106.5	279.29
Na (cmol/kg)	0.29	0.09
K (cmol/kg)	0.14	0.12
Ca (cmol/kg)	1.33	1.69
Mg (cmol/kg)	0.23	0.66
ECEC (cmol/kg)	4.80	3.06
Base saturation (g/kg)	50.41	52.56
Exchangeable acidity	0.06	0.06

Weeds were hand-hoed at 4 and 8 WAP. Physiologically mature popcorn ears were harvested on 4th July and 21st August in 2009 and 2010 seasons, respectively and sun dried for four months when popping percentage reached 80% among the dried grains. Ten plants were randomly tagged in each plot for the collection of the following data; Plant height was measured at 11 weeks after planting (WAP) with a measuring tape from the soil surface level to the collar of the highest fully expanded leaf and up to the tassels as soon as they appeared. Leaf area was also determined at 11 (WAP) using the formula, LA= L x W x 0.72, where L is leaf length, W is widest portion of leaf and 0.72 is plant constant [29]. The resultant value was divided by area of ground occupied by the plant to obtain LAI. Total Dry matter (TDM) was determined after harvesting by collecting and oven drying the above ground parts at 70°C until constant weight was achieved. The number of days to 50% tasselling and silking, 1000-grain weight, ear length, number of grain rows ear^{-1}, and the total grain yield (t ha^{-1}) were also determined. Nutrient composition was determined in the laboratory by crushing plant materials in a Wiley mill. The powdered samples were sieved and analyzed using IITA [30] standard procedures. Data collected were subjected to analysis of variance using SAS Version 9 and treatment means compared using Duncan Multiple Range Test –DMRT [31].

3. RESULTS

3.1 Effects of Nitrogen

The application of nitrogen significantly (p=0.05) increased plant height, leaf area index (LAI), and total dry matter (TDM) above the control (Table 2). Plants grew more luxuriantly with higher nutrient supply while those receiving lower supply took longer days to mature. Increasing the N rates significantly (p=0.05) increased vegetative parameters up to 120 kg N ha^{-1} in 2009 but not beyond 80 kg N ha^{-1} in 2010. In other words, the 120 and 80 kg N ha^{-1} rates favoured the aforementioned parameters in 2009 and 2010, respectively. Increase in rates of N significantly (p=0.05) lowered the number of days to 50% tasselling and silking (Table 3) whereas plants that received 120 kg N ha^{-1} rate significantly lowered (p = 0.05) number of days used to reach tasselling and silking stages.

The 1000-grain weight was significantly (p=0.05) higher at 120 kg N ha^{-1} in 2009 than other rates, whereas this increase did not exceed 80 kg N ha^{-1} in 2010 (Table 4). At 120 kg N ha^{-1}, the 1000-grain weight increased by 6.83% in 2009, while 80 kg N ha^{-1} resulted in an 11.69% increase in 1000-grain weight in 2010 above the control (Table 3). The ear length and number of grain rows ear^{-1} were significantly (p=0.05) higher at 80 kg N ha^{-1} in both years than other rates, followed by the 120 kg N ha^{-1} (Table 4). Increasing N from 80 to 120 kg N ha^{-1} decreased the number of grain rows ear^{-1} by 6.27 and 5.90% in 2009 and 2010, respectively (Table 4). The total grain yield increased significantly (p=0.05) with increase in N rates up to 80 kg N $ha^{-1}$and declined thereafter (Table 4). Yield increase was in the order 80 > 120 > 40 > 0 kg Nha^{-1}, which corresponded to 23.78, 33.55, 50.32% during 2009 and 15.14, 36.41 and 76.76 in 2010 above the 120, 40 and 0 kg N ha rates of N applied respectively (Table 4). Concentrations of N, P and K in plant tissue were significantly (p=0.05) higher at 120 kg N ha^{-1} than other N rates while Ca and Mg concentrations were higher at 40 kg N ha^{-1}, than others in both years (Table 5).

3.2 Effects of Liming

Significant increase in plant height was observed when 500 kg ha^{-1} of lime was applied, whereas LAI value was statistically at par when 500 and 1000 kg ha^{-1} of lime was applied but significantly (p=0.05) higher than the control (Table 2). The TDM in 2009 was significantly (p=0.05) higher in plots treated with 500 kg ha^{-1} of lime whereas 1000 kg ha^{-1} rate resulted in higher TDM in 2010 with an increase of 13.71% and 25.62% above the 500 and 0 kg ha^{-1} rates (Table 2).

