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Nitrogen uptake and grain yield of some maize (*Zea mays L.)* varieties under low urea application to soil in Omoku, Rivers State, Nigeria.

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Abstract

Field experiments to evaluate N-uptake and grain yield response of some maize (*Zea mays L.*) varieties to low urea fertilizer rates at the Teaching and Research Farm of Federal College of Education (Technical), Omoku, Rivers State Nigeria; were conducted in four seasons from 2015 to 2018, using five maize varieties of Bende white, DMR-ESRY, Mangu white, Oba super 4 and Oba super 2. The experiment was laid out in a factorial design fitted into a Randomized Complete Block Design (RCBD) with three replications, and conducted at two late and two early cropping seasons. Soil, N-uptake and grain yield data were collected. Analysis of the N-uptake of the maize cultivars was done at tasseling. Data collected were analyzed with GENSTAT 12th edition software (2010) package, and treatment means were separated with Duncan multiple Ranges Test at 5% ($P \leq 0.05$) level of probability. Initial soil result shows that the texture was sandy with slightly acidic. Apart from Ca and Mg contents, which were above critical levels, other cations were low. Organic carbon and nitrogen were also low. Micronutrients were sufficient. The analysis shows that N uptake differs significantly among the five varieties of maize at the rates of 0, 30 and 60 Kg N ha-1 urea application. Bende white (521.9 g kg-1) was significantly higher in N uptake. Mangu white was significantly higher in grain yield. The maize grain yield varies in the order: Mangu white (3.33 t ha-1) > Bende white (3.06 t ha-1) > DMR-ESRY (2.85 t ha-1) > Oba super 4 (2.54 t ha-1) > Oba super 2 (2.51 t ha-1). The influence of N-rate and N-uptake on the varieties and season was positive. The urea rate of 60 kg N ha-1 produced better yield with the local maize varieties of Bende white and Mangu white on the sandy soil of Omoku.

Keywords: Maize, Nitrogen, N-uptake, Grain yield

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1.0 Introduction

Nitrogen (N) plays a unique role among other essential elements in crop production because it is required proportionally more than other nutrients to achieve maximum crop yield. Being a primary plant nutrient, it plays vital functions in the plant metabolism in determining growth and yield. It is a characteristic essential element of proteins and a fundamental component of many enzymes (Onasanya *et al.,* 2009). Nitrogen is a principal structural constituent of cells, as its level increases, the rate of vegetative and reproductive growth also increases in plants due to increase in the assimilatory surface of plants as well as photosynthesis (Shrikanth *et al.,* 2015).

Maize is an essential economic crop in Nigeria, as in some other parts of the world. The importance of nitrogen in maize cultivation cannot be overstressed. Maize is an exhaustive crop plant which requires a considerable quantity of nitrogen fertilization for growth and yield. Nitrogen uptake, biomass production and grain yields are strongly correlated; the nitrogen requirement of a maize crop is strongly related to grain yield (Kafle and Sharma, 2015). Its availability throughout the growing period is crucial because it is essential for plant growth and makeup 1 to 4 percent of dry matter of maize (Gul *et al.,* 2015). Regrettably, only a few soils can supply enough N to good maize production without the use of fertilizer N. Consequently, N deficiency is prevalent than any other nutrient deficiency in maize production. It can be asserted. Therefore, maize responds positively to N fertilizer application. Managing nitrogen is of great concern to agronomists, farmers and environmentalists alike. Adoption to low soil N fertility status is vital as maize varieties exhibit a differential response to yield at low and high N fertilizer application.

One strategy to improve maize productivity and to reduce the effect of low soil N on maize production is selecting cultivar(s) with superior grain yields under low soil N. Adoption of such varieties should be based on N-uptake response under low N conditions. N management poses a severe challenge among farmers in Omoku because of the absence of site-specific recommendations. Research into the evaluation and adoption of maize cultivars with improved grain yield under the low N conditions will be beneficial to the farmers. This study was therefore designed to evaluate the rate of N-uptake of five maize varieties at low levels of urea fertilizer application, and recommend suitable adaptive cultivar(s) to farmers.

2.0. Materials and Methods

2.1. Area of study

The experiment was conducted at the Teaching and Research Farm of Federal College of Education (Technical), Omoku, Rivers State. Omoku the headquarters of Ogba/ Egbema/Ndoni Local Government Area (ONELGA) is located on the North-Eastern fringe of Rivers State, on latitude 6° 40' East and longitude 5° 21' North in the tropical rainforest zone of South-South, Nigeria.

