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Nitrogen (N) and Phosphorus (P) Fertilizer Application on Maize (*Zea mays* L.) Growth and Yield at Ado-Ekiti, South-West, Nigeria

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

Nutrient depletion as a result of continuous cultivation without supplementary addition of external inputs is a major challenge to agricultural productivity in South-west Nigeria. An experiment was set up to evaluate the effects of nitrogen (N) and phosphorus (P) fertilizer application rates on the performance of maize (*Zea mays* L.) in field trials at the Teaching and Research Farm, Ekiti State University, Ado-Ekiti, south-west Nigeria. The treatments consisted of 2 factors (i) N at 0, 30, 60, 90kg $N.ha^{-1}$ (ii) P at 0, 15, 30, 45kg $P{\cdot}ha^{-1}$ in all possible combinations and laid out in a randomized complete block design arranged with three replicates. Data of plant height, leaf area, stem girth and cob length, cob diameter, 100 grain weight and grain yield were collected. The result showed that plant height, stem girth and leaf area· $plant^{-1}$ increased with N and P fertilizer rates. Cob length, cob diameter, 100 grain weight and grain yield, significantly (P=.05) increased with N and P application such that 90kg $N{\cdot}ha^{-1}$ and 30kg $N{\cdot}ha^{-1}$ gave the highest values. It may be concluded that application of the combination of N at $90kg{\cdot}ha^{-1}$ and P at $30kg{\cdot}ha^{-1}$ which produced the highest grain yield of maize could be regarded as the optimum for N and P in the study area. Therefore, further work should be carried out to ascertain the validity of this rate for maximum productivity.

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1. INTRODUCTION

Cereals are the main crops grown in a wide range of environments in various parts of the world and can provide approximately 55% of proteins, 15% of fats, 70% of glucosides and 50-55% calories needed by man [1,2]. Maize is an important cereal crop in Nigeria, which is a useful ingredient in the formulation of livestock feed and other food preparations [3]. It is consumed fresh or processed, depending on the users' demand to provide raw materials for industrial preparation of several by-products like corn starch, corn oil, dextrose, corn syrup, corn flakes, cosmetics, wax, alcohol and tanning materials [4]. Thus, maize production and utilization are being promoted as viable ventures to farmers because of the numerous benefits and economic importance [5].

Maize is a heavy feeder of nutrients particularly nitrogen, phosphorus and potassium which are needed for good growth and high yield of crops [6]. The low fertility status of most tropical soils is a hindrance to production of maize, which removes a lot of nutrients from the soil. Thus, without an adequate nutrient supply, maize would fail to produce high grain yield [7]. Inorganic fertilizers supply the needed nutrients, and thus enhance plant luxuriant growth, development and yield [8].

Nitrogen is a major yield determining factor in maize production [9]. It is a critical component of protein, which controls the metabolic processes, required for optimum plant growth, and so must be available in sufficient quantity throughout the growing season of plant [10]. Unfortunately, the capacity of tropical soils to supply N declines rapidly as a result of agricultural activities, hence the inherent quantity of N derived from soil organic matter must be supplemented by other external sources.

Phosphorus is also required by maize for growth, being an essential component of nucleic acid, phosphorylated sugar, lipids and protein and so, plays a vital role in grain production [11]. It forms high-energy phosphate bonds with adenine, guanine and uridine, which act as carriers of energy for many biological reactions. It is important for seed and fruit formation and hastens crop maturation. Phosphorus hastens the ripening of fruits and can counteract the effects of excess N applied to the soil. Root growth and development are critical for early P uptake by plants, since it is relatively unavailable and immobile in many soils [12]. Thus, maize P requirement is high at the early stages of growth [13]. Adediran and Banjoko [14] reported positive and significant responses of maize to low P rates in the southern guinea savanna zones of Nigeria. Thus, in order to achieve high yields of maize, there is need for balanced N and P nutrition of maize. Several fertilizer trials, carried out in different locations in Nigeria showed that responses to applied N and P, in term of growth and grain yield depend on maize varieties with hybrid cultivars requiring higher fertilizer rates for optimum yield. Therefore, in view of the importance of maize as a grain crop and the role of nitrogen and phosphorus in its high productivity, this study was designed to examine the effect of varying nitrogen and phosphorus fertilizer rates on growth and yield of maize at Ado-Ekiti, Southwest Nigeria.

2. MATERIALS AND METHODS

2.1 Site Description

A field trial was conducted at the Teaching and Research Farm, Ekiti State University, Ado-Ekiti, Ekiti State, Nigeria, in 2010 and 2011 cropping seasons. The location experiences a tropical climate with distinct wet and dry seasons from late March to October and a dry spell in August. Mean annual rainfall, rainy days and temperature were 1367mm, 112 and 27°C, respectively. The soil of the study site has been identified as an Alfisols [15] derived from granitic rocks of the basement complex, highly leached with low to medium organic matter content. The site had been under continuous cultivation for some years to some arable crops, among which are maize, cassava, cocoyam before it was left to fallow for three years, prior to the commencement of this study.

