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Response of a Low-N Tolerant Maize Variety (*Zea Mays* L.) to the Application of Cattle Manure in the Savanna-Forest Zone of Nigeria

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Abstract:

Low N-tolerant maize varieties introduced in Nigeria savannas are not as performant as expected because of progressive declining soil fertility combined with low use of fertilizers. Hence the need to find alternative sources of supply of maize crop nutrients, especially nitrogen, more accessible to resource-poor farmers. An experiment was conducted at the teaching and research farm of the University of Jos, Plateau state, Nigeria, during two cropping seasons (2019 and 2020), to evaluate the response of a low-N tolerant maize variety (Zea mays L. var BR 9928-DMRSR LN C1) to the use of cattle manure under a range of 0, 5, 10, 15 and 20 t ha-1 for vegetative growth parameters and yield components. The field experiments were laid out in a randomized complete block design, replicated three times. For growth vegetative parameters, data were collected on plant height, stem girth, leaf area index, and number of leaves per plant, while the number of grains per cob and the grain weight were collected for yield components. The data were thereafter subjected to statistical analysis using Proc GLM procedures (SAS version 9.2) to compute analysis of variance (ANOVA), and the least significant difference test (LSD-test) for means separation. The results showed that the low-N tolerant maize variety responded better when associated with (any level of) cattle manure than without for all vegetative growth parameters as well as for all yield components in both cropping seasons. They kept on increasing with the rate of cattle manure applied.

Keywords:

Low-N Tolerant Maize, Maize, Cattle Manure, Yield, Savannah Forest, Nigeria

1. Introduction

Maize (*Zea mays* L.) is the most important cereal in the world after wheat and rice with regard to cultivation areas and total production, Eka and Osagie [1]. For most countries in sub-Saharan Africa (SSA), it is one of the commonly grown grain crops

and remains a source of staple food and food security, as well as a major source of income to farmers among whom many are resource-poor, Sanchez [2].

In Nigeria, maize has become over the years a major cereal and one of the most important food crops, taking over acreages from traditional crops such as millet and sorghum. In 2018, about 10.2 million tons of maize was produced from 4.8 million hectares, making Nigeria the highest producer in Africa, FAOSTAT [3]. This performance is the result of research efforts by breeders and agronomists that have led to the production of many technologies including high-yielding varieties that are tolerant to drought, diseases, low nitrogen, and Striga infestation, Kamara *et al.,* [4].

Despite the availability of these high-yielding varieties in Nigeria, maize yields are still low in the Nigeria savannas mainly because of progressive declining soil fertility combined with low use or no fertilizers. Shorter fallow periods and continuous cropping arising from rapid population expansion have resulted in soil deficiency both in macronutrients, such as N, P, and K, and in key micro-nutriments such as copper and zinc. As a consequence, maize yields as low as 1 t ha-1 can be observed without the addition of fertilizers, Kamara et al., [5].

Therefore, until mineral fertilizers are made more accessible to farmers, the utilization of organic fertilizers (cattle manure), in spite of its low content in crop nutriments, particularly in nitrogen, can be considered and if possible promoted among maize crop producers, in particular in association with low-N tolerant maize varieties as they have the ability to utilize small quantities of nitrogen to attain their yield potential.

This study was designed to examine the influence of cattle manure, an organic fertilizer little known among maize producers in Jos areas of Plateau State in Nigeria, on the performance of a low N-tolerant maize variety. Cattle manure contains all crop nutriments including N, P, and K in the low ratio of 3:2:1.

Even though there is no documentation on the metric tons of cattle manure produced annually on the Plateau, cattle manure is found in large quantities in slaughterhouses of the region which unfortunately do not have any management system or policy for abattoir wastes. Intestinal contents of slaughtered animals are generally washed into open drains or into nearest water courses, or even just allowed to degrade in the open into heaps.

The objective of this study is to examine if good use can be made out of slaughterhouse wastes, in particular cattle manure, in a region experiencing strong growth in the meat industry. The impact of its application on the production of maize variety, a low-N tolerant maize variety will be assessed by measuring maize vegetative growth parameters (plant height, stem girth, number if leaves, leaf index area,) as well as its yield components (number of grains per cob and grain weight).

