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EFFECTS OF VARIATION IN N:K RATIO IN SOILS ON THE GROWTH, NUTRIENT AVAILABILITY AND YIELD OF MAIZE (ZEA MAYS L.)

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ABSTRACT

This study was undertaken in two distinct ecological zones of Edo state of Nigeria to determine the effects of variation in N:K ratio in soils on the availability of N, K and on the growth and yield of maize. The two sites used were Rubber Research Institute of Nigeria (RRIN) Iyanomo (forest) and the Teaching and Research Farm of Ambrose Alli University, Emaudo, Ekpoma (derived savanna). RRIN is located in coastal plain sand while Emaudo is located in a transition zone between the coastal plain and basement complex of Edo state, Nigeria. The soils of the two experimental sites were analyzed for physicochemical properties before the commencement of the experiments. The experiments were carried out in two stages: Pot experiments in the screen house and Field experiments. Each of the experiments had ten treatments (adjusted ratios) that were fitted into randomized complete block design and replicated three times. The following adjusted N:K ratios of 0:0 (control), 1:1, 2:1, 3:1,:4:1, 5:1, 2:1, 3:1, 4:1, and 5:1 were used with maize (suwam - 1 variety) as the test crop. Results from the screen house revealed that N/K ratio 4:1 had the highest dry matter yield for both locations, (RRIN; 2.60 g/pot and Emaudo; 2.75 g/pot) but these values were not significantly different ($P< 0.05$) from what were obtained from N/K ratio 3:1 and 2:1, respectively. The N:K ratio in soil had influence on the availability of N, and K. Under field conditions, N/K ratio 4:1 had the highest grain yield for both locations (RRIN; 3.46 ton/ha and Emaudo; 3.33 ton/ha), and the highest cob field weight (RRIN; 9.92 ton/ha and Emaudo; 9.33 ton/ha), hence its recommendation.

Key words: N:K ratios, N and K availability, growth, Maize, yield.

INTRODUCTION

Inorganic fertilizers are essential component of any system in which the aim is to maintain good yield in the absence of organic manure (Ayoola, 2006). However the rate of application and dosage has a greater influence on both crop yield and its environment (Gruhn, et al.,., 2000). Excessive application of fertilizer as opined by

Smaling and Braun (1996) does not really enhance sustainability, crop nutrient uptake nor significantly increase yields but tends to encourage economic waste and damage to the environment. Inadequate application, on the other hand, can retard growth and lower yield in short term and in the long run jeopardizes sustainability

through soil mining and erosion. This precarious tilt between "excessive" and "inadequate" is the major challenge of fertilizer recommendation efforts and can only be effectively bridged when nutrients are applied at the right ratios.

Soil nutrient leaching and low level of soil organic matter has made nitrogen a limiting nutrient to maize production in Nigeria (Adetunji, 1991; Azeez, 2009). However, high supply of N is frequently associated with acidification and accumulation of ammonia in the rhizosphere (Roem Klees and Berendse, 2002). Increases in N availability may also lead to strong P and K shortage which might exclude some plant species through vitality (Lawniczak, 2009).

Potassium is known to play a major role in osmoregulation, enzyme activation and carbohydrate translocation (Zhi-Yong, et al., 2009). The release and fixation of K is as a function of fertilizer application rate and soil parent material (Simonsson, et al., 2007). Furthermore, K supply might affect N uptake in leaves, photosynthetic activity and water use efficiency (Egilla, et al., 2005).

Majority of tropical soils are fragile and low in plant nutrients (Carsky and Iwuafor, 1995; Juo and Wilding, 1996) and with climate that is characterised by high rainfall and insolation which are however not evenly distributed in the various ecological zones. Hence, variation in the performance of crops, the soil condition and nutrient status are expected among the ecological zones.

In this study, we performed a screenhouse house experiment and a back up field experiment to determine the effects of Variation of N:K Ratio in Soils on the growth, nutrient availability and Yield of Maize (Zea mays L.). To better understand the variations in N:K ratios, we examined the growth responses, nutrient concentrations in earleaf at silk and crop yield for the best combination of N:K ratios in soils of this locality.

