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Growth and Yield of Two Maize Varieties under the Influence of Plant Density and NPK fertilization

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ABSTRACT: This study assessed growth and yield performances of maize under the influence of inorganic fertilizer, population density and variety using the following treatments: maize varieties DMR-ESR-Y and Suwan-1-SR; 70 × 30cm and 100 × 40cm plant spacing; 0, 60 and 120 kg NPK/ha . Data were collected on number of leaves per plant, plant height, ear height, leaf area, leaf area index, days to 50% flowering, days to tassel and silk appearances, stem dry mass, root dry mass, cob mass, number of kernel rows, number of kernels per cob, harvest index, treatment yield per hectare. The result showed that combination of 120kgN/ha, DMR-ESR-Y and 47, 619 plants/ha improved root, shoot, leaf sheath and plant dry masses, cob length, cob diameter, shelling percentage, moisture content at harvest, harvest index, number of cobs per plant as well as number of kernels per row. It is, therefore, recommended that combination of 120kgNPK/ha, DMR-ESR-Y and 47,619 plants/ha should be used for better maize production to cater for the ever increasing population of consumers in Southern Guinea savannah agro-ecological zone of Nigeria and other area with the same climatic and edaphic conditions.

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To increase maize yield, nutritional approach is a better channel. This is because the major processes of plant development and yield formation require major nutrients like N, P, K and Mg in balanced forms (Randhawa and Arora, 2000). Based on this, it has been established that maize fail to produce good grain without application of adequate nutrients (Adediran and Banjoko, 2003). The nutrients can be adequately supplied by inorganic fertilizers. Inorganic fertilizers exert strong influence on plant growth, development and yield (Stefano *et al.*, 2004). The advantage of using inorganic fertilizers is that nutrients are immediately made available to plants and exact amount of a given element can be measured before feeding 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. Plant density is an efficient management tool for maximizing grain yield by increasing the capture of solar radiation within the canopy. An optimum plant population for maximum economic yield exists for all crop species and varies with cultivars and environments (Bruns and Abbas, 2005). Generally, the most appropriate spacing is the one which enables the plants to make the best use of the conditions at their disposal (Mlik *et al*., 1993). 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 (Sangoi, 2000). This is because maize is very sensitive to variation in population density. Very close spacing interferes with normal plant development and increases competition with attendant yield reduction. However, 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 per unit area without exceeding the economic threshold can increase the competitive ability of the crop plants in weed-infested field. However, growing crops in narrower row spacing can reduce weed growth, although the degree of reduction

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will depend on the crop (Alford *et al*., 2004). Plant population density resulting in interplant competition has important effects on the vegetative and reproductive development of maize (Zhang *et al*., 2006). Maize plant has small capacity to develop new reproductive structures in response to increase in available resources per plant. However, if plant density is too high, there will be reduction in the availability of resources per plant, especially in the period surrounding silking. This results in marked fall in yield per plant which cannot be offset by increase in plant stands (Sangoi, 2000).

High yielding and disease or pest resistant maize varieties have become sin qua non to profitable maize production. Research efforts at national, regional and international levels often lead to 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 (Olakojo and Iken, 2001). Most of the Nigeria's cereal crop farmers still adopt the local varieties inherited from their great grandfathers despite low yield potentials of those varieties. Maize hybrids respond differently to population densities as well as soil and climatic conditions. It is believed that new hybrids have greater grain yield at higher plant densities than local varieties because improved hybrids are normally smaller, produce longer leaves, have higher leaf areas per plant, and have lower mutual leaf shading problems than the local cultivars. Therefore, this research was conducted to determine the influence of variety, plant density and NPK fertilizer on growth and yield of maize.

