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Performance of *Zea mays* as Influenced By variety, Inorganic Fertilizer and Plant Density

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Authors' contributions

This work was carried out in collaboration between all authors. Author IK designed the study and wrote the manuscript. Author OST did the field work, collected and presented the data. Author YAA supervised the work and guided the conduct of the experiment and data collection. Authors WBB, OFA, TBS, and YO are my co-researchers. All authors read and approved the final manuscript.

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ABSTRACT

A study was conducted to assess growth and yield performances of maize under the influence of inorganic fertilizer, population density and variety. Treatments used were factorial combinations of two maize varieties (DMR-ESR-Y and Suwan-1-SR), 70 × 30 cm and 100 × 40 cm plant spacing and three levels of NPK 15:15:15 (0, 60 and 120 kg NPK/ha). Data were collected on leaf production, plant height, ear height, leaf area, leaf area index, days to 50% flowering, days to tassel and silk appearances, stem dry weight, root dry weight, cob weight, kernel rows per cob, harvest index and final grain yield. It was revealed that combination of 120 kgN/ha with DMR - ESR - Y and 47619 plants/ha could improve dry matter, yield and yield components. Therefore, production of

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DMR‐ESR‐Y maize variety with application of 120 kgNPK/ha at population density of 47619 plants/ha can be used for better maize yield improvement to cater for the ever increasing population of consumers especially in the ecological zone where the research was conducted.

Keywords: NPK fertilizer; population density; maize variety; growth performance and yield improvement

1. INTRODUCTION

Maize is an important cereal crop that is grown as food for human and feed for livestock. The dramatic transformation of maize production from subsistence to commercial level in both Southern and Northern Guinea savanna of Nigeria is a good proof that maize has become a major source of income to many farmers. That is why maize is rated the third most important cereal crop after sorghum and millet based on cropped land and quantity produced [1]. This rating might partly be because maize is a staple for many people in the country as the grain could be processed into different dishes for men and feed for animals. It is equally a sine qua non raw material to breweries which in turn fattens the economy of the nation. In Nigeria, savannah zone is the major area for the production of the crop in Nigeria. The consumption of the crop is by the majority of the inhabitants of the country and it increases on regular basis. So, the yield should have a boost to cater for the demand of the consumers. Maize contains 9.7396% grain protein, 4.85% grain oil, 9.4392% grain crude fibre, 71.966% grain starch, 11.77% embryo while fodder contains 22.988% acid detergent fibre, 51.696% neutral detergent fibre, 28.797% fodder cellulose, 40.178% fodder dry matter, 26.845% fodder crude fibre, 10.353% fodder crude protein and 9.095% fodder moisture [2-3].

Nutritional approach is a better channel for achieving yield increase in maize production. This is because the major processes of plant development and yield formation requires major nutrients like N, P, K and Mg in balanced form [4]. To establish this further, it has been established that maize fails to produce good grain in the absence of adequate nutrients [5]. These nutrients can be adequately supplied by inorganic fertilizers. Inorganic fertilizers exert strong influence on plant growth, development and yield [6-9]. The advantage of using inorganic fertilizers is that nutrients are immediately made available to plants and exact needed amount of a particular nutrient element can be measured before feeding the plants. Because inorganic fertilizer has its nutrients in soluble form and are immediately made available to plants, their effects are usually direct and fast. Equally, they are quite high in nutrient contents and only relatively small amounts are required for crop growth. Nitrogen which is a part of the major nutrients is a component of protein and nucleic acids and when it is at sub-optimal level, plant growth is reduced [10-12]. Moreover, nitrogen deficiency decreases grain yield and plant weight in hybrid maize but harvest index may not differ significantly from the control [13-15]. However, inorganic nitrogen fertilizer is easily leached out by rain or irrigation [16]. Also, its nutrients may become unavailable as a result of fixation, leaching or gas emission leading to reduced fertilizer efficiency [16]. Furthermore, It aids decomposition of soil structure. Nevertheless, inorganic fertilizer is a major input in crop production process and its use is the most adopted agricultural technology by farmers in Nigeria [17].