2.2 Soil Sampling and Laboratory Analysis

Prior to planting, ten core samples randomly collected from 0-15cm soil depth, were bulked to form a composite sample, which was analyzed. The samples were thoroughly mixed, dried, crushed and sieved, using a 2 mm sieve. Particle size distribution was carried out by the hydrometer method [16]. The pH was determined in water (ratio1:1, soil: water). Soil pH in KCl (1:1), 20g of soil and 20ml of water was used and equilibrated for 30 minutes with occasional stirring. pH was determined and measured in KCl [17]. Organic carbon was determined by wet dichromate method [18] and the total N by the micro kjeldahl digestion method [19]. Available P was determined using Bray extraction method [20], while exchangeable cations were determine by extracting with neutral 1M NH_4OAc in a solution ratio of 1:10 and measured by flame photometer. Magnesium was determined with an atomic absorption spectrophotometer. Effective cation exchange capacity (ECEC) was obtained using summation method (i.e. sum of Ca, K, Mg, Na and exchangeable acidity). The determination of exchangeable acidity was made using the extraction-titration method.

2.3 Treatments and Experimental Design

The experiment is a 2x4 factorial, the two factors are (i) N at 0, 30, 60, 90 kg N $\cdot ha^{-1}$, (ii) P at 0, 15, 30, 45 kg P$\cdot ha^{-1}$ and in all possible combination of N and P fertilizer laid out in a randomized complete block design arranged with three replicates. The source of N was urea (46% N) while that of P was single super phosphate (18% P_2O_5). A basal application of K (50kg $K_2O\cdot ha^{-1}$) in form of muriate of potash (KCl) was applied to all treatment plots. Three seeds of early maturing maize variety were sown per hole at 75 x 25cm spacing in a 3x5m treatment plot and later thinned to one seedling per stand at one week after emergence giving a population of 53333 maize plants per hectare. Weeds were controlled manually by hand at 3 weeks after planting.

2.4 Data Collection

Data were collected on growth parameters of randomly selected maize plants in each plot. Plant height was measured from soil level up to the tip of highest leaf with a tape meter rule. Stem diameter was measured with the aid of Vernier Caliper from top middle and bottom portion of the same stem and the averages calculated. The leaf area per plant was calculated as the product of leaf length and widest middle portion of the leaf and then multiplied by a correction factor 0.75 [21]. Yield parameters included ear height, cob length, cob diameter, 100 seed weight and grain yield which was determined at 12.5% moisture content.

2.5 Data Analysis

Data collected on growth and yield parameters were subjected to analysis of variance (ANOVA) using Statistical Analysis System Institute Package [22]. The differences between treatment means were separated using Duncan's Multiple Range Test (DMRT) at 5% level of probability.

3. RESULTS AND DISCUSSION

3.1 Physical and Chemical Properties of the Soil Used

The data on physical and chemical properties of the soil prior to cropping are presented in Table 1. The data indicated that the soil were slightly acidic loamy sand. The values for N and P were below the critical level values obtained for soils in South-west Nigeria, as reported by [23]. The low N and P values can be explained in the light of the low organic matter content of the soil such that maize would be expected to benefit from added N and P fertilizers.

3.2 Effects of N and P Fertilizer Application on Growth Parameters of Maize

The result of this study showed that N and P individually had significant (P=0.05) effects on plant height. Plant height has been described as a measure of growth related to the efficiency in exploitation of environmental resources [4]. This growth character is directly linked with the productive potentials of plants in terms of fodder and grain yield [24]. The highest N dose in this study (Table 2) resulted in the tallest plant (139.8cm) which was not significantly different from 139.27cm obtained from 60kg $N.ha^{-1}$ application. Grazia et al. [25] noted that plant height can be increased with N application. Also, increase in plant height with nitrogen and phosphorus application has been reported by Ayub et al. [26] and Cheema [27]. This observation is also in agreement with the findings of Babatola [5] who reported that increasing level of fertilizer application led to increase in growth and yield of crops. Law-Ogbomo and Law-Ogbomo [28] reported that in *Zea mays,* plant height was increased with successive increment in NPK fertilizer application rate up to 600 $kg\cdot ha^{-1}$. Stem girth increased significantly (P=.05) with N application to maximum values of 2.92cm while leaf area and number of leaves increased up till 60 $kg.ha^{-1}$ with values of 692cm^2 and 14.30 respectively after which there is reduction.