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, in the Southern Guinea savannah zone of Nigeria (Latitude 8° 29'N and Longitude 4° 35'E). The land was ploughed and harrowed and left flat. Soil samples of the field were taken using systemic sampling method. The samples were bulked together to have a composite sample which was passed through 2mm sieve and analysed for physical and chemical characteristics (Table 2). The field was then divided into 36 plots of 3m x 3m dimension. The treatments used were two open pollinated yellow maize varieties (DMR-ESR-Y and Suwan-1-SR) , two plant spacing of 70 × 30cm and 100 × 40cm to obtain 47619 and 25,000 plants/ha and three levels of NPK 15:15:15 (0, 60 and 120 kg ha) (Table 1). All the tested factors were combined in a 2x2x3 factorial to have a total of twelve treatment combinations (Table1). 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 using the above stated spacings. 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 hand weeding with hoe was used from time to time until harvest to keep the experimental plots weed free. The emerged seedlings were thinned to two at two weeks after planting (WAP). At four weeks after planting (WAP), three levels (0, 60 and 120 kg/ha) of NPK 15:15:15 were applied. Data collection started five weeks after planting. Data collection was on weekly basis. Data collected were number of leaves per plant (the 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 mass, root dry mass, leaf sheath dry mas, cob mass, number of kernel rows per cob, harvest index, yield per treatment per hectare. Data collected were subjected to Analysis of Variance (ANOVA) using Genstat 5.2 statistical package while significant means were separated using Least Significant Difference (LSD) at 5% probability level.

Table1: Treatment combinations and their designations

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

Table2: Physical and chemical analyses of the experimental site soil

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/100g)	2.6
Particle Size Analysis	
Sand (%)	67
Silt (%)	14
Clay (%)	18
Textural class	Sandy loam

RESULTS AND DISCUSSION

Leaf production at all periods of data collection was statistically the same with occasional numerical difference. This implies that the effects of all the treatment combinations were the same for leaf production. Application of NPK fertilizer and non-application did not show any difference for leaf production (Table 3). This migh have resulted from having soil with enough nitrogen for leaf production. As a result of this situation, the control plants had enough nutrient to perform as the fertilized plants or even better than them. It could also be because the number of nodes present in plant was not increased by the applied fertilizer. Instead of this, there were long internodes which could only favour tallness at the expense of leaf production which directly depends on the nodes present at a time. This does not occur only in inorganic fertilizer but also in application of organo-mineral fertilizer with different methods (Dania *et al*., 2012). Similar to the effect of fertilizer application was the influence of plant spacing on leaf production.

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

	Weeks after planting					
Treatments	**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 (plant/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

The tallest plants in this experiment were from treatment T10 (120Nkg/ha + SUWAN-1-SR + 47619 plants/ha) while the shortest plants were from treatment T3 (0kgN/ha + DMR – ESR – Y + 25000 plants/ha) (Table4). The increased height of the maize was aided by application of 120 kg NPK/ha with denser plant population. 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 (Fashina *et al.*, 2002). The resulting luxuriant growth from application of fertilizer results in larger dry matter production (Obi *et al.*, 2005) through better utilization of solar radiation and mobilization of more nutrient through developed roots (Saeed *et al.*,2001). From our results, there was linearity in the relationship between NPK application rate and height increase. Therefore, it could be conveniently said that increase in NPK fertilizer application rates aids production of more cells which is manifested in plant increase in height. Higher population density did not bring much difference into maize height (Table4). This implies that space may not hinder plant height though the girth of the plant could be affected due to limitation in the available resources needed for sturdiness of the plants. The genetic difference of the maize varieties did manifest when the two varieties were treated equally. It was evident that plants from Suwan-1-Sr were taller than DMR-ESR-Y. This might have resulted from more efficient use of available growth resources by Suwan-1-Sr. Root dry mass, shoot dry mass, leaf sheath dry mass and straw mass were all best increased 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 to increase in dry matter yield of different plant parts as observed in this experiment (Table5).

What was observed from plant height was carried on to dry matter production of different plant parts. This resulted from the aid provided by the fertilizer to enhance vegetative life of the plants (Obi *et al.*, 2005). Better growth of root tips results in better absorption of water and nutrients needed for luxuriant growth. This in turn increases the photosynthetic area of the plant leaves for better interception of solar energy and consequent increase in assimilate production (Saeed *et al.*, 2001). This assimilate is then partitioned into different plant parts and, therefore, increase in dry matter production occurs. Even distribution of assimilate produced was evident in higher dry root, shoot and leaf sheath masses recorded. The maize cob length, cob diameter, number of kernel rows, number of cobs per plant, shelling percentage, harvest index and grain moisture content at harvest in this experiment were improved by treatment T12 (120kgN/ha + DMR – ESR – Y + 47619 plants/ha) while the least improvement was from T1(0kgN/ha + SUWAN-1-SR + 25000 plants/ha). It was only number of rows per cob that was highly improved by T10 (120Nkg/ha + SUWAN-1-SR + 47619 plants/ha). All the differences in the above parameters were statistically significant except in the harvest index. Varietal influence was not statistically evident except in cob length, cob diameter and grain moisture content at harvest. In the same vein, population density resulted in significant difference in cob length only (Table 6).

