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APPLICATION OF TAXONOMIC CLASSIFICATION IN SOIL FERTILITY MANAGEMENT USING MAIZE (Zea mays L.) AS TEST CROP IN INCEPTISOLS OF GUMA, BENUE STATE, NIGERIA

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ABSTRACT

This experiment was conducted during rainy season of 2017 and 2018 in Guma, Benue State with the aim to determine the optimum fertilizer rate for maize production and also to evaluate growth and yield response of maize to fertilizer application among the Inceptisols of Benue. Orba Super II Hybrid was sourced from Fadama III as well as Commercial NPK 15: 15: 15 at the rates of 0: 0: 0, 60: 30: 30, 90: 45: 45, 120: 60: 60 and 150: 75: 75 kg/ha representing 0.48, 0.72, 0.96 and 1.20 kg/ha were used for the experiment. The soils were low in fertility. NPK fertilizer applications significantly increase performance of maize relative to control during the 2017 and 2018 growing seasons. In terms of growth parameters, plant height and number of leaves in 2017 were highest (122.21 cm and 11.32) and lowest (68.06 cm and 8.82) at fertilizer rate of 150: 75: 75 kg/ha and control respectively while in 2018, the highest (65.64 cm and 12.20) and lowest (50.64 cm and 10.28) plant height were obtained at 90: 45: 45 kg/ha fertilizer rate and control. Data during 2017 cropping season showed that the highest and lowest LAI were 0.25 and 0.16 at 800 and 150: 75: 75 kg/ha fertilizer rate and control respectively; whereas, during 2018 cropping season, the highest and lowest values were 0.52 and 0.39 from 600 kg/ha and 150: 75: 75 kg/ha, respectively. The optimum level of NPK for successful production of maize grains was NPK 90: 45: 45 kg/ha based on the fact that it had the greatest yield.

Keywords: Maize production, Fertilizer applications, Maize grains

1. INTRODUCTION

Declining soil fertility is a serious limitation to crop production in Nigeria. The primary causes are loss of organic matter, macro and micronutrient depletion, acidity, topsoil erosion and deterioration of physical soil properties (Zelleke et al., 2010).

Maize is one among major grain crop in Savannah zone occupying 42% of the land covered by grain crops and its productivity is low (16 qt ha-1) due to low soil fertility (SNNPRS, 2007). Although, different factors are contributing, soil fertility is a major concern. Yet, some studies conducted in the area have shown the deficiency of most nutrients viz. P, Fe, Cu, Mn and Zn (Mulugeta, 2006; Alemayehu, 2007). The unavailability and increasing loss of soil nutrient calls for efficient fertilizer use as against blanket application currently practiced. It is on the bases of differences in soil morphology, physical and chemical characteristics that soils are classified. Since different soil types have different nutrient content, it is therefore, important to ensure the

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required quantity of fertilizer (nutrient) be supplied to specific soil type in order to minimize crop yield and profit hence, minimize cost.

Hence, use of inorganic fertilizers has considerable importance as to take remedial measures in fertility management and boosting the production. Studies conducted by various researchers demonstrated the positive outcomes of application of fertilizer nutrient management in many areas (Okoruwa, 1998; Dauda, 2008; Ano, 1991; Obi, 1989; Boateng et al., 2006). Therefore, this study was conducted to evaluate growth and yield response of maize to variable rates of NPK fertilizer; so as to identify the optimum rate for the crop.

2. MATERIALS AND METHODS

Experimental Site

The study was conducted during the 2017 and 2018 season at the Daudu in Guma L.G.A of Benue State. Benue State lies within the lower river Benue trough in the middle belt region of Nigeria. Its geographic coordinates are Latitude 6° 25' and 8° 8' North, longitude 7° 47' and 10° 0' East; and shares boundaries with five other states namely: Nasarawa State to the north, Taraba State to the east, Cross-River State to the south, Enugu State to the south-west and Kogi State to the west including the Republic of Cameroon on the south-east. Guma is one of the Local Governments in Benue that is bonded to North by Nassarawa State, Logo Local Government Area in the East and Makurdi Local Government Area in the South.