2. Materials and Methods

2.1. Experimental Site

A field experiment was conducted at the teaching and research farm of the Faculty of Agriculture of the University of Jos in the Plateau state, Nigeria. It is located on latitude 09°55′00″ N and on longitude 08°53′25″, with an elevation of 1238 m above the sea level. The experimental site lies within the savannah agro-ecological zone of

the Plateau state of Nigeria, with a mean annual rainfall of 1233 mm and a mean daily temperature of 20°C.

2.2. Maize Variety, Cattle Manure Rates and Experimental Design

A low-N tolerant maize variety (BR 9928-DMRSR LN C1) was obtained from the International Institute of Tropical Agricultural (IITA), Ibadan, Oyo State, Nigeria, while cattle manure was obtained from the livestock market abattoirs of Jos, the city capital of the Plateau state of Nigeria. The samples of manure were air-dried, crushed through a 2 mm sieve and analyzed following standard laboratory procedures in order to determine its chemical properties.

Prior to the commencement and at the end of the experiment, soil samples were taken randomly at depth of 15 to 30 cm using soil auger from the experimental plots, and were mixed together to form a composite sample. They were air-dried, sieved through 2 mm mesh-size sieve and taken to the laboratory to determine the soil's physicochemical properties using standard laboratory procedures.

The experiment was laid out in a randomized complete block design (RCBD) in factorial arrangements replicated three times. Each replicate consisted of 15 plots, each carrying a treatment, and fixed inter and intra row spacing of 0.75 m, and 0.2 m, respectively. Each plot was measured 6 x 0.75 m and a total block size of 109.5 m (6 x 18.25 m) was marked out for the study. Alleys of 0.5 m and 1 m were left between plots and blocks respectively to prevent treatment drift to adjacent blocks. The treatments were: T1 – 0 t. ha-1, T2 – 5 t. ha-1, T3–10 t. ha-1, T4 – 15 t. ha1 and T5 – 20 t. ha-1 of cattle manure.

2.3. Cultural Practices

The land used for the experiment had been under continuous cultivation for the past six years, and was occupied by common weeds, including Bermuda grass, Setaria faberi, Sida acuta, and Imperata cylindrica. It was manually stumped and thereafter about 300 ml of glyphosate was mixed in 20 l of water and sprayed to the existing vegetation. Fourteen days after glyphosate application the land was ploughed and harrowed mechanically.

Two seeds of the low-N tolerant maize variety (BR 9928-DMRSR LN C1) were planted at a depth of 2 to 4 cm which was later thinned to one healthy plant per stand. Immediately after planting, atrazine mixed with paraquat was applied as pre-emergence weed control. One half of each rate of cattle manure was applied to the plots two weeks before planting and the other half two weeks after planting using ring method of application after being pulverized.

2.4. Measurements

Data were collected from the two middle rows leaving the outside rows and a distance of 50 cm at the ends of each middle row to serve as borders. Five plants were randomly tagged from two middle rows in each plot for sampling and data were collected at maturity and at harvest for vegetative growth parameters (plant height, stem girth, number of leaves, and leaf area index) and yield components (number of grains per cob, and grain weight), and later on analyzed using Proc GLM procedures (SAS version 9.2) to compute analysis of variance (ANOVA). The least significant difference test (LSD-test) at 5% probability was used for means separation when analysis of variance indicated the presence of significant differences.

3. Results and Discussion

3.1. Physicochemical Properties of Soil and Cattle Manure

The physicochemical properties of the soil for cropping season at the experimental site showed that the soil textural classification was sandy loam, moderately acidic with a pH value of 5.08. The low nutrients observed prior to cattle manure application can be attributed to continuous cropping without soil amendments inputs, which led to depletion of organic carbon, organic matter, total nitrogen, available phosphorus and exchangeable cations as presented in Table 1, The soil at experimental site had high proportion of sand content with low cation exchange capacity which implies that cations would be easily leached as soil texture determines the degree of retention or leaching of basic cations. However, prior to application of cattle manure available P, Na and K were seemingly low based on the ratings of FMANR [6], for the ecological zone. According to Peng *et al.,* [7] the critical soil nitrogen content in the soil for maximizing maize growth has to be above 0.2%. The results from soil analysis, therefore, indicated a deficiency in nitrogen content, which justifies the application of cattle manure to the field.