Plant density is an efficient management tool for maximizing grain yield through increasing capture of solar radiation within the canopy. An optimum plant population for maximum economic yield exists for all crop species and varies with cultivar and environment [18]. Generally, the most appropriate spacing is the one which enables the plants to make the best use of the materials at their disposal [19]. For each production system in maize, there is a population density that maximizes the utilization of available resources and allows expression of maximum attainable grain yield potential in that environment [20-21]. This is because maize is the most sensitive crop to variation in population density among grass family members. Very close spacing interferes with normal plant development and increases intra-specific competition resulting in yield reduction. In contrast, too wide spacing may result in excessive vegetative growth of plant and abundant weed population due to availability of more feeding area. Therefore, the use of optimum plant population density without exceeding the economic threshold can increase the competitive ability of the crop plants to suppress weed spread on the field. Similarly, growing crops in narrower row spacing can reduce weed growth, although the degree of reduction is crop-dependent [22-23]. Plant population density which results in inter-specific competition has direct effects on the vegetative and reproductive development of maize [24]. However, it should be noted that maize has small capability to develop new reproductive structures in response to an increase in available resources. Nevertheless, if plant density is too high, there will be reduction in the availability of resources per plant, especially in the period surrounding silk appearance leading to marked fall in yield per plant which could not be offset by increase in plant number [20].

The quest for improved high yielding and disease or pest resistant maize varieties has become sine qua non for profitable maize production. Research efforts at national, regional and international levels often lead to the release of new cultivars that must be tested in various agro-ecological zones for adaptation, yield potential and disease tolerance before their release to farmers [25-26]. Despite that, most of the maize farmers in Nigeria still adopt the local varieties despite their low yield potential. This situation contributes greatly to low yield in maize production in the country. This is not only in maize but also in sorghum, rice and other cereal crops. Among the cereals, hybrid maize responds differently to high population density as well as soil and climatic conditions and they produce higher grain yield at higher plant densities than the local varieties. They are also smaller, produce longer leaves, have higher leaf areas per plant, and have fewer self-shading problems than the local cultivars.

Maize production in the sub-saharan Africa was reported to have an increasing trend of between 2% to 3% annually [27]. This current rate of its production cannot fulfil the growing demand of ever increasing human population in Nigeria. At present, expansion of the production area is not feasible because of ever increasing population and the use of agricultural land for industrial and residential purposes. So, there is need for a shift from extensive to intensive production of the crop. At present, there are different high yielding cultivars but the technologies used in producing the crop as well as unfavourable climatic and edaphic factors, it is still difficult to meet the demand for maize consumption due to poor yield. Therefore, this work was conducted to determine the role of variety, plant density and NPK fertilizer in improving growth and yield of maize.

2. MATERIALS AND METHODS

A study to assess the growth and yield performances of two maize varieties (SUWAN-1-SR and DMR – ESR – Y) under the influence of three levels of inorganic fertilizer and two different plant population densities was conducted at the Teaching and Research Farm of the Faculty of Agriculture, University of Ilorin, Ilorin, Nigeria. The university is located in the Southern Guinea savannah zone of the country between Latitude 8°29'N and Longitude 4°35'E. The land was mechanically ploughed and harrowed and left flat. Soil samples of the field were systemically taken and bulked to have a composite sample which was passed through 2 mm sieve and analysed for physico-chemical characteristics (Table 2). The field was then divided into 36 plots of size 3m × 3m. The treatments used were two open pollinated yellow maize varieties (DMR-ESR-Y and Suwan-1-SR), two population densities (47619 and 25,000 plants/ha) and three levels of NPK 15:15:15 (0, 60 and 120 kg NPK/ha) (Table 1). All the tested factors were combined in a 2× 2×3 factorial to have a total of twelve treatment combinations (Table 1).The experiment was laid out in Randomized Complete Block Design with three replications.

The two maize varieties (DMR-ESR-Y and Suwan-1-SR) were sown at a depth of 2cm in line with the stated densities. Immediately after planting, a pre-emergence herbicide (Atrazine) was applied with the aid of knapsack sprayer at the rate of 5L/ha to control weeds while supplementary manual weeding was resorted from time to time until harvest. This was done to keep the plots weed-free and to forestall introduction of another source of variation into the experiment.