The geology of the areas comprise of cretaceous sediments of predominantly sandstone and shale. The major physiographic units of the study areas consist of undulating plains, hills and lowlands and the differences between them reflect the underlying geology.

Annual rainfall of the areas ranged from 1100 mm to about 2000 mm, and its distribution is characterized by two peak periods (July and September) separated by a short August break. The relative humidity ranges from 50.4% to 92.6% (Adamgbe and Ujoh, 2012). The study area lies within the middle Benue trough consisting of a sedimentary terrain, and igneous rocks at the northern part. The sedimentary terrain comprises mainly sandstone of Makurdi Sandstone with common fold axes trending Southwest-Northeast (Burke et al., 1970). The weather conditions during the growing season of this study in 2017 and 2018 were as shown in Table 1.

Table 1: Weather data at the experimental site during the 2017 and 2018 growing seasons

Month	Rainfall (mm)	No. of rainfall days	Relative Humidity (%) 1500UTC-4.00pm Pro LT0900 UTC-100am LT	Temperature (^{0}C)Max., Min.
2017				
April	107.0	8	70.47	36.3, 25.7
May	208.9	8	78.63	33.2,24.5

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June	139.2	12	80.68	32.1, 23.8
July	108.2	11	84.70	31.0, 22.5
August	224.3	18	82.70	30.1, 22.9
2018				
April	47.9	4	68.49	36.1, 24.7
May	230.1	9	80.67	32.5, 23.7
June	144.1	11	79.68	32.1, 22.5
July	145.5	14	83.69	31.4, 22.8
August	275.5	21	83.73	30.8,22.2

Field work

Reconnaissance soil survey was carried out to identify the soil types of the experimental sites. This implies that auger samples of the soil was collected and analyzed in the laboratory for particle size distribution, exchangeable cation, cation exchange capacity (CEC) to determine percentage base saturation. Profile pits were sunk in each of the experimental site during the first and second year of the research (that is before the start and after the experiments).

Soil Sample Collection and Preparation

Soil samples were collected from a profile pit according to horizons, air-dried, crushed and sieved through a 2 mm mesh sieve, and analysed for physical and chemical properties.

Laboratory Analysis

The soil samples collected from the field were air-dried, gently crushed and sieved. The particle size distribution (PSD) was determined using Buoyoucos hydrometer method as described by Day (1965). Soil reaction (pH) was determined using the electrometric method using pH meter in 1:1 soil: water ratio as described by Hesse (1971), and organic carbon was determined using the Walkey-Black method as described by Hesse (1971). The Macro Kjeldahl method was used to analyze for total N, while the Bray I method as described by IITA (1979) was used to analyze for available P. Exchangeable cations (Ca, Mg, K, Na) were determined from NH4OAC filtrate. Exchange acidity was determined using the Barium chloride-triethanolamine method as described by Peech (1965). Effective cation exchange capacity (ECEC) was calculated by the summation of the exchangeable bases and exchangeable acidity while the percentage base saturation was equally calculated by dividing the sum of exchangeable bases over the effective cation exchange capacity and multiplying by 100.

Crop Sampling and Data Collection

Central row plants were used for data collection. Ten (10) plants from the middle rows were used to compute the score for each plot at 4, 6 and 8 WAP. The mean height from the 10 randomly selected plants from the middle rows were taken as the score for each plot. Growth parameters such as, plant height, number of leaf per plant, leaf area per plant, leaf area index, and stem diameter; yield components such as, ear weight, ear length, ear diameter, and grain yield were recorded 14 WAP.

Statistical Analysis

All data collected were subjected to one-way analysis of variance (ANOVA) test at 5% level of significance. Where the treatments means are significant, the treatments were separated using the Fisher Least Significant Difference (FLSD) (Steel & Torrie, 1984).