Table 1. *Physicochemical properties of the soil prior to and after treatment application 2019/2020.*

	pre-cropping	**Post- cropping**			
Properties	**0 t.ha^{-1}**	**5 t.ha^{-1}**	**10 t.ha^{-1}**	**15 t.ha^{-1}**	**20 t.ha^{-1}**
PH (H_20) 1:1 ratio	5.08	5.52	5.76	5.96	6.07
Organic carbon (gkg-1)	4.90	7.30	20.10	21.20	31.20
Organic Matter (gkg-1)	20.34	33.82	34.72	35.83	36.45
Total Nitrogen (gkg-1)	0.60	0.70	0.72	0.82	0.86
Available P (mgkg-1)	5.72	6.91	6.98	7.02	7.08
Potassium (cmol kg-1)	0.34	0.37	0.37	0.38	0.40
Calcium (cmol kg-1)	0.44	2.11	2.43	2.64	2.73
Magnesium (cmol kg-1)	0.21	0.59	0.84	2.01	2.92
Sodium (cmol kg-1)	0.80	0.84	0.86	0.88	0.89
CEC (cmolkg-1)	1.02	1.77	1.76	1.82	1.83
ECEC (cmol kg-1)	1.13	1.23	1.23	1.45	1.47
Sand (gkg-1)	600.5	600.8	700	700.1	710.9
Silt (gkg-1)	300	90	200.2	200	150.7
Clay (gkg-1)	100	300.2	100.8	100.9	120.4
Textural class	Sandy loam				

The post-harvest soil analyses indicate a tremendous increase of organic matter in the site soil, ranging from 60 to 90%, which means a better CEC, less soil acidity, and therefore more ability of the soil to supply the important nutrients to the maize plant. In general, maize as a crop does not tolerate pH conditions of less than 5.5; it grows best at a soil pH between 5.5 and 7.3 with pH 6.0 - 6.5 being optimum. In this range, N, P, K, Ca and Mg are readily available, Sharma [8]. This is supported by the results of chemical analyses of the site soil carried out after harvest as they indicate that the levels of total nitrogen and available phosphorus have slightly increased, while that of potassium did not change in spite of the uptake. Given the small quantities of crop nutrients contained in the cattle manure applied, these results confirm the efficiency of this variety of maize in the utilization of small amounts of crop nutrients. Cattle manure application has therefore improved physical conditions for the retention of nutrients and their availability to the crop.

Table 2. *Chemical Composition of Cattle manure used.*

Properties	Cattle manure
pH in (H_2O) 1 : 1	5.38
Organic Carbon gkg-1	34.08
Total Nitrogen gkg-1	2.06
Aviable P concentration gkg-1	15.22
Potassium (cmolkg-1)	0.4
Calcium (cmolkg-1)	1.45
Magnesium (cmolkg-1)	0.58
Sodium (cmolkg-1)	0.25

3.2. Impact of Cattle Manure on Vegetative Growth and Yield Components of the Low-N Maize Variety

The influence of cattle manure application on vegetative growth parameters of the low-N tolerant maize variety is presented in Table 3 and Table 4. The results show that every level of cattle manure applied had a significant effect, not only on plant height and stem girth, but also on the leaf area index and the number of leaves per plant. These parameters kept on increasing in a significant manner with the increase of the rate of cattle manure application; in other words, the greater the quantity of manure applied to the soil the higher the response. The same trend is observed in both cropping seasons. These results means that the low-N tolerant maize variety performed better with than without cattle manure, as far as vegetative growth parameters are concerned. This result is in tandem with findings of Fawuzi [9], Uzo [10], Eleduma [11], Aminifard *et al.,* [12], as well as those of IFA [13], Tisdale and Nelson [14] who reported that good plant growth was attributed to adequate nutrient supply in cattle and poultry manure plots, particularly nitrogen and phosphorus which promotes crop performance. Hyunju *et al.,* [15] also reported that application of cattle manure increased plant growth and stalk diameter, silage and dry matter yields.