The emerged seedlings were thinned to two at two weeks after planting (WAP). At four weeks after planting (WAP), NPK 15:15:15 was applied at the rate of 0, 60 and 120 kg NPK/ha to the designated plots according to the treatment combinations. Data collection started five weeks after planting at one week interval. Data collected were leaves per plant (green and dead leaves separately), plant height, ear height, leaf area, leaf area index, days to 50% flowering, days to tasselling and silk appearance, stem dry weight, root dry weight, leaf sheath dry weight, cob weight, kernel rows per cob, harvest index and yield per hectare. All data collected were subjected to Analysis of Variance (ANOVA) and, correlation analysis using Genstat 5.2 statistical package while significant means were separated using least significant difference (LSD) at 5% probability level.

3. RESULTS AND DISCUSSION

Number of leaves produced at all the periods of data collection was the same statistically ($p \leq 0.05$). All the treatments were not different from one another. Application of NPK fertilizer and non-application had the same effect on the measured parameter (Table 3). It has also been found that application of organo-mineral fertilizer with different methods could not aid increase leaf production over the control [28]. This could have resulted from having soil with enough nitrogen for leaf production and that the control plants had enough nutrients to grow and develop like fertilized plants. Furthermore, it could be because the nodes present in plant were not increased in number by the applied fertilizer. Instead of this, the internodes grew longer to favour tallness at the expense of leaf production which directly depends on the number of nodes present at a time. Similar to the effect of fertilizer was the influence of plant spacing. The tallest plants in this experiment were from treatment T10 (120Nkg/ha + Suwan - 1 - SR + 47619 plants/ha) while the shortest plants were found in treatment T3 (0kgN/ha + DMR - ESR - Y + 25000 plants/ha) (Table 4).

Appreciable plant height is basic to better trapping of solar energy for enhanced photosynthetic ability. In this work, maize height was improved by application of 120 kg NPK/ha at denser plant population density. This could be traced to the function of nitrogen in aiding vegetative growth of the plants through promoting apical growth of roots and shoots. The inorganic fertilizer used made sufficient growth nutrients available for the plants to have improvement in cell activities, cell multiplication, cell enlargement and consequent luxuriant growth [29]. The resulting luxuriant growth from application of fertilizer results in larger dry matter production [30] through better utilization of solar radiation and mobilization of more nutrient through developed roots [31]. From our results, there was linearity in the relationship between nitrogen application rate and height increase. Therefore, it could be conveniently said that the more the nitrogen applied using NPK fertilizer, the more the cell division at the apices because increase in height is a manifestation of such growth division. Higher population density did not seem to have affected differences in height (Table 4). This is because the direction of the growth is vertical and not horizontal. So, space did not constitute a source of stress to the plant growth. The genetic diversity of the maize variety did manifest when the two varieties were treated equally. Despite this insignificant difference ($p \leq 0.05$), it was evident that plants from Suwan-1-Sr were taller than DMR-ESR-Y.

Root dry weight, shoot dry weight, leaf sheath dry weight and straw weight were all enhanced by T12 (120kgN/ha + DMR - ESR - Y + 47619 plants/ha) while they were least influenced by T1 (0kgN/ha + Suwan - 1 - SR + 25000 plants/ha). Except for the population density, varietal difference also contributed significantly ($p \leq 0.05$) to increase in dry matter yield of different plant parts as observed in this experiment (Table 5). What was observed from plant height was carried on to dry matter production of different plant parts. This enhancement resulted from the