Crop Management

Maize seeds were planted in each of the treatment plots already prepared (3 seeds per hole) at a spacing of 90cm x 50cm between and within rows. Prior to seed germination, the whole plots were sprayed with weed control chemicals (Glyphosyte and Atrazine) so as to suppress weed invasion in the plots. After germination, the maize seedlings were thinned to two seedlings per hole. Two weeks after planting, the maize seedlings were ring-dressed with the respective fertilizer rate according to the treatments indicated above and top dressed with urea fertilizer at six (6) weeks after planting. Improved maize variety (Orba Super II Hybrid) was used for the experiment. All other agronomic practices like hoeing, weeding, and so on were kept normal for all the treatments.

3. RESULTS AND DISCUSSION

Soil Characteristics

Table 2 showed the physical and chemical properties of the soils of the study area. Variability in clay distribution down the profile pit of the study site was low ranging from 4.13 to 9.66 %. The soil of the area had no definite pattern of distribution of clay content with dept. However, over a very long period of time, pedogenetic processes such as erosion, deposition, eluviations, and weathering can change the soil texture (Foth, 1990; Brady and Weil, 2002). The relative differences in clay content among the soil units could be due to slight differences in topography and cultivation as well as their parent materials. The sand and silt content increased or decreased irregularly with depth. A similar observation was made by Miura et al., (1997). The soil texture reflects the nature of the parent material from which the soils are developed. Soil texture has an important role in the assessment of soil characteristics.

The soils were moderately acidic in reaction ranging from 5.9 to 6.8. Soil pH plays a very important role in Ni's availability in soil. Total nitrogen contents were generally less than 1.0 gkg-1. The low observed total nitrogen content may be due to some pedogenic process. It is obvious that climate, vegetation and human activities contribute to low level of total nitrogen. High temperatures and human activities of bush burning and cultivation both reduce soil organic matter (SOM) accumulation and consequently nitrogen content. According to Landon (1991), low OC and low N content might be associated with continuous cultivation, lack of incorporation of fertilizer and relatively higher temperature of the study area. This correlate with the result of Jones, (1973) who asserted that savannah region of West Africa soils are generally low in total nitrogen. The available P ranged from 11.25 to 21.25 ppm and was rated moderate. The exchangeable bases (Ca, Mg, K and Na) were low in all the soils. Calcium is the most prevalent cation on the exchange complex with values ranging from 0.08 cmolkg-1 to 3.45 cmolkg-1. Next to calcium is magnesium which ranged from 0.56 cmolkg-1 to 0.93 cmolkg-1. The low exchangeable bases of these soils may be due to the underlying materials, intensity of weathering, leaching, low activity clay, very low organic matter content and the lateral translocation of bases (Krasilinikoff et al., 2002; Kang and Balasubramanian, 1990; Kang, 1993). Similar findings were reported by Idoga (2005) Fagbami and Akamigbo, (1986).

The CEC of the soils generally ranged from 9.68 to 11.06 cmolkg-1. The CEC content of the soils were irregularly distributed with depth and were therefore, rated very low which imply that the soils were low in their nutrient holding capacities especially for basic cations. The base saturation values varied from 51to 62 % which and had not regular pattern of distribution with depth. Base saturation is the amount of positive charge ions (except H+ and Al3+) that are adsorbed on the surface of soil particles can be high (> 50%) or low (< 50 %). A high base saturation indicates that the exchange sites on a soil particle are dominated by non-acidic ions and vice versa. The base saturations were rated low to moderate.