The dominant soil of Omoku is Typic kandiudult derived from the alluvial plain of the upper Delta (Sombrero-Warri morphological region) (Ayolagha and Onuegbu, 2001). Its elevation is 17.69 m (58 feet) above sea level and has two main seasons - rainy and dry seasons. Omoku enjoys a bimodal annual rainfall pattern ranges from 2040 to 3000 mm (between April and October) with a break in August. The dry season occurs from November to March with occasional interrupted by intermittent rainfall. The mean ambient temperature is 28.8°C with a maximum of 38.3°C with a relative humidity of 68-80%. The town experiences monthly sunshine of 4.2 hours during the raining season. The experimental site was located in a middle part toposequence (slope 0-2%) and was well-drained.

2.2. Land Clearing and Preparation

The site was ploughed and harrowed, mapped out and marked into plots in preparation for the sowing of the maize seeds.

2.3. Source of Seed / Planting Material:

The five maize cultivars were DMR-ESRY (downy mildew and streak resistant early yellow grain variety), Bende White, Mangu White, Oba Super 2 and Oba Super 4, were obtained from the National Root Crop Research Institute (NRCRI), Umudike near Umuahia, Abia State. The varieties have been marketed in Nigeria for sometimes. Each variety has its N requirements, either as N – insufficient or N – sufficient.

2.4. Experimental Design/Treatment:

The experimental design was a factorial design fitted into a Randomized Complete Block Design (RCBD) arrangement replicated three times. The factors were the three (3) rates of urea fertilizer and five (5) cultivars of maize. The rates of urea were 0 kg N ha^{-1} (control), 30 kg N ha^{-1} and 60 kg N ha^{-1}. Each replicate was separated by 2 m alley to avoid treatment interaction. The size of each plot was 8 x 3m = $24m^2$ while the area of each rate was 15 x 8 = $120m^2$. Each replicate had fifteen (15) plots. The entire arrangement had a total of 45 plots within a total land area of 49 x 26m = $1274m^2$.

2.5 Planting and Cultural Practices:

The first experiment was established on 29th August 2015. Each plot had four (4) rows of length 8 m spaced at 0.75m inter-row and 0.5m as intra-row giving a total of 124 plants equivalent to a plant population density of 53,333 per hectare. Three seeds were hand planted per stand, later thinned to two (2) seedlings to maintain a uniform number of plants. Before planting P as single super phosphate and K as muriate of potash were applied at the rate of 30 kg P_2O_5 ha^{-1} and 15 kg K_2O ha^{-1} respectively, as basal application. Urea fertilizer was applied in two equal split doses at 2 and 6 WAP respectively. Weeding was done manually twice. Insect pests were controlled with the use of the insecticide *Lambda* applied through knapsack sprayer at 2 *l* ha^{-1}. The field borders were kept clean to minimize encroachment by insects and rodents. The inner two (2) rows in each plot were used for destructive sampling. The experiment was repeated the on 16th April 2016, 25th August 2017 and 6th March 2018 respectively.

The experimental site was geo-reference on the following coordinates:

Length 1: 05.37699º N, 006.67405º E to 05.37662º N, 006.67389º E

Width 1: 05.37662º N, 006.67389º E to 05.37651º N, 006.67406º E

Length 2: 05.37657º N, 006.67406º E to 05.37695º N, 006.67424º E

Width2: 05.37695º N, 006.67424º E to 05.37699º N, 006.67405º E

2.6 Soil Sampling and Analysis

Before sowing, topsoil samples were randomly collected at a depth of 0 – 15cm for analysis. The samples adequately mixed in a clean plastic bowl to obtain a composite sample. It was later taken to the laboratory where it was air-dried, crushed and sieved through 2 mm sieve to remove debris and stones. The sieved sample was analyzed following standard laboratory procedures:

2.6.1 Particle size distribution **-** was determined using the Bouyoucos hydrometer method using 0.5 N sodium hexametaphosphate as a dispersant (Landor, 1991).

2.6.2. Soil pH **-** was determined using the glass electrode method in 1:2.5 soil to water (V/V) suspension (Peech, 1965).

2.6.3 Soil Organic Carbon **-** was determined using the Walkley-Black method (1934), and organic matter was obtained by multiplying soil organic carbon by a factor of 1.724.

2.6.4 Total nitrogen of the soil and plant tissue was analyzed using the micro-Kjeldahl and distillation method described by Bremmer and Mulvaney (1982).

2.6.5 Available Phosphorus - was determined using the Bray P1 method (Olsen and Sommer, 1982).

2.6.6. Exchangeable Cations (Ca, Mg, Na and K) **-** determined after extracting the soil samples by ammonium acetate (1N NH4OAc) at pH 7.0 (Chapman, 1965). Na and K were analyzed by flame photometer while exchangeable Ca and Mg were determined by EDTA complex metric titrations.