Liming did not significantly (p=0.05) affect the number of days to 50% tasselling in both years, but number of days to 50% silking was significantly higher (p=0.05) in both years when plots were treated with 500 kg ha^{-1} of lime only (Table 3). Increase in 1000-grain weight was statistically similar at 500 and 1000 kg ha^{-1} lime rates in both years, but significantly higher than the control (Table 3). Liming resulted in significantly (p=0.05) longer ears and higher number of grain rows ear^{-1} in both years (Table 4). Similarly, total grain yield was highest at 500 kg ha^{-1} of lime, whereas increasing lime up to 1000 kg ha^{-1} tended to decrease grain yield with the yield being statistically at par with that of control (Table 4). Liming at 500 and 1000 kg ha^{-1} resulted in yield increases of 24.02 and 4.02% in 2009 and 18.03 and 8.02% in 2010 above the zero lime controls, respectively.

The application of lime at 1000 kg ha^{-1} resulted in significantly (p=0.05) higher N and Ca uptake in crop in both years (Table 5). The P and Mg concentrations were highest from plants treated with 500 kg ha^{-1} lime. Effect of liming was not significant (p=0.05) in 2009, but was statistically at par at 0 and 500 kg ha^{-1} lime rates and significantly (p=0.05) higher than tissue K content at 1000 kg ha^{-1} liming rates in 2010 (Table 5). There were no significant interaction effects between N fertilizer and liming rates. Application of lime served more or less as a precursor for the N fertilizer uptake as even indicated by significant interaction effects between N fertilizer and liming rates. The critical pH level for the test crop is 5.7. The changes liming has caused due to its effects on soil pH are indeed reflected in the treatment effects observed in plots where liming was done relative to the control treatment that received no liming (Tables 6 and 7). The mean pH after one week of application increased with increase in N up to the 40 kg N ha^{-1} rate, which was significantly higher than pH, at all other N levels (Table 6). In contrast, the pH values at harvest were better with the application of 500-1000 kg ha^{-1} lime in both years and resulted in significantly lower acidity compared to the control (Tables 6 and 7). The N x L interaction in both years was highly significant (Table 7). At 500 and 1000 kg ha^{-1} lime rates, there was a resulting increase in pH values in both years. At harvest, change in pH was significantly higher at 120 kg N ha^{-1} plots than all other N treated plots in the two years. Liming at 1000 kg ha^{-1} resulted in the highest pH change in both years above the 500 and control levels of lime. The N x L interaction was highly significant in both years. At 1000 kg ha^{-1}, liming resulted in high pH values and thus indicating a reduction in soil acidity level.

Table 2. Effects of Nitrogen and liming on popcorn height (cm), leaf area index and total dry matter plant-[1]

Treatment	Height (cm)		Leaf area index		Total dry matter plant $^{-1}$	
Nitrogen (kg N/ha)	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
0	123.73c	155.21d	1.48d	1.76d	120.67d	120.35d
40	157.44b	189.15c	2.60c	2.69c	142.11c	159.82c
80	145.94b	229.09a	3.12b	3.81a	158.01b	213.90a
120	172.53a	206.11b	3.96a	3.54b	192.83a	199.89b
SE±	4.93	4.30	0.07	0.07	3.42	7.02
Lime (kg/ha)						
0	150.36b	182.08c	2.62b	2.69b	151.65b	154.86c
500	158.69a	203.67a	2.77a	3.09a	159.23a	171.08b
1000	150.67b	198.92b	2.88a	3.06a	149.33c	194.54a
SE±	4.27	2.53	0.06	0.06	2.96	6.08

Means followed by the same letter(s) within same column are not significantly different at p=0.05 using DMRT.

Table 3. Effects of Nitrogen and liming on days to 50% tasselling and silking, and 1000 grain weight of popcorn

Treatment	Days to 50 percent tasselling		Days to 50 percent silking		1000-grain weight	
Nitrogen (kg N/ha)	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
0	49.66a	51.39a	59.55a	59.89a	189.31b	181.26c
40	48.33b	48.72b	59.66a	56.61b	199.98b	187.01b
80	47.16c	46.11c	57.44b	55.17c	202.24b	202.45a
120	46.50d	44.61d	55.50c	53.17d	218.50a	188.83b
SE±	0.37	0.40	0.38	0.30	4.78	4.13
Lime(kg/ha)						
0	47.95a	47.21a	57.66b	55.63b	198.87b	183.77b
500	47.58a	47.08a	58.50a	56.21a	202.42a	189.42a
1000	48.20a	48.88a	57.95b	56.79a	206.25a	188.48a
SE±	0.14	0.35	0.33	0.26	4.14	3.58

Means followed by the same letter(s) within same column are not significantly different at p=0.05 using DMRT.