Plant Characteristics

Maize growth characteristics in 2017 and 2018 were significantly better with the use of fertilizer than the control where fertilizer was not applied (Table 3). The higher growth traits on fertilizer might be due to readily availability of nutrients during the growth period of the crop. An increase in maize plant growth at different application rates was also reported by Rajeshwari et al. (2007). The result during 2017 showed that the highest and lowest LAI were 0.25 and 0.16 observed at NPK 120:60:60 and 150:75:75 kg/ha fertilizer rate and control, respectively; whereas, during 2018, the highest and lowest values were 0.52 and 0.39 from NPK 90:45:45 kg/ha and 150:75:75 kg/ha, respectively. The higher LAI could be related with more number of leaves per plant. Similarly, Makinde (2007) and Laekemariam and Gidago (2012) on maize reported highest leaf area per plant and LAI on the rates of fertilizers. However, there were no significant differences in the effect of the fertilizer on the performance of plant height, leaf area, LAI and stem diameter in 2017 and number of leaves in 2018 growth attributes determined in this study. This lack of performance differences in some of the growth traits between the two growing seasons may likely be due to the fact that the same quality of fertilizer as well as similar field experimental conditions was used in both seasons. Furthermore, there were also no significant differences in the weather conditions during the 2017 and 2018 growing seasons. The observed significant performance in growth parameters with the application of fertilizer could be due to the ability of the fertilizer to supply the nutrient elements necessary to promote more vigorous growth, improve meristematic and physiological activities in the plants, as well as improve the soil properties; thereby resulting in the synthesis of increased photo- assimilates that enhanced maize yielding ability. The greater 2017 and 2018 plant height, number of leaves, leaf area, LAI and stem diameter in maize occurred with higher rates of NPK fertilizer of up to 150:75:75 and 90:45:45 kg/ha. This finding corroborates with the report of Okoruwa (1998) who observed significant increases in LAI and dry matter accumulation in maize with successive increases in fertilizer rates. Generally, all the traits were very strongly correlated with each other which suggest that, in the case of limited field resources, the performance evaluation of one or more of these traits may provide a reasonable index for the prediction of the probable performance of these other closely associated traits.

Yield components (ear weight, ear length, ear diameter and grain yield) were also significantly increased with application of fertilizer which resulted in an overall increase in grain yield per hectare (Table 4). Ogbonna and Obi (2005) reported similar results where increases in fertilizer application resulted in high dry matter partitioning towards increased grain yield and higher harvest index. The NPK fertilizer rate of 150:75:75 and 90:45:45 kg/ha seemed most satisfactory in obtaining the best maize yield of 1.04 and 2.48 t/ha in both cropping seasons. Beyond this level (90:45:45kg/ha of NPK fertilizer in case of 2018), increases in fertilizer application had no additional advantage on boosting maize grain yield under the Inceptisols of Guma growing conditions. This implies that the onset of luxury consumption of nitrogen and the production of vegetative growth at the expense of high grain yield occurred beyond a fertilizer rate of NKK 90:45:45 kg/ha in the case of 2018. Without the application of fertilizer, the average maize grain yield from this study was 0.56 t/ha which is within the yields generally obtained by peasant farmers who are not able to afford any fertilizer input in this agro-ecological zone.

The significant differences observed in the annual variations of all the maize plant morphology and yield parameters could be attributed to the essential nutrient elements contained in the fertilizer that are associated with increased photosynthetic efficiency (Dauda et al., 2008). The plant height was highest (107.80 cm) in 2017, mean while, all other parameters produced the highest values (11.50, 5.47, 0.45 m2 and 85.30 mm) in 2018. Among the yield parameters, the best productions were all observed in 2018 cropping season (Table 5). The performance of the plant morphology and yield parameters could be an influence of residual deposits of nutrient that was utilized thereby, given rise to better performance in 2018.

Table 2: Physical and Chemical Properties of the Study Site before the Experiments

		Particle size distribution								Exchangeable Cation						
Horizon	**Depth (cm)**	**Sand**	**Silt (%)**	**Clay**	**Text. Class**	**pH H_2O**	**O.C (g/kg)**	**T. N (g/kg)**	**A.P (ppm)**	**Ca**	**Mg**	**K**	**Na (cmolkg^{-1})**	**TEB**	**CEC**	**BS (%)**
A	0-10	70.89	19.45	9.66	LS	6.2	4.11	0.11	18.75	3.13	0.93	0.23	0.09	4.38	8.19	53.5
Bt_1	10-32	82.67	13.20	4.13	SL	5.9	3.84	0.15	11.25	3.45	0.75	0.30	0.13	4.66	9.06	51.4
Bt_2	32-64	79.66	14.24	6.10	SL	6.3	3.66	0.13	21.25	3.29	0.78	0.26	0.17	4.48	7.71	58.1
Bt_3	64-76	80.45	10.50	9.05	LS	6.7	4.08	0.24	13.25	3.19	0.68	0.33	0.09	4.28	8.03	53.3
Bt_4	76-102	82.47	8.65	8.88	LS	6.8	3.48	0.19	16.28	0.08	0.56	0.26	0.09	2.99	5.68	52.6