Table4: Effects of NPK, variety and population density on height of maize at different growth stages

	Weeks after planting					
Treatments	**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 (plant/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

Table5: Effects of NPK, variety and population density on dry matter production of maize

Treatments	**Root Dry Weight (g)**	**Stem Dry Weight (g)**	**Leaf Sheath Dry Weight (g)**	**Straw Weight (g)**
Fertilizer rate(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 plant/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

Table6: Effects of NPK, variety and population density on yield parameters

Treatment	**Cob Length (cm)**	**Cob Diameter (cm)**	**Shelling Percentage (%)**	**Grain Moisture at Harvest (%)**	**Harvest Index (%)**	**Number of Cob per plant**	**Number of Rows per cob**	**Number of Kernel per Row**
Fertilizer rate (kgNPK/ha)								
0	11.04	4.70	69.5	11.98	42.3	1.750	12.5	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
Density (plant/ha)								
25000	12.50	5.03	76.4	12.63	46.1	1.778	13.00	17.67
47,619	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
Variety								
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

This implies that the major influencing component of the treatments was NPK fertilizer. Other components only had supportive roles in bringing betterment to the life of the plant. Yield parameters were improved. This might be because of judicious assimilate partitioning. 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 while the major sink is the cob and its constituents. The harvest index was high enough to show evidence of translocation of photo-assimilates to the economic parts of the plants at the reproductive stage. The nutrient balance in NPK15:15:15 prevented unnecessary vegetative growth that would have been detrimental to the reproductive life of the plant. 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 (120kgN/ha + DMR – ESR – Y + 47619 plants/ha) while the lightest ones were from T1 (0kgN/ha + SUWAN-1-SR

+ 25000 plants/ha). For the mass of 100seeds, the heaviest grains were from T11 (120kgN/ha + DMR – ESR – Y + 25000 plants/ha) while the lightest ones were from T2 (0kgN/ha + SUWAN-1-SR + 47619 plants/ha). The highest grain yield per hectare was from T12 (120kgN/ha + DMR – ESR – Y + 47619 plants/ha) while the lowest yield was from T1 (0kgN/ha + SUWAN-1-SR + 25000 plants/ha) (Table 7).

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

Treatment	Cob Weight (kg)	100 Kernel weight (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 (plant/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

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*

The yield components were enhanced by application of 120kg NPK. This may be attributed to NPK being parts of the essential nutrients that aid the meristematic growth and other physiological activities of plants. These in turn result in efficient absorption of water and nutrients as well as interception of solar radiation and carbon dioxide. These activities promote higher photosynthetic activities for production of adequate photo-assimilates which will subsequently be translocated to various sinks for production of higher total dry matter (Jaliya *et al*., 2008). 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 is a consequence of better potassium nutrition. In addition to this reason, higher plant density also contributed effectively to higher grain yield production. The reason for this is not farfetched. The final yield depends on yield components of which plant population is a part. However, the nutritional stress that would have resulted from having higher plant density and which would have led to low grain yield (Moriri *et a*l., 2010) was catered for by application of 120kgNPK/ha.

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 per cent 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**
Number of cobs per plant	0.022ns
Number of grains per row	0.283ns
Number of 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

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 be used to predict what the yield could have been because they correlated so low with the grain yield. (Table8). However, grain yield could be strongly determined from data on 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).

*Conclusion***:** This study revealed that combination of 120kgN/ha + DMR – ESR – Y + 47619 plants/ha could improve root, shoot, leaf sheath and plant dry masses, cob length, cob diameter, shelling percentage, moisture content at harvesting, harvest index, number of cobs per plant as well as number of kernels per row. It could, therefore, be recommended that combination of 120kgNPK/ha, DMR – ESR – Y and 47619 plants/ha be used for better maize production to cater for the ever increasing population of consumers in the Southern Guinea savannah agro-ecological zone of Nigeria and other areas with the same climatic and edaphic conditions.

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