Table 1. Treatment combinations and their designations

Designations	Treatments
T1	0 kgNPK/ha + Suwan-1-SR + 25000 plants/ha
T2	0 kgNPK/ha +Suwan-1-SR+ 47619 plants/ha
T3	0 kgNPK/ha + DMR-ESR-Y + 25000 plants/ha
T4	0 kgNPK/ha + DMR-ESR-Y + 47619 plants/ha
T5	60 kgNPK/ha + Suwan-1-SR + 25000 plants/ha
T6	60 kgNPK/ha + Suwan-1-SR + 47619 plants/ha
T7	60 kgNPK/ha + DMR-ESR-Y + 25000 plants/ha
T8	60 kgNPK/ha + DMR-ESR-Y + 47619 plants/ha
T9	120 kgNPK/ha + Suwan-1-SR + 25000 plants/ha
T10	120 kgNPK/ha + Suwan-1-SR + 47619 plants/ha
T11	120 kgNPK/ha + DMR-ESR-Y + 25000 plants/ha
T12	120 kgNPK/ha + DMR-ESR-Y + 47619 plants/ha

aid provided by the fertilizer in improving vegetative lives of the plants [31]. The growth of the root tips led to better absorption of water and nutrients needed for luxuriant growth of the plants. This in turn increases the photosynthetic area of the plants for better interception of solar energy and consequent assimilate production [30]. This assimilate was then partitioned into different plant parts and, therefore, increase in dry matter production occurred. Even distribution of photo-assimilates produced was evident in higher dry root, shoot and leaf sheath weight recorded in this experiment.

Table 2. Physical and chemical analysis of the experimental site

Parameters	Values
pH(1:1) H_20	6.5
Nitrogen (%)	0.3
Organic Matter (%)	1.86
Available P (mg/kg)	10.2
Ca^{++} (Cmol/kg)	1.2
Mg^{++}(Cmol/kg)	0.8
Na^{++}(Cmol/kg)	0.2
K^{++}(Cmol/kg)	0.4
C.E.C (meq/100 g)	2.6
Particle size analysis	
Sand (%)	67
Silt (%)	14
Clay (%)	18
Textural class	Sandy loam

The maize cob length, cob diameter, kernel row, number of cobs per plant, shelling percentage, harvest index and grain moisture content at harvest were improved by treatment T12 (120kgN/ha + DMR‐ESR‐Y + 47619 plants/ha) while the least influence was from T1(0kgN/ha + Suwan‐1‐SR + 25000 plants/ha). It was only number of rows per cob that was improved better by T10 (120 Nkg/ha + Suwan‐1‐SR + 47619 plants/ha). All the differences in the above parameters were statistically significant ($p \leq 0.05$) except for the final harvest. Varietal influence did not statistically affect the measured parameters except for cob length, cob diameter and grain moisture content at harvest. In the same vein, population density had significant effect ($p \leq 0.05$) on cob length (Table 6). This implies that the major influencing component of the treatments was NPK fertilizer. Other components only had supportive role in bringing betterment to the life of the plants.

Yield parameters contribute better because there was judicious partitioning of photo-assimilates as revealed by the harvest index (HI). The case would have been different if translocation of assimilates produced was majorly directed to the vegetative parts. The major source of assimilates at the reproductive stage is the flag leaf with the major sink being the cob and its constituents. The harvest index was high enough to show efficient partitioning of photo-assimilates to the economic parts of the plants at the reproductive stage. It might be that nutrient balance in NPK15:15:15 prevented unnecessary vegetative growth that could have been detrimental to the reproductive lives of the plants. So, all the growth stages had rightful supply of nutrients for better performance at any instance. The implication here is that nutrient balance should always be considered anytime we want to embark on any fertilizer programme. The heaviest cobs were produced by T12 (120 kgN/ha + DMR‐ESR‐Y + 47619 plants/ha) while the lightest ones were from T1 (0 kgN/ha + Suwan‐1‐SR + 25000 plants/ha). For the weight of 100seeds, the best treatment was T11 (120 kgN/ha + DMR‐ESR‐Y + 25000 plants/ha) while the least influence was from T2 (0kgN/ha +Suwan‐1‐SR+ 47619 plants/ha). The highest grain yield per hectare was produced by T12 (120kgN/ha + DMR‐ESR‐Y + 47619 plants/ha) while the least yield was from T1 (0kgN/ha + Suwan‐1‐SR + 25000 plants/ha) (Table 7). All the yield components were enhanced by application of 120kg NPK. This result may be attributed to NPK being part of the essential nutrients that aid the meristematic and physiological activities that lead to efficient absorption of water and nutrients as well as interception of solar radiation and carbon dioxide assimilation. These activities promote higher photosynthetic activities for production of adequate photo-assimilates which will subsequently be partitioned to various sinks for production of higher total dry matter [32]. The improvement of the vegetative parts brought about better influence on the yield parameters like harvest index and weight of 100 grains which consequently improved the final yield. In the same vein, success in producing higher yield could be attributed to availability of potassium nutrition which is a component of the fertilizer used. This is because the major function of potassium nutrition in cereal production comes at the grain production and filling stages. So, better grain yield was a consequence of optimum

