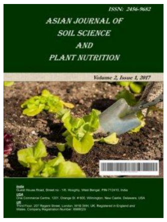


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# The Effect of Solid (Granular) and Liquid (Foliar) Fertilizers Application on the Growth and Yield of Maize (*Zea mays L*) in Soils of Obubra, Cross River State, Nigeria

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Author EAA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors EAA and LJA managed the analyses of the study. Author LJA managed the literature searches. Both authors read and approved the final manuscript.*

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## ABSTRACT

The research was carried out in the month of April, 2018 to determine the effect of solid (granular) and liquid (foliar) fertilizers application on the growth and yield of maize in soils of Obubra. Five (5) composite soil samples were collected at the depth of 0-20 cm for the analysis of physical and chemical properties before application of the fertilizers. The experimental layout was randomized Complete Block Design (RCBD) with three treatments and five replications in a plot area of 25 m x 20 m (500 m2) which corresponds to 0.05 ha-1. The plot was designed and blocked into subplots, each measuring 6 m x 4 m (24 m2). Each block was separated from the other with a distance of one meter (1 m) apart and between subplots 0.5 m apart. Three treatments made up of treatment one (T1) zero application at 0 kg ha-1, treatment two (T2) liquid (foliar) N.P.K 20:20:20 at the rate

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of 100 mil of N, 50 mil of P2O5, 33.3 mil of Mp ha-1 and treatment three (T3) solid (granular) N.P.K 20:20:20 at the rate of 44.4 kg of N, 40 kg of P2O5 and 33.3 kg of Mp ha-1 were replicated five times making a total of fifteen (15) subplots. Parameters of plant heights and number of leaves were observed at 6 and 8 weeks after planting. Plant heights, number of leaves, number of cobs, weight of 1000 seeds in each subplot and weight of grain after shelling were analyzed respectively. Results on soil analyses showed that the soil texture was sandy loam with deficiencies in primary nutrients and other nutrients. On the plant heights, the result was significant ($P \leq 0.05$) and on the number of leaves, the result for 6 weeks was not significant ($P \geq 0.05$) while that of 8 weeks was significant ($P \leq 0.05$). On the number of cobs, 1000 seeds and weight of grain after shelling were also significant ($P \leq 0.05$). The solid (granular) fertilizer showed to be more effective than liquid (foliar) fertilizer and should therefore be recommended for the growth and yield of maize in the area.

*Keywords: Maize; growth and yield; fertilizer.*

## 1. INTRODUCTION

Maize, other names corn, Indian corn, mealis (English), mais (French), milho (Portuguese), maize (Spanish), Dura ash shahami (Opabic), makai, butta (Hindi) belongs to the family *poaceae*. Tribe - *maydeae*, Genus – *Zea* and Specie - *mays*. However, there are a number of theories regarding the origin of maize but it seems most probable that it originated in Mexico or Central America [1] where it has been in cultivation for more than 700 years [2]. Maize was brought to Europe by Columbus and was introduced into Africa by the Portuguese. Maize today is probably the next most important grain cereal after wheat in the world [3]. It is now found all over the world and its natural habitat is the tropics. In Nigeria, Maize is one of the major staple foods, fodder and industrial crop for commercial and subsistence level where it is grown in all agro ecological zones [4,5]. Maize is predominantly the cereal crop of Southern Nigeria, just as sorghum and millet are in the Northern Nigeria [4]. The crop to some extent is cultivated practically throughout the country. Maize is one of the oldest and widely cultivated World’s cereals and strong annual crop/grass, usually producing one stem and growing to a height of 1- 4.5 m. Older/local varieties of the crop mature after 100 – 120 days but more rapidly maturing varieties are now available. The male inflorescence called a tassel for hybrid varieties is produce after 50 – 60 days as a continuation of the main stem. The female inflorescence, called the ear or cob is a modified spike formed on a short branch in the axils of the largest foliage leaves.

Maize grows in a wide range of zones with altitude ranging from 100 - 2900 m above sea level and evenly distributed rainfall of 400 – 1200 mm during the growing period. Require well drained light loam or silty loams of alluvial soils with a pH of 5.5 - 7.0 and warm temperatures between 15-30ºC for good yields. It does not tolerate water logging. Cold conditions extends the maturity period whereas high temperatures lower the yields. Its ability to strive under different ecological conditions in Nigeria has led to increased production. The major pests of maize are fall army worm stalk borer, maize aphids and cutworms [6]. Major diseases include Maize Lethal Necrosis Disease (MLND), Maize smut and Northern leaf blight [7].