Table 4. Effect of Nitrogen and liming on ear length (cm), No. of grain rows ear^{-1} and total grain yield of popcorn

Treatment	Ear length (cm)		No. of grain rows ear^{-1}		Total grain yield (tha^{-1})	
Nitrogen (kg N/ha)	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
0	12.30b	11.90d	12.84c	12.46c	1.35c	1.42d
40	13.22b	12.77c	13.62b	13.35b	1.52b	1.84c
80	15.79a	15.20a	14.74a	14.00a	2.03a	2.51a
120	15.11a	14.26b	13.87b	13.22b	1.64b	2.18b
SE±	1.60	0.46	0.24	0.28	0.07	0.10
Lime (kg/ha)						
0	13.58b	12.86c	13.44b	12.78c	1.49b	1.83b
500	14.88a	14.30a	14.03a	13.69a	1.86a	2.16a
1000	13.85b	13.45b	13.83b	13.30b	1.55b	1.98b
SE±	0.33	0.40	0.21	0.24	0.06	0.09

Means followed by the same letter(s) within same column are not significantly different at p=0.05 using DMRT

4. DISCUSSION

Increase in plant growth and yield parameters observed can be attributed to the essentiality role of N for photosynthetic and plant metabolic activities, as well as optimum use of other available soil nutrients. Plant response to N peaked at maxima of nutrient resource utilization which corresponds to maximum yield. This is in agreement with Onasanya et al. [14] and FAO 13] reports that deficiency of N resulted in inefficient nutrient utilization and uptake in plants. Beyond this maximum point, there is luxury consumption characterized by excessive vegetative growth at the detriment of economic yield. Reduction in the number of days to 50% tasselling with increase in N application may have resulted in decrease in barrenness among plants, an enhancement of vigour, promoting increase in root exploratory tendencies of plants, enhanced nutrient uptake, increased photosynthetic activities and meristematic tissue development in as much as N was not limiting. This is in consonance with Yadav [32] and Shrestha [33] reports that earliness to silking is due to rapid growth occasioned by increase in N rates applied.

Consequent increase in grain yields with increasing N levels is directly proportional to increase in yield parameters such as number of grains per ear^{-1}, 1000-grain weight, weight of grains and ear length. This is consistent with reports of Tena and Bayene [34] that the total number of grains is bound to increase with increase in soil fertility. Significant grain yield increases with successive increment in N rates from 0 to 200 kg ha^{-1} have been reported [32,33]. According to Akmal et al., [12] increased LAI results in higher solar capture and radiation use efficiency (RUE) in the crop canopy. By an improved net assimilation rate (NAR), more photo-assimilates are contributed for higher dry matter and biomass formation. This is directly due to increased leaf area duration, offering wider green surface area for solar capture which stimulates growth and thereby delaying senescence. Increase in tissue nutrient concentrations at the maximum level of N indicates that there was maximum uptake of nutrient elements and optimum utilization of available nutrients occasioned by adequacy of N supply [13]. This implies that plants developed proportionally and in establishing effective photosynthetic apparatus were able to accumulate dry matter for yield formation. The increase in grain yield is obvious, considering the higher requirements of N and its essentiality in photosynthesis and plant metabolism.