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Table 3: Effect of Fertilizer rates on Maize Plant Morphology among the Inceptisols of Guma

Fertilizer Rates (kg/ha)	Cropping Season 2017	Cropping Season 2018
Plant Height (cm)		
N0:P0:K0	68.06±3.34^{b}	50.64±1.26^{b}
N60:P30:K30	116.84±5.19^{a}	57.80±1.41^{ab}
N90:P45:K45	116.24±4.72^{a}	65.64±1.57^{a}
N120:P60:K60	115.84±3.25^{a}	58.52±2.16^{ab}
N150:P75:K75	122.21±1.75^{a}	60.08±6.93^{ab}
P-Value	*<0.01*	*0.04*
No. of Leaves		
N0:P0:K0	8.82±0.22^{c}	10.28±0.30^{b}
N60:P30:K30	10.66±0.10^{b}	11.68±0.33^{a}
N90:P45:K45	11.32±0.28^{a}	12.20±0.31^{a}
N120:P60:K60	10.72±0.21^{b}	11.76±0.23^{a}
N150:P75:K75	11.08±0.13^{ab}	11.60±0.17^{a}
P-Value	*<0.01*	*0.01*
Leaf Area (cm^2)		
N0:P0:K0	1.94±0.06^{b}	5.02±0.19^{cd}
N60:P30:K30	2.97±0.21^{a}	5.83±0.13^{ab}
N90:P45:K45	2.79±0.20^{a}	6.32±0.12^{a}
N120:P60:K60	3.02±0.13^{a}	5.41±0.31^{bc}
N150:P75:K75	3.08±0.19^{a}	4.78±0.24^{d}
P-Value	*<0.01*	*<0.01*
Leaf Area Index (LAI)		
N0:P0:K0	0.16±0.00^{b}	0.41±0.01^{cd}
N60:P30:K30	0.24±0.01^{a}	0.48±0.01^{ab}
N90:P45:K45	0.23±0.01^{a}	0.52±0.01^{a}
N120:P60:K60	0.25±0.01^{a}	0.45±0.02^{bc}
N150:P75:K75	0.25±0.01^{a}	0.39±0.02^{d}
P-Value	*<0.01*	*<0.01*
Stem Diameter (mm)		
N0:P0:K0	47.80±1.27^{b}	73.40±3.08^{c}
N60:P30:K30	61.16±1.59^{a}	90.80±1.50^{ab}
N90:P45:K45	60.98±1.41^{a}	96.40±2.16^{a}
N120:P60:K60	60.46±1.76^{a}	85.52±5.41^{ab}
N150:P75:K75	63.64±1.70^{a}	80.40±5.05^{bc}
P-Value	*<0.01*	*<0.01*

Means on the same column (in each section) with different superscript are statistically significant ($p<0.05$); ns=not significant

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Table 4: Effect of Fertilizer rates on Maize Yield parameter under the Inceptisols of Guma