To obtain maximum growth and yield of maize, many research findings have shown that neither organic nor inorganic fertilizers alone can result in sustainable productivity [8]. Liquid (foliar) fertilizer is a form of fertilizer obtained by dissolving NPK 20:20:20 or NPK 15:15:15 in water to form soluble substance [9]. This dissolution can be made in a can bottle or any container. The fertilizer is spread to the leaf of the plant where quantities of the major plants food can be absorbed through the leaf at one time. The solid (granular) fertilizers have different nutrient elements required by plants in its composition, but the most essential ones are nitrogen, phosphorus and potassium. The nitrogen contain 1- 5% weight by plant and exist as nitrate ($NO_3^-$), ammonium ion ($NH_4^+$) and urea (Co $(NH_2)_2$). The nitrate form dominates in moist warm and aerated soils and it is the preferred form of nitrogen in plants. The phosphorus varies in concentration from 0.1 – 0.4% in plant and available as phosphate ion ($H_2PO_4^-$), orthophosphate ($HPO_4^{2-}$). Here the phosphate ion dominates in soil with optimal pH values. Other forms like phosphate are component of fertilizers and form orthophosphate during hydration. These phosphate ions are involved in the major soil chemical reactions and numerous metabolic pathways in plant nutrition with the most essential being the storage and transfer of energy [10].

The soils of the Tropical Rain Forest are heavily leached of plant nutrients due to heavy rainfall in the area [11]. The soils of Obubra belong to the soil order, Ultisols which are extensively weathered [12]. The soils are highly leached and therefore acidic in reaction probably due to high amounts of rainfall in the area [1]. Their major constraints include the sandy nature of the surface, prone to severe and internal erosion, low potassium reserve and high acidity thus necessitating regular liming [13,14]. The soils are generally suitable for most arable crops and cash crops [14]. Therefore, the objective of this study was to investigate the comparison of the effect of solid (granular) and liquid (foliar) fertilizers application on the growth and yield of maize.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

This research was carried out in the month of April, 2018 in sandy loam texture soils belonging to the soil order, Ultisols [12] at the Cross River University of Technology teaching and research farm, Ovonum, Obubra Local Government Area of Cross River State, Nigeria. Obubra lies between Latitude 06º5'8.466" N and 08º3280" E. The rainfall distribution is between 2250 – 2500 mm, a mean annual rainfall of 2375 mm [12]. The average temperature and humidity are 25ºC and 70%. The study area has a number of economic activities such as lumbering, fishing and craftsmanship. The area witnesses two major seasons usually characterized by heavy and incessant showers.

### 2.2 Experimental Site, Procedures, Treatments and Experimental Design

The research site is about 0.5 km away from the University Lecture Halls. Before the design of the experimental plot, composite soil samples were collected in a random manner using soil auger and analyzed for physical and chemical properties of the soil. Thereafter, the experimental plot was cleared during the month of March in the 2018 farming season. The plot was designed and blocked into subplots, each measuring 6 m x 4 m (24 $m^2$). Fifteen subplots containing eight ridges each were constructed making a total of one hundred and twenty ridges in the experimental plot. The total area of the experimental plot was 25 m x 20 m which gives a total of 500 $m^2$ (0.05 $ha^-$). Each block was separated from the other with a distance of 1 m apart and between subplots 0.5 m apart. The experimental design used was Randomized Complete Block Design (RCBD) with five replications in three (3) treatments namely treatment one (T1) - Zero application at the rate of 0 kg $ha^{-1}$ treatment two (T2) – liquid fertilizer (NPK 20:20:20) at the rate of 100 mil of N, 50 mil of $P_2O_{5,}$ 33.3 mil of Mp $ha^{-1}$ and treatment three (T3) – Solid fertilizer (NPK 20:20:20) at the rate of 44.4 kg of N, 40 kg of $P_2O_5$ and 33.3 kg of Mp $ha^{-1}$.

### 2.3 Sampling and Data Collection

The planting material (maize seeds) was obtained from local market of Ikom, Cross River State, Nigeria. The central row plants were used for data collection where growth parameters namely plant height, number of leaf per plant with yield components such as number of cobs; number of seeds per row and weight of grain after shelling were recorded. Plant height (cm) was measured from the base of the plant to the upper of the top most leaves. The numbers of functional leaves per plant was a visual count of the green leaves. The number of cobs was through counting from randomly selected cobs and the grain after shelling was weighed.