Table 1. The physical and chemical properties of soil of the study site prior to cropping

Parameters	2010	2011	Methods
pH (1:1) H_2O	4.82	4.60	Glass electrode pH meter [17]
Organic carbon ($g \cdot kg^{-1}$)	3.41	2.24	Wet dichromate [18]
Total nitrogen ($g \cdot kg^{-1}$)	0.21	0.26	Modified Kjeldal [19]
Available phosphorus ($mg \cdot kg^{-1}$)	4.06	5.60	Bray 1[20]
Exchangeable bases ($cmol \cdot kg^{-1}$)			
K	0.17	0.20	Flame photometer
Ca	2.28	2.42	Atomic absorption spectrophotometer
Mg	0.92	0.45	
Na	0.43	0.60	
Exch. Acidity	0.17	0.16	
Effective cation exchange capacity	3.97	3.83	
Particle size analysis ($g \cdot kg^{-1}$)			
Sand	786	813	Hydrometer method [16]
Silt	128	132	
Clay	140	54	
Textural class	Loamy sand	Sandy loam	

Table 2. Effect of N and P fertilizers rate on growth parameters of maize

Treatments	Plant height (cm)	Stem girth (cm)	Leaf area (cm^2)	Number of leaves per plant
Nitrogen ($kg \cdot ha^{-1}$)				
0	126.48c	2.73b	624.63a	12.83b
30	130.57b	2.60c	665.16a	12.91b
60	139.27a	2.72b	748.16a	14.30a
90	139.83a	2.92a	692.30a	12.75b
Phosphorus ($kg \cdot ha^{-1}$)				
0	110.79c	2.40c	588.98c	12.58a
15	135.27b	2.65b	672.58b	12.83a
30	135.22b	2.80ab	683.54b	13.00a
45	154.80a	2.92a	754.90a	13.02a
Mean	134.02	2.69	678.78	12.85
SE±	70.5	0.23	62.4	0.31

Means followed by the same letter in each column are not significantly different at P=.05 using DMRT

Phosphorus application increased maize plant height, stem girth, leaf area and number of leaves but the application rate of 15kg and 30kgP$\cdot ha^{-1}$ in plant height, stem girth and leaf area was not different (Table 2). Plant height increased from 110.79cm in the control to 154.80cm at 45kg$\cdot ha^{-1}$ P. The increase in leaf number was not significant with P application.

Ear height is strongly influenced by soil, water, nutrients, light situation and plant competition due to plant density whose optimization is necessary to maximize the genetic potential of maize cultivars. Ear height increased with N rates from 71.3cm in the control up till 81.0 cm at 60kg N$\cdot ha^{-1}$ and decreased at 90kg N.ha^{-1} (Table 3). However, this maximum ear height was not significantly different from 30kg N$\cdot ha^{-1}$ rate. P application did not significantly increase ear height (Table 3).

3.3 Effects of N and P Fertilizer Application on Yield Components of Maize

Cob length and cob diameter increased significantly (P=.05) with N application. The maximum cob length (17.68cm) and cob diameter (3.92cm) were recorded at 90 kg N$\cdot ha^{-1}$. The least cob length (15.19cm) and cob diameter (3.45cm) were recorded in control plot. However, maize fertilized with 30 kg N$\cdot ha^{-1}$ and 60 kg N$\cdot ha^{-1}$ rates were not significantly different in terms of these features. The significant response may probably be due to adequate supply of N which enhanced more photosynthetic activities of the plant. Crawford et al. [29] had stated that N is an essential requirement for cob and kernel growth in maize. Also, Akhtar and Silva [30] had observed significant increases in cob diameter and cob length with increase rates of nitrogen from different N sources.

Phosphorus application to maize was significantly affected, the highest value of cob length (17.60 cm) and cob diameter (4.73 cm) was obtained with 45kg P·ha^{-1} which is 7.8 and 5.7% increase over the control. The maximum dry cob yield (12.61t·ha^{-1}) was obtained at 60kgN·ha^{-1} treated plants whilst the control plant had the least (4.42t·ha^{-1}). The dry cob yields obtained with the application of 30, 60 and 90kg/ha N was106, 185 and 170% increase relative to the untreated plant respectively. Also for P application of 45kg·ha^{-1} gave the maximum dry cob yield (13.4t·ha^{-1}) which was 72% increase over the untreated plants.

3.4 Effects of N and P Fertilizer Application on 100 Grain Weight of Maize

The effect of N and P fertilizer application on 100 grain weight is presented in Table 3. The 100 grain weight is an important yield determining factor; it expresses the magnitude of seed development for deriving the grain quality and yield per hectare [31]. The effects of N and P rates on 100 grain weight showed that N application resulted in significant (P=.05) increase as the rate increase and for P, it increased up to 30kg·ha^{-1} after which there was reduction. This suggests a linear relationship between maize grain weight and increase rate of N and quadratic relationship with P application. Ma et al. [32] had reported a linear increase in the weight of 100 grain in two varieties of maize and this was attributed to increase in nitrogen which plays very important roles in several physiological processes in plants.