*2.6.7 Exchangeable Acidity (EA***,** defined as the sum of Al and H) was determined using the titration method after extraction with 1.0 m potassium chloride (Page *et al.,* 1982).

2.6.8 Base Saturation **-** was determined by expressing the sum of the exchangeable cations as a percentage of ECEC values: K^+, Na^+, Ca^+ and Mg^{2+}.

2.7 Data Collection

Leaf samples from the outside rows were used for agronomic data collection while the inner rows were used for grain yield and yield components.

2.7.1. Grain Yield

The weight of all dehusked ears obtained from a plot was summed and converted to yield per hectare (t ha^{-1}). The formula calculated the total grain yield: total grain yield (tons ha^{-1}) = grain weight (g)/m^2/100 (Khan *et al.,* 2014).

2.7.2 Plant Tissue N Leaf samples were collected at tasseling stage from the five (5) maize plants destructive samples oven-dried at 80^{0}c for 72 hours, ground to pass through 0.5 mm sieve, and standard laboratory procedure followed for N determination.

2.7.3 Determination of N uptake of the maize varieties

N-uptake of the maize plants was determined by the formula:

N content (%) / dry matter yield (kg ha^{-1}) x 100

2.8 Data Analysis

Data collected were analyzed with the GENSTAT 12th edition software (2010) package. The treatment means were separated with Duncan multiple Ranges Test at 5% ($P \leq 0.05$) level of probability.

3. Results and Discussion

3.1 Pre-Planting evaluation of the soil

The analysis of the pre-planting soil of the evaluation site as presented in table 1 shows that the soil was slightly acidic with low cation exchange capacity (CEC) and effective cation exchange capacity (ECEC), medium total N, organic carbon and available P but very high percentage base saturation. The particle size distribution of the soil sample shows that the soil textural class was sandy soil. Most of the soil fertility indices such as ECEC, available P, organic C and total N were below critical limits. Micronutrients were sufficient. The slight acidity of the soil influences a lot of chemical properties of the soil, including microbial activity, crop root growth, nutrient availability, among others. It influences nutrient availability and toxicity, microbial activity, and root growth (Kamalu *et al.,* 2017). Aluminium (Al), iron (Fe) and manganese (Mn) toxicities are minimized at slightly acidic pH. Micronutrients and phosphorus (P) availability are expected to be at a maximum. Slightly acidic pH also indicates that the level of microorganisms responsible for N mineralization would be in abundance since they function best in soils with a pH range of 5.5 to 6.5 (Fairhurst, 2012). It influences soil chemical characteristics that affect crop response to fertilizer application. Most fertilizers are mineralized within that pH status and made available to crops.

Table 1: Chemical and physical properties of soil at 0-15cm depth of the experimental site before cropping.

Soil parameter		Value
pH		6.10
Exchangeable cations:		
Ca		5.50
Mg		2.08
Na		0.21
K	cmol kg^{-1}	0.11
Exchangeable acidity		0.11
Effective CEC		8.01
Cation exchange capacity		7.90
Base saturation (%)		98.63
Org. C (g kg^{-1})		0.23
Total N (g kg^{-1})		0.023
Avail. P (mg kg^{-1})		3.12
Micro-nutrients:		
Cu		1.10
Mn	mg kg^{-1}	83.5
Fe		250.00
Zn		45.5
Particle size distribution:		
Sand		910.0
Clay	g kg^{-1}	56.0
Silt		34.0
Textural class		sandy soil

Analysis of nitrogen (N) uptake of the five maize cultivars at tasseling as presented in table 2 shows that N uptake differs significantly among the five varieties of maize. Bende white was significantly higher than the other varieties at p≤0.05; followed by DMR-ESRY, Mangu White, Oba Super 2 and Oba Super 4 respectively. The differences in N-uptake could be attributed to the genotypic characteristics of the maize varieties, environmental factors and the interaction of both. The maize variety with genotype associated with high N absorption will perform better even under low N conditions. Invariably, the maize varieties have their levels of N uptake. This finding is consistent with the assertion of Khan *et al.* (2014b) that maize cultivars differ in their response to nutrient supply when grown in the same geographic environment. The result also agrees with the findings of Olowoboko *et al.* (2017) that different levels of nitrogen significantly improved maize growth, dry matter yield and nutrient uptake.

Table 2: Effect of maize varieties on nitrogen uptake (g kg^{-1}) at tasseling

Variety	**Nitrogen Uptake**
Bende White	521.9^{a}
DMR-ESRY	437.0^{b}
Mangu White	410.0^{c}
Oba supper 4	386.9^{d}
Oba supper 2	392.1^{d}

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability.