### 2.4 Laboratory Analyses

Five (5) composite soil samples were collected from the site and air-dried, gently crushed with pestle and mortar and sieved through a 2.00 mm sieve to obtain the fine earth fraction for the analysis. Particle size analysis was determined by Bouyoucos hydrometer methods using sodium hexametaphosphate (VII) as dispersant [15]. Soil texture was determined using USDA soil textural triangle [16]. Five (5) undisturbed soil samples were collected by 100 $cm^3$ metallic cores and oven-dried at 105ºC to constant weight for determination of bulk density. The pH was determined potentiometrically with a glass electrode pH meter in water at 1:2.5 soils: water ratio [17]. Organic Carbon was determined following the Walkley and Black wet oxidation method as outlined by [18]. Total nitrogen was determined by the micro-kjeldhal method [15]. Available phosphorus was determined by extraction with Bray P-I extractants described by [19]. Exchangeable acidity was determined by

**Table 1. Fertilizer type, rate applied on each plot and hectare**

| TRTS. | Treatment and replication | Fertilizer type | Rate applied/each plot | Rate applied/ha |
|---|---|---|---|---|
| T1 | $T_1R_1$, $T_1R_2$, $T_1R_3$, $T_1R_4$& $T_1R_5$ | Nothingness | Nothingness | Nothingness |
| T2 | $T_2R_1$, $T_2R_2$, $T_2R_3$, $T_3R_4$& $T_2R_5$ | NPK 20:20:20 | 0.24 mil of N, 0.12 mil of $P_2O_5$, 0.08 mil of Mp | 100 mil of N, 50 mil of $P_2O_5$, 33.3 mil of Mp |
| T3 | $T_3R_1$, $T_3R_2$, $T_3R_3$, $T_3R_4$& $T_3R_5$ | NPK 20:20:20 | 0.11 kg of N, 0.10 kg of $P_2O_5$, 0.08 kg of Mp | 44.4 kg of N, 40 kg of $P_2O_5$, 33.3 kg of Mp |

successive leaching of soil with neutral unbuffered 1N KCl using 1:10 Soil: Liquid ratio. The amount of $H^+$ and $Al^{3+}$ in the leachate was determined by the titration method [15]. Exchangeable cations were determined with 1N ammonium acetate (pH 7.0) using 1:10 Soil: Water ratio. $Ca^{++}$ and $Mg^{++}$ in the filtrate were determined with an atomic adsorption spectrophotometer (AAS) while $Na^+$ and $K^+$ were determined with a flame photometer as described by [15]. Cation exchange capacity (CEC) was determined by the neutral ammonium acetate (pH 7.0) method. While effective cation exchange capacity was calculated by summing up exchangeable acidity ($H^+$ and $Al^{3+}$) and exchangeable bases ($Ca^{2+}$, $Mg^{2+}$, $K^+$ and $Na^+$). Base saturation was determined by dividing the summation of exchangeable bases ($Ca^{2+}$, $Mg^{2+}$, $K^+$ and $Na^+$) by the effective cation exchange capacity and multiplies by 100. The formula is as follows:

$$\text{Base saturation} = \frac{\text{Total Exchangeable bases}}{\text{ECEC}} \times \frac{100}{1}$$

## 2.5 Data Analysis

Data collected on various growths and yield parameters were subjected to analysis of variance (ANOVA) in Randomized Complete Block Design (RCBD). The treatments mean were separated by F-LSD test at 5% probability level using GenStat software version 8.10.

# 3. RESULTS AND DISCUSSION

## 3.1 Soil Properties before Trial of Fertilizer

The result on the soil physical and chemical properties before trial of fertilizer is shown in Table 2. The results showed that the soil had a sandy loam texture with high proportion of sand content and deficient in nutrients. The soil pH (5.4) showed very strongly acidic milieu [20]. The organic carbon, total N, and available phosphorus were low. The low contents in organic carbon, total N and available P could be attributed to the effects of intensive cultivation of the soils in the area. This conforms to the work of [21,9] who stated that continuous cultivation of land results in the reduction of soil nutrients especially organic carbon. The low content of available P might be attributed to the pH. The exchangeable bases were low with no Mg2+. This might be attributed to high rainfall in the areas which leaches the basic cations down the profile. The exchangeable acidity was high indicating the acidic condition of the soil. The soil requires fertility management practices.