Table 5. Effects of Nitrogen and liming on the nutrient composition of popcorn

Treatment	**Nitrogen (%)**		**Phosphorus (%)**		**Potassium (%)**		**Calcium (%)**		**Magnesium (%)**	
Nitrogen (kg N/ha)	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
0	1.83c	1.47c	1.75c	1.86b	3.63b	6.05b	0.42c	0.43ab	0.25b	0.25b
40	2.88ab	2.38b	2.32b	1.92b	4.11ab	4.91c	0.46a	0.46a	0.30a	0.32a
80	2.58b	2.57b	2.17b	1.86b	3.31b	4.80c	0.40d	0.39b	0.23c	0.23c
120	3.05a	2.90a	2.56a	2.04a	4.68a	6.75a	0.43b	0.41b	0.25b	0.26b
SE±	0.09	0.08	0.05	0.03	0.14	0.10	0.06	0.16	0.10	0.02
Lime (kg/ha)										
0	2.34b	2.12b	2.08b	1.93a	3.92a	5.75a	0.42c	0.41b	0.25b	0.24b
500	2.39b	2.24b	2.38a	1.97a	3.96a	5.76a	0.43b	0.43a	0.28a	0.29a
1000	3.03a	2.63a	2.14b	1.86b	3.92a	5.39b	0.44a	0.45a	0.25b	0.24b
SE±	0.07	0.07	0.05	0.02	0.12	0.08	0.05	0.14	0.09	0.02

Means followed by the same letter(s) within same column are not significantly different at p=0.05 using DMRT

Table 6. Soil pH after one week of lime application and at harvest

Treatment	**Soil pH one week after liming**		**Soil pH at harvest**	
N kg ha^{-1}	**2009**	**2010**	**2009**	**2010**
0	6.13c	6.16c	6.32c	6.57b
40	6.65a	6.68a	6.58ab	6.58b
80	6.40b	6.41b	6.54b	6.59b
120	6.36b	6.39b	6.61a	6.68a
SE+-	0.022	0.020	0.018	0.027
Lime (kg ha^{-1})				
0	6.15b	6.18b	6.50b	6.53b
500	6.51a	6.52a	6.50b	6.59b
1000	6.50a	6.53a	6.54a	6.73a
SE+-	0.019	0.017	0.015	0.023
Interaction				
N x L	**	**	**	**

Means followed by the same letter(s) within same column are not significantly different atp=0.05 using DMRT,
***= significant different at p=0.05*

Table 7. Interaction between nitrogen x lime rates for soil pH after liming

Nitrogen (Kg N ha^{-1})	Lime (Kg ha^{-1})					
	2009			2010		
	0	500	1000	0	500	1000
0	5.24c	6.75a	6.78a	5.28c	6.76a	6.81a
40	6.41a	6.53b	6.64b	6.44a	6.55b	6.67b
80	6.25b	6.57b	6.40c	6.28b	6.54b	6.40c
120	6.33b	6.22c	6.53b	6.35a	6.23c	6.61b
SE+-	0.029			0.034		

Means followed by the same letter(s) within same column are not significantly different at p=0.05 using DMRT

The significant effects of lime on plant height, TDM either at 500 or 1000 kg ha^{-1} liming rates is indicative of positive influence of liming in neutralizing soil acidity, thereby enhancing nutrient availability and uptake for vigorous plant growth. Several workers have reported that liming is beneficial for increasing soil pH, Ca and Mg saturation, neutralization of Al toxicity, increase in available plant nutrients, and uptake by roots as well as utilization of the same by plants [8,13,35,25,9]. Yield components such as ear length, higher number of grain rows ear^{-1}, 1000-grain weight, contributed to higher grain weight of ears and subsequently increased yield at 500 kg ha^{-1}. With an increase of 20.0 and 24.83% in 2009, and 9.09 and 18.03% in 2010, the 500 kg ha^{-1} out-performed both the 1000 kg ha^{-1} and control lime rates, respectively in both years. This can be attributed to the increase in distribution and partitioning of assimilates leading to the increase observed in dry matter deposition [36,37]. The neutralizing effect of lime on soil acidity and amelioration of H^+ or Al^{-1} toxicity (which curtails the roots ability for nutrient absorption and uptake), obviously resulted in higher nutrient profile of the crops, leading to balanced nutrition of the plants and an overall enhancement of the crops performance with respect to yield increases.

CONCLUSIONS

Maize grain yield performance was better and most rewarding with the application of 80 N ha^{-1} while grain yield were best when 500 kg ha^{-1} lime rate was applied. The application of lime at 1000 kg ha^{-1} resulted in higher N and Ca uptake in both years. The P and Mg concentrations were highest with 500 kg ha^{-1} lime. K content in crop tissue was higher at 1000 kg ha^{-1} liming rates than others in 2010.Therefore, application of 80 kg N ha^{-1} and 500 kg ha^{-1} of lime are recommended for a profitable popcorn production in Calabar, Nigeria.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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