N uptake of the maize cultivars increased with the rates of application of urea from the control to 60 kg N ha^{-1} (Table 3). N uptake in plots applied with 30 and 60 kg N ha^{-1} was significantly higher than the control, but N uptake in 60 kg N ha^{-1} was significantly higher than 30 kg N ha^{-1} at p≤0.05 probability level. The differences in N-uptake could be attributed to the differences in the availability and uptake of N by the maize plants. The maize cultivars differ in their levels of N uptake at the same rate of urea application. The maize variety with a genotype associated with high N absorption will perform better even under low N conditions. N uptake increased with an increasing rate of urea application. This finding is consistent with the report of Kostandi and Soliman (2008) cited in Hokmalipour and Darbandi (2011) that increasing N rates from 30 to 60 and or 90 kg per acre produced more significant response on the N uptake and yield, followed by a limited response at 120 kg N per acre. Camberato (2017) posited that the application of fertilizer N leads to an increase in net mineralization of soil N with subsequent consumption of the mineralized N by the crop. The differences obtained at 30 kg N ha^{-1} were not as significant as that obtained at 60 kg N ha^{-1}. This finding is in tandem with the report of Bashir *et al.* (2012) that genotypic differences at varying levels of urea application were not very apparent at a lower level of urea application from which it can also be concluded that maize varieties were unable to extract sufficient N from low urea level.

Table 3: Effect of urea rates on nitrogen uptake (g kg^{-1}) of maize at tasseling

Urea	Nitrogen Uptake
0	327.8^{c}
30	424.5^{b}
60	**536.8^{a}**

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability.

The response of seasons to nitrogen uptake of the maize varieties is presented in table 4. The analysis shows there was a significant difference in N-uptake among the four seasons of the experiment. The late cropping season of 2015 was significantly higher than other seasons at the same level; followed by early cropping season of 2016 and late cropping season of 2017, and finally by early 2018 cropping season. There was no significant difference among the late 2016 and early 2017 seasons.

Table 4: Effect of seasons on nitrogen uptake (g kg^{-1}) of maize at tasseling

Seasons	**Nitrogen Uptake**
2015 (Late)	485.9^{a}
2016 (Early)	415.2^{b}
2017 (Late)	419.8^{b}
2018 (Early)	398.0^{c}

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability.

The analysis of the grain yield of the five (5) varieties of maize as presented table 5 shows that there was a significant difference in their grain yield. Mangu white was significantly higher than the other varieties, followed by Bende white, DMR-ESRY, Oba super 4 and Oba super 2, respectively. The differences exhibited in maize grain yield among the cultivars could be attributed to the differences among the cultivars for N-uptake and utilization. This agrees with the report of Anjorin (2013) that maize varieties varied in their response to nitrogen application across the fertility environments while some were consistence. It also agrees with the report of Singh *et al.* (2010) that cultivars identified as low responsive to applied N sometimes perform better at low N than do N-responsive hybrids or open-pollinated maize varieties. The maize variety with higher N uptake ability absorbed more N, thereby resulting from increases in grain yield. Increased grain yield could therefore be seen as a function the N uptake ability of the maize variety under N condition during the growing stages. The soil condition and other environmental factors also enhance the N uptake of the maize plants. There was no significant difference between Oba super 2 and Oba super 4. These maize varieties had similar N uptake ability under low N condition which could be seen as a function of their genetic flair for N uptake.

Table 5: Effect of Maize Varieties on Grain Yield (t ha^{-1})

Variety	Grain yield (t ha^{-1})
Bende White	3.04^{b}
DMR-ESRY	2.85^{c}
Mangu White	3.33^{a}
Oba supper 4	2.54^{d}
Oba supper II	2.51^{d}

Means followed by the same letter(s) in the same column are not significantly different at 5% level of probability.

4.0 Conclusion

The study shows the positive influence of low urea application to the soil in Omoku on the N-uptake and grain yield of the maize varieties. The five (5) maize varieties responded to the applied urea rates in terms of N-uptake and grain yield, respectively. The application rate of 60 kg N ha^{-1} was significantly higher than 30 kg N ha^{-1} and 0 kg N ha^{-1}. The truism that maize is nitro positive was confirmed by this study on Omoku soil, Rivers State Nigeria. However, the maize varieties vary in their responses to the nitrogen application rates, although some were relatively consistent. This variation can be attributed to the level of N-uptake, which influenced the grain yield of maize varieties. It was found out that the local varieties of Bende white and Mangu had higher N uptake than the hybrid varieties of DMR-ESRY, Oba super 2 and Oba super 4 at the low urea application rates. The grain yield of the maize varieties was in the order of Mangu white > Bende white > DMR-ESRY > Oba super 4 > Oba super 2. It is therefore recommended that 60 kg N ha^{-1} can be used for maize cultivation on the sandy soil of Omoku for better yield.

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