**Table 2. Results on soil properties before application of fertilizer**

| Physico-chemical properties | Quantity |
|---|---|
| Sand (%) | 74.0 |
| Silt (%) | 16.0 |
| Clay (%) | 10.0 |
| pH ($H_2O$) | 5.4 |
| Org. Carbon (%) | 1.13 |
| Total nitrogen (%) | 0.14 |
| Av. P (mg/kg) | 15.63 |
| **Exchangeable cations (cmol/kg)** | |
| $Ca^{2+}$ | 2.4 |
| $Mg^{2+}$ | 0 |
| $K^+$ | 0.09 |
| $Na^+$ | 0.07 |
| **Exchangeable acidity (cmol/kg)** | |
| $Al^{3+}$ | 1.32 |
| $H^+$ | 2.36 |
| ECEC | 6.64 |
| B.S (%) | 44.58 |
| **Textural class** | **Sandy loam** |

## 3.2 Plant Height (cm)

The plant heights were measured in centimeters (cm) in each subplot. The results are presented in Table 3. The results analyzed for the 6 and 8 weeks after planting were highly significantly (P≤0.05) difference. Treatment three ($T_3$) recorded the highest plant height, mean values of 57.94 and 64.02 followed by treatment two ($T_2$) which recorded mean values of 52.24 and 58.24, followed by treatment one ($T_1$) which recorded the least number in plant height, mean values of 41 and 53.08. Treatment three ($T_3$) that recorded the highest followed by treatment two ($T_2$) could be attributed to the effect of fertilizers applied which enhanced the growth and yield. This agrees with [22] who elucidated that there was high significant difference in maize plant height in plots treated with fertilizers compared to zero application.

## 3.3 Number of Leaves

Numbers of leaves per plant on 10 plants in the middle row were counted and their mean obtained for each treatment at 6 and 8 WAP. The

**Table 3. Results of plant heights at 6 weeks and 8 weeks after planting**

| TRTS. | 6WAP | | | | | | | 8WAP | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R1 | R2 | R3 | R4 | R5 | Total | Mean | R1 | R2 | R3 | R4 | R5 | Total | Mean |
| 1 | 40.1 | 35.6 | 40 | 43.2 | 46.1 | 205 | 41 | 55 | 50 | 56.1 | 49.8 | 54.5 | 265.4 | 53.08 |
| 2 | 50.1 | 50.2 | 53.5 | 56.2 | 51.2 | 261.2 | 52.24 | 50 | 56 | 65.2 | 59.5 | 60.5 | 291.2 | 58.24 |
| 3 | 60 | 45 | 60.1 | 60.5 | 64.1 | 289.7 | 57.94 | 64 | 61.5 | 68.5 | 69.4 | 56.7 | 320.1 | 64.02 |
| BLK Total | 150.2 | 130.8 | 153.6 | 169.9 | 161.4 | 755.9 | | 169 | 167.5 | 189.5 | 178.7 | 171.7 | 876.7 | |

*F-LSD (0.05) ** F-LSD (0.05) **

*WAP = Week after Planting R = Replication, TRTS =Treatments, * = Significant; ** = not significant*

**Table 4. Results of number of leaves at 6 weeks and 8 weeks after planting**

| TRTS. | 6WAP | | | | | | | 8WAP | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R1 | R2 | R3 | R4 | R5 | Total | Mean | R1 | R2 | R3 | R4 | R5 | Total | Mean |
| 1 | 9.2 | 10 | 7.5 | 8.2 | 8.1 | 43 | 8.6 | 10.5 | 9.5 | 10.6 | 10 | 10 | 50.6 | 16.12 |
| 2 | 9.7 | 9.6 | 10.6 | 10.2 | 10.1 | 50.6 | 10.12 | 13 | 11 | 13 | 12 | 11.4 | 60.4 | 12.08 |
| 3 | 11.1 | 11 | 10.2 | 9.3 | 11.5 | 53.1 | 10.62 | 14 | 13.5 | 13 | 12.5 | 15 | 68 | 13.6 |
| BLK Total | 30 | 30.6 | 28.3 | 27.7 | 30.1 | 146.7 | | 37.5 | 33.8 | 36.6 | 34.5 | 36.4 | 179 | |

*F-LSD (0.05) ** F-LSD (0.05)*; WAP = Week after Planting R = Replication, TRTS =Treatments, * = Significant, ** = not significant*

**Table 5. Results of number of cobs in each subplot**

| TRTS. | R1 | R2 | R3 | R4 | R5 | Total | Mean |
|---|---|---|---|---|---|---|---|
| 1 | 5 | 5.5 | 5.5 | 5 | 5.5 | 26.5 | 5.3 |
| 2 | 6.5 | 6.5 | 6.5 | 6 | 6 | 31.5 | 6.3 |
| 3 | 7 | 8 | 7 | 7 | 7 | 37 | 7.4 |
| BLK Total | 18.5 | 20 | 19 | 19 | 18.5 | 95 | |