Table 3. *Response of Low- N tolerant maize variety to cattle manure on plant height and stem girth in 2019 and 2020.*

Treatments (t. ha^{-1})	Plant height (cm)			Stem girth (cm)		
	2019	2020	Mean	2019	2020	Mean
0	112.20e	104.22e	108.21e	2.4e	2.3e	2.35e
5	120.44d	117.40d	118.14d	3.3d	3.4d	3.35d
10	123.24c	126.61c	124.93c	4.2c	3.5cd	3.85cd
15	130.11b	132.30b	131.21b	4.6b	4.3b	4.45b
20	137.10a	137.50a	137.3a	5.0a	5.4a	5.20a
LSD (0.05%)	0.83	0.71	0.74	0.86	0.76	0.78
In a column and for a given character, mean having similar letter(s) are not significantly different						

Table 4. *Response of Low- N tolerant maize variety to cattle manure on leaf area index and number of leaves/ plant in 2019 and 2020.*

Treatments (t. ha^{-1})	Leafe area index (cm^2)			Number of leaves/plant		
	2019	2020	Mean	2019	2020	Mean
0	523.6e	533.2e	528.4e	6.5d	7.4d	6.95e
5	585.8d	579.3d	582.55d	9.2c	7.5c	8.35d
10	609.3c	612.6c	610.95c	9.3c	8.8c	9.05c
15	625.4b	633.1b	629.25b	10.4b	10.9b	10.65b
20	685.4a	679.3a	682.35a	11.5a	11.8a	11.65a
LSD (0.05%)	0.45	0.57	0.73	0.06	0.09	0.19
In a column and for a given character, mean having similar letter(s) are not significantly different						

The reaction of the low-N tolerant maize variety on yield components to the application of cattle manure is shown in Table 5. As with the vegetative growth parameters, the number of grains per cob and their weight is higher when maize was planted with cattle manure than without; the same trend is observed in the two cropping seasons.

Table 5. *Number of grains/cob and Grain weights in 2019 and 2020.*

Treatment (t. ha^{-1})	No. of grains/cob			Grain weight(Kg)		
	2019	2020	Mean	2019	2020	Mean
0	150.3e	243.3e	196.8e	0.70e	1.02e	0.86e
5	255.6d	333.4d	294.5d	1.12d	1.53d	1.33d
10	331.7c	384.4c	358.05c	1.80c	1.98c	1.89c
15	374.6b	421.7b	398.15b	2.10b	2.69b	2.40b
20	388.7a	493.9a	441.3a	2.87a	3.21a	3.04b
LSD (0.05)	97.43	101.23	78.66	0.02	0.06	0.07
In a column and for a given character, mean having similar letter(s) are not significantly different						

This result is to be linked directly to that of the vegetative parameters, in particular to an improved leaf area index (LAI) through the use of cattle manure which has strongly influenced maize dry matter accumulation and grain yield through increased interception and utilization of solar radiation for photosynthesis. It should also be noted here that the performance of the yield components increases with the increase in the amount of cattle manure brought to the soil.

The increase in number of grains per cob and grain weight might be due to availability of N at proper time, which is required for better growth and development of plants and improvement in moisture retention and soil structure by cattle manure. These findings are similar to the findings of Prasad, Shah *et al*., Shah and Ahmad, and Laekemariam and Gidago [16,17,18,19] who concluded that the significant effect of N fertilizer and farm yard manure had on the number of kernels per cob.

4. Conclusion and Recommendation

The study was carried out to evaluate the influence of cattle manure on growth and yield of Low-N tolerant maize variety (*Zea mays* L. var BR 9928-DMRSR LN C1). It was carried out in a Randomized Complete Block Design with three replicates. Six parameters were assessed to achieve the objectives of the study-plants height, stem girth, number of leaves, leaf area index, number of grains/cob and grain weight of maize. The results indicated clearly that cattle manure significantly improved vegetative growth parameters and yield components of maize with an increase in the rates of cattle manure, with 20 t. ha^{-1} producing superior results. Based on the findings of this study, the Low-N tolerant maize variety responded better when associated with (any level of) cattle manure than without for vegetative growth and yield components of maize plants in both cropping seasons. However, the use of cattle manure is strongly recommended to poor resource farmers planting this low-N tolerant maize variety in the savannah areas of Nigeria. They can adopt the use of cattle manure for improving soil organic matter, soil structure and the biological life of the soil and subsequently improving yield in Jos north area of Plateau State.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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