Fertilizer Rates (kg)	Cropping Season	
	2017	**2018**
Ear Weight (kg)		
N0:P0:K0	35.60±3.19[d]	126.00±17.10[c]
N60:P30:K30	58.80±1.36[c]	200.00±0.00[b]
N90:P45:K45	87.60±1.60[a]	240.00±14.10[a]
N120:P60:K60	79.40±3.22[b]	220.00±16.70[ab]
N150:P75:K75	89.00±1.41[a]	204.00±11.7[ab]
P-Value	*<0.01*	*<0.01*
Ear Length (cm)		
N0:P0:K0	7.10±0.45[c]	10.76±0.57[b]
N60:P30:K30	8.66±0.15[b]	14.84±0.18[a]
N90:P45:K45	10.14±0.40[a]	15.88±0.53[a]
N120:P60:K60	9.74±0.39[ab]	15.40±0.67[a]
N150:P75:K75	10.80±0.37[a]	14.32±0.58[a]
P-Value	*<0.01*	*<0.01*
Ear Diameter (cm)		
N0:P0:K0	65.04±6.43[c]	143.30±17.00[b]
N60:P30:K30	89.73±0.98[b]	223.40±3.53[a]
N90:P45:K45	110.70±4.29[a]	241.44±8.57[a]
N120:P60:K60	107.60±4.93[a]	224.30±10.70[a]
N150:P75:K75	113.84±6.18[a]	210.60±9.66[a]
P-Value	*<0.01*	*<0.01*
Grain Yield (t/ha)		
N0:P0:K0	0.56±0.06[c]	1.00±0.00[c]
N60:P30:K30	0.80±0.08[b]	2.00±0.00[b]
N90:P45:K45	0.96±0.04[ab]	2.48±0.27[a]
N120:P60:K60	0.92±0.04[ab]	2.06±0.12[ab]
N150:P75:K75	1.04±0.04[a]	1.68±0.13[b]
P-Value	*<0.01*	*<0.01*

Means on the same column (in each section) with different superscript are statistically significant ($p<0.05$)

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Table 5: Annual Variation of Maize Plant Morphology and Yield Parameters among the Inceptisols of Guma

Plant Morphology/Yield Parameters	Cropping Season		Df	T-Value	P-Value
	2017	2018			
Plant Morphology					
Plant Height cm)	107.80±4.40	58.54±1.70	31	10.49	<0.01**
Number of Leaves	10.52±0.20	11.50±0.17	47	3.72	<0.01**
Leaf Area (m^2)	2.76±0.11	5.47±0.14	45	14.97	<0.01**
Leaf Area Index	0.23±0.01	0.45±0.01	45	14.97	<0.01**
Stem Diameter (mm)	58.81±1.30	85.30±2.20	38	10.20	<0.01**
Yield Parameters					
Ear Weight (kg)	70.10±4.30	198.10±9.60	33	12.16	<0.01**
Ear Length (cm)	9.29±0.30	14.24±0.43	43	9.38	<0.01**
Ear Diameter (cm)	97.40±4.20	208.60±8.20	35	12.01	<0.01**
Grain Yield (t/ha)	0.85±0.04	1.84±0.12	29	7.93	<0.01**

**significant at 99% CL

Table 6: Correlation Matrix of plant morphology and yield parameters

	PltHt	No. of Lvs	Leaf Area	LAI	Stem Dm	Ear Wt	Ear Lt	Ear Dm	GrnYd
PltHt	-								
No. of Lvs	0.04	-							
Lv Area	0.62**	0.64**	-						
LAI	0.62**	0.64**	0.85**	-					
Stem Dm	0.52**	0.71**	0.94**	0.94**	-				
Ear Wt	0.59**	0.67**	0.88**	0.88**	0.86**	-			
Ear Lt	0.49**	0.70**	0.85**	0.85**	0.84**	0.96**	-		
Ear Dm	0.59**	0.67**	0.89**	0.89**	0.87**	0.98**	0.98**	-	
GrnYd	0.50**	0.71**	0.81**	0.81**	0.82**	0.88**	0.87**	0.88**	-

**significant at 99% CL

The correlation between plant height and Number of leaves and between plant height and Ear Length (0.04 and 0.49) were weak while all other parameters were strongly correlation and ranged from 0.50 to 0.98. The weak correlation experienced among some of the maize plant traits was due to the fact that they were not effectual. However, the strong correlations among the other traits suggested that they depend on each other to influence the increase or the decrease of one another (Table 6).

4. CONCLUSION

From the above results, it could be concluded that yield advantages were gained by cultivating maize in Inceptisols of Guma with fertilizer, albeit at moderate application rates. The yield potential by farmers in this study area can be successfully maximized with the application of NPK 90:45:45 kg/ha.

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