Table 3. Effects of NPK, variety and population density on leaves at different growth stages

Treatments	Weeks after planting					
	5	6	7	8	9	10
Fertilizer rate (kgNPK/ha)						
0	6	7	7	8	8	10
60	7	8	8	8	8	10
120	7	8	9	8	8	10
$L.S.D_{(0.05)}$	ns	ns	ns	ns	ns	ns
Density (plants/ha)						
25,000	7	8	8	8	8	9
47,619	7	8	8	8	8	9
$L.S.D_{(0.05)}$	ns	ns	ns	ns	ns	ns
Variety						
Suwan-1-Sr	7	8	8	8	8	9
DMR-ESR-Y	7	8	8	8	8	9
$L.S.D_{(0.05)}$	ns	ns	ns	ns	ns	ns

Table 4. Effects of NPK, variety and population density on height of maize at different growth stages

Treatments	Weeks after planting					
	5	6	7	8	9	10
Fertilizer rate (kgNPK/ha)						
0	70.0	72.6	75.6	116.1	124.9	125.5
60	94.5	99.1	101.0	121.7	131.9	133.4
120	102.4	105.7	108.6	138.1	141.9	143.1
$L.S.D_{(0.05)}$	11.69	12.12	11.73	ns	ns	ns
Density (plants/ha)						
25,000	90.2	93.6	96.6	125.8	132.5	133.8
47,619	87.8	91.3	93.5	124.8	133.3	134.2
$L.S.D_{(0.05)}$	ns	ns	ns	ns	ns	Ns
Variety						
Suwan-1-Sr	90.5	94.4	97.0	132.4	137.9	138.6
DMR-ESR-Y	87.5	90.5	93.1	118.2	127.9	129.4
$L.S.D_{(0.05)}$	ns	ns	ns	ns	ns	ns

Table 5. Effects of NPK, variety and population density on dry matter production of maize

Treatments	RDW(g)	SDW(g)	LSDW(g)	SW(g)
Fertilizer ate(kgNPK/ha)				
0	2.896	3.896	0.926	8.25
60	3.612	4.512	1.487	10.65
120	4.480	5.590	2.452	13.89
$L.S.D_{(0.05)}$	0.2183	0.3992	0.2776	0.694
Density plants/ha)				
25,000	3.611	4.661	1.576	10.74
47,619	3.714	4.671	1.668	11.12
$L.S.D_{(0.05)}$	ns	ns	ns	ns
Variety				
Suwan-1-Sr	3.562	4.518	1.487	10.52
DMR-ESR-Y	3.763	4.813	1.757	11.12
$L.S.D_{(0.05)}$	0.1782	0.3259	0.226	0.566

RDW=Root dry weight, SDW=Stem dry weight, LSDW=Leaf sheath dry weight, SW=straw weight

Table 6. Effects of NPK, variety and population density on yield parameters

Treatment	CL (cm)	CD (cm)	SP (%)	GMC (%)	HI (%)	CPP	RPC	KPR
Fertilizer rate (kgNPK/ha)								
0	11.04	4.70	69.5	11.98	42.3	1.750	12.5b	16.17
60	12.11	4.93	78.7	11.78	47.6	1.833	12.42	17.33
120	15.72	5.72	83.5	14.43	52.3	1.833	14.42	21.67
$L.S.D_{0.05}$	0.821	0.402	9.60	1.013	ns	0.3876	1.632	3.079
Densities (plant/ha)								
25000	12.50	5.03	76.4	12.63	46.1	1.778	13.00	17.67
47619	13.41	5.20	78.1	12.83	48.6	1.833	13.22	19.11
$L.S.D_{0.05}$	0.670	ns	ns	ns	ns	ns	ns	ns
Varieties								
Suwan-1-SR	12.82a	4.917	76.4	11.98b	45.1	1.722	13.61	17.89
DMR-ESR-Y	13.09a	5.317	78.4	13.48a	49.7	1.889	12.61	18.89
$L.S.D_{(0.05)}$	0.670	0.328	ns	0.827	ns	ns	ns	ns