*F-LSD (0.05)*; WAP = Week after Planting R = Replication, TRTS =Treatments, * = Significant*

**Table 6. Result of 1000 seeds weight in each subplot**

| TRTS | R1 | R2 | R3 | R4 | R5 | Total | Mean |
|---|---|---|---|---|---|---|---|
| 1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.5 | 0.1 |
| 2 | 0.2 | 0.1 | 0.2 | 0.2 | 0.2 | 0.9 | 0.18 |
| 3 | 0.3 | 0.2 | 0.3 | 0.3 | 0.3 | 1.4 | 0.28 |
| BLK Total | 0.6 | 0.4 | 0.6 | 0.6 | 0.6 | 2.8 | |

*F-LSD (0.05) **

*WAP = Week after Planting R = Replication, TRTS =Treatments, * = Significant*

**Table 7. Result of weight of grain after shelling in kg**

| TRTS | R1 | R2 | R3 | R4 | R5 | Total | Mean |
|---|---|---|---|---|---|---|---|
| 1 | 0.9 | 0.8 | 1.2 | 1.0 | 1.2 | 5.1 | 1.02 |
| 2 | 1.3 | 1.4 | 1.4 | 1.3 | 1.3 | 6.7 | 1.34 |
| 3 | 1.3 | 1.6 | 1.5 | 1.7 | 1.5 | 7.6 | 1.52 |
| BLK Total | 3.5 | 3.8 | 4.1 | 4.0 | 4.0 | 19.4 | |

*F-LSD (0.05) *; WAP = Week after Planting R = Replication, TRTS =Treatments, * = Significant*

result is presented in Table 4. The result shows that number of leaves for 6 weeks was not significant (P≥0.05) while that of 8 weeks was significant (P≥0.05) with treatment three ($T_3$) recording the highest number of leaves, mean values of 10.62 and 13.6 respectively, followed by treatment two ($T_2$) which recorded mean values of 10.12 and 12.08 and treatment ($T_1$) recording the least mean values of 8.6 and 10.12 at both 6 weeks and 8 weeks after planting. The highest number of leaves recorded in treatment three ($T_3$) followed by treatment two ($T_2$) was due to the fertilizer application which boasted the growth of vegetative part of the plant.

### 3.4 Number of Cobs (kg)

The result on the number of cobs in each subplot is presented in Table 5. The result shows that treatment three ($T_3$) recorded the highest number of cobs, a mean value of 7.4 followed by treatment two ($T_2$) which recorded the mean value of 6.3 and treatment one ($T_1$) recorded the least mean value of 5.3. There was high significant ($P \leq 0.05$) difference in the number of cobs. This could be attributed to application of fertilizer resulting to taller plant which bears more cobs. This conforms to [23] who noticed that plant height is an important parameter of yield of maize as usually taller plant bears more cobs and offers more yield.

### 3.5 1000 Seeds (g)

The result of 1000 seeds weight in each subplot is presented in Table 6. The result shows that treatment three ($T_3$) recorded the highest weight with mean value of 0.28 g followed by 0.18 g recorded in treatment two ($T_2$) and treatment one ($T_1$) recorded the least mean value of 0.1 g. The result analyzed was significant ($P \geq 0.05$). The highest weight of seeds was recorded in treatment three ($T_3$) followed by treatment two ($T_2$) which might be attributed to the effect of fertilizers applied for better growth and grain filling of maize of crop.

### 3.6 Weight of Grain after Shelling

The result on the weight of grain after shelling is shown in Table 7. The result shows that there was significant ($P \leq 0.05$) difference. Treatment three ($T_3$) recorded the highest number, mean value of 1.52 followed by treatment two ($T_2$) which recorded the mean value of 1.34 and treatment one ($T_1$) recorded the least, mean value of 1.02. The high values recorded in treatment three ($T_3$) and treatment two ($T_2$) could be attributed to the fertilizers applied resulting in maximum grain numbers. The result agrees with [5 and 3] who reported that maize crop fertilized with fertilizers produced maximum grain number per cob.

## 4. CONCLUSION AND RECOMMENDATION

The study concludes that the soil was generally deficient in nutrients for growth of maize. The application of treatments affected the physical and chemical properties of these soils in plots applied with treatments as shown in the growth performance and yield of the crop (maize). This shows that treatment three ($T_3$) performed the best, followed by treatment two ($T_2$) while treatment one ($T_1$) came least in both growth and yield. The solid (granular) fertilizer was found to be more effective and therefore should be recommended for maize production in the area and nutrient management should also be adopted for the soil if it is to be put into agricultural use.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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