3.5 Effects of N and P Fertilizer Application on Grain Yield of Maize

Grain yield is an important economical part of the plant which is available to man and livestock. It is affected by environmental factors and genetic potential of plant. Grain yield was significantly affected by both N and P application as indicated in Table 3. Sole application of N at 90kg·ha^{-1} produced grain yield 3102.5 kg·ha^{-1} compared to 1853.6 kg·ha^{-1} in the control. Falhi [33] had reported that the use of nitrogen gives significant increases in maize grain yield. The increase in yield from application of N was mainly due to greater plant height, stem diameter and leaf area of the plant [34]. Nyende et al. [35] had stated that the rapid growth rate may have promoted photosynthetic activities in maize plants with resultant high carbohydrate production during fruiting, based on the premise that the growth of plant is positively correlated with their yields. Also, increase in fodder yield with N and P application has also been reported by [26,36,27]. Phosphorus fertilizer rate at 30 kg·ha^{-1} produced grain yield of 3091.5 kg·ha^{-1} and beyond which there was a significant reduction while the least value was recorded in the control plot. This could probably be as a result of plant growth which might be affected due to deficiency of Zn induced by high P levels as reported by Sinha et al. [37].

Table 3. Effect of N and P fertilizers rate on yield and yield components of maize

Treatments	Ear height (cm)	Cob length (cm)	Cob diameter (cm^2)	Dry cob weight (t·ha^{-1})	100 grain weight (g)	Grain yield (kg·ha^{-1})
Nitrogen kg·ha^{-1}						
0	71.26c	15.19c	3.45c	4.42d	20.45c	1853.6d
30	78.74a	16.20b	3.57b	9.10c	25.10b	2403.2c
60	80.98a	16.73b	3.60b	12.61a	26.30b	2901.7b
90	76.26b	17.68a	3.92a	11.93b	28.71a	3102.5a
Phosphorus kg·ha^{-1}						
0	75.19a	16.32b	3.01b	3.64d	19.34d	1990.7d
15	75.13a	17.30a	3.38b	8.32c	21.60c	2521.4b
30	79.17a	17.50a	4.32a	11.45b	24.21a	3091.5a
45	79.34a	17.60a	4.73a	13.40a	23.60b	2106.3c
Mean	77.21	17.18	3.86	9.20	22.19	2427.48
SE±	0.026	0.23	0.036	1.38	4.50	76.8

Means followed by the same letter(s) in each column are not significantly different at P=.05 using DMRT

3.6 Effects of N x P Fertilizer Application on Maize

Nitrogen and phosphorus and their interaction effect were significant (P=.05) on 100 grain weight and grain yield (Table 4). Since the interaction of N × P rate was significant; mean values for each treatment combination are presented in Table 4. Means Comparison of interaction effect indicated that among all interactions, the highest grain yield (3420 $kg{\cdot}ha^{-1}$) was recorded in the combination of 90 kg $N{\cdot}ha^{-1}$ with phosphorus application of 30 kg $P{\cdot}ha^{-1}$ followed by the combinations of similar nitrogen level with lower rate of 90 kgN +15 kg $P_2O_5{\cdot}ha^{-1}$. This combination produced 21% and 34% more yield than when N or P were applied alone and more than 78% the yield obtained from control plots. Irrespective of N rate, there was increase in 100 grain weight as P application increased up to 30 kg P except at the control plot where there is no nitrogen application.

Table 4. Effects of N x P interactions on grain yield of maize

Fertilizer ($kg{\cdot}ha^{-1}$)		100 grain weight(g)	Grain yield ($kg{\cdot}ha^{-1}$)
Nitrogen	Phosphorus		
0	0	20.5f	1921h
	15	20.7f	2321f
	30	21.0f	2534e
	45	21.4f	2106g
30	0	23.2e	2412ef
	15	24.3d	2607d
	30	24.8d	2532e
	45	23.6e	2710c
60	0	25.6c	2423ef
	15	26.3c	2650d
	30	26.9b	2734c
	45	25.7c	2801b
90	0	26.9b	2825b
	15	27.6b	3102b
	30	28.8a	3420a
	45	28.5a	2905bc
Mean		24.72	2625.19
SE±		3.22	77.6

Means followed by the same letter in each column are not significantly different at (P=.05) using DMRT

4. CONCLUSION

The applications of N and P fertilizer thus have a profound significant influence on the growth and performance of maize. From this study, it may be concluded that application of the combination of N at $90kg{\cdot}ha^{-1}$ and P at $30kg{\cdot}ha^{-1}$ which produced the highest grain yield of maize could be regarded as the optimum for N and P in the study area. Therefore, further work should be carried out to ascertain the validity of this rate for maximum productivity.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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