CL=Cob length, CD=Cob diameter, KPR=kernel per row, RPC=row per cob, CPP=cob per plant, SP=Shelling percentage, HI=Harvest index, GMC = grain moisture content at harvest.

Table 7. Effects of NPK, variety and population density on maize grain yield and its components

Treatment	COBWT (kg)	100GWT (g)	Yield (kg/ha)
Fertilizer rate (KgNPK/ha)			
0	4.57	4.81	3759
60	4.80	5.02	4157
120	6.28	5.33	5796
L.S.D (0.05)	0.792	ns	899.5
Density (plants/ha)			
25000	4.96	5.34	4284
47619	5.48	4.76	4858
L.S.D (0.05)	ns	ns	ns
Variety			
Suwan-1-Sr	4.95	4.66	4179
DMR-ESR-Y	5.49	5.44	4963
L.S.D (0.05)	ns	0.757	734.5

ns= not significant at 5% probability level, COBWT= Cob weight, 100GWT= 100 Kernel weight, GWT= Grain weight

Table 8. Relationship between grain yield and morphological parameters of maize

	Weeks after planting					
	5	**6**	**7**	**8**	**9**	**10**
r values						
Yield vs No of leaves	0.094ns	0.207ns	0.261ns	0.295ns	0.264ns	0.030n
Yield vs Plant height	0.306ns	0.314ns	0.335*	0.193ns	0.216ns	0.230ns

*ns=not significant, *Significant at 5% probability level*

potassium nutrition. In addition to this, higher plant density contributed effectively to production higher grain yield production because the final yield depends on the yield components of which plant population is a part. However, the nutritional stress that would have resulted from having higher density and led to low grain yield [33-41] was catered for through application of 120 kgNPK/ha. So, the plants were well fed to exhibit their full potentials. Genetic make ups of each variety had more influence on these parameters than fertilizer application and variation in population density.

Leaf production, plant height and leaf area data in this experiment could not determine final yield because they correlated so low with it(the grain yield) (Table 8). However, final grain yield could be strongly determined by leaf sheath, root, stem, total dry weight, cob diameter, cob length, moisture content at harvest, cob weight and shelling percentage because they correlated highly and significantly with the final yield (Tables 9 and 10).

Table 9. Relationship between grain yield and plant dry matter components

Grain yield	r
Versus	
Leaf sheath dry weigh	0.655***
Root dry weight	0.656***
Stem dry weight	0.648***
Total dry weight	0.694***

**** denotes significance at 0.1 percent probability level*

Table 10. Relationship between grain yield and yield parameters

Grain yield	r
Versus	
100 grain weight	0.127ns
Cob diameter	0.544***
Cob length	0.622***
Cob weight	0.964***
Harvest index	-0.040ns
Moisture content at harvest	0.420**
cobs per plant	0.022ns
grains per row	0.283ns
rows per cob	0.1195ns
Shelling percentage	0.364*

, **, * denote significant correlation coefficients at 5, 1 and 0.1% probability levels respectively. ns denotes insignificance of correlation coefficient at 5% probability level*

4. CONCLUSION

This study revealed that combination of 120kgN/ha + DMR-ESR-Y + 47619 plants/ha could improve root, shoot, leaf sheath and plant dry weights, cob length, cob diameter, shelling percentage, moisture content at harvesting, cobs per plant, kernels per row, final yield per hectare and the harvest index. Therefore, DMR-ESR-Y maize variety could be produced at population density of 47619 plants/ha with application of 120 kgNPK/ha to have better yield to cater for the ever increasing population of maize consumers in the study area and other areas with the same climatic conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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