MATERIAL AND METHODS

The two sites used for this experiment were located in Rubber Research Institute of Nigeria (RRIN) Iyanomo (rain forest), the soils are derived from the coastal plain sand parent material and the Teaching and Research Farm of Ambrose Alli University, Emaudo annex, Ekpoma (derive savanna), the soils are from the transition zone between the coastal plain and basement complex, both in Edo state, Nigeria. Soils from RRIN used for the study are Inceptisols, classified as Typic Dystrudept and specifically located at latitude 60 09" and 85" N and longitude 5o 35'' and 58'' E (Orimoloye, 2011), while soils from Emaudo are Ultisols, classified as Rhodic paleudults and located at latitude 6.180 and 6.460 E and longitude of 6.000 and 6.400 N (Bazuaye, 2009).

The experiment was carried out in two stages: Pot experiment in the screen house (screen house ionic experiment). Field experiment (field ionic experiment). Surface Soil samples taken from each of the representative sites, were air dried, sieved and analyzed for its physical and chemical properties, 1000g each were weighed and placed in 1.5 liter plastic cups, based on the soil test values, using the following adjusted ratios: 0:0, (control) 1:1, 2:1, 3:1, 4:1, 5:1, 1:2, 1:3, 1:4 and 1:5 N:K ratios (screen house). Nitrogen was applied as urea, and potassium as muriate of potash. Using Maize as the test crop, distilled water was used for irrigation, the above ground portions of maize plants, were harvested six weeks after planting (WAP). The experiment was repeated in the field as a fol-

low up of the screen house work. The screen house recommendation alone cannot be adopted for field studies because of differences in soil volume ratio, root restriction, number of plants per pot, total nutrient exhaustion, short duration and other controlled conditions. The field ionic studies were conducted in two locations, RRIN and Emaudo, respectively. The experiment was a randomized complete block design. N:K ratio trials were laid out consisting of 10 treatments randomized among the plots within the blocks. Each plot size was 2.5m x 2.0m and the planting distance adopted was 75 X 25cm with a space of 50cm between plots and 80cm between blocks. Agronomic growth traits were measured at 4 and 8 WAP. Two ear leaf samples were randomly selected from the centre row of each plot at silk and were analyzed for their nutrient contents of N and K. Three plants in each plot (middle row) were harvested from 15 plants in each plot to eliminate the effect of cross feeding. The harvested maize cob was dried and dehusked and the dry weight (yield) noted. All data obtained from laboratory, screen house and field studies were subjected to statistical analysis (SARS).

Soils/plant tissue analysis

Soil pH was measured in 1:1 soil water suspension (Macleans, 1982). Exchange acidity (Al3+, H+) was extracted with 1NKCl (Thomas, 1982). Organic Carbon was determined by wet dichromate acid oxidation method (Nelson and sommers, 1982). Exchangeable cations (Ca, Mg, K and Na) were extracted with 1N NH4OAC at pH 7.0. Potassium and Na were determined with a flame emission photometer while Ca and Mg were determined with atomic absorption spectrophotometer (Anderson and Ingram, 1993). Effective cation exchange capacity (ECEC) was calculated by the summation of exchangeable bases and exchange acidity (Anderson and Ingram, 1993). Particle size distribution was determined by the hydrometer method according to Okalebo et al.,. (2002). Plant samples were oven dried at 700c for 72 hours, milled and sieved through 0.5mm mesh sieve. Nitrogen was determined using the macro-kjedahl method (Anderson and Ingram, 1993), Potassium was determined by flame photometer.

RESULTS AND DISCUSSION

The physical and chemical properties of the soils used for the experiments are presented on Table 1. The Soils from the two sites were acidic in nature and had low eletrical conductivity, total nitrogen, organic carbon, exchangeable po-

TABLE 1: Physical and chemical properties of experimental sites.

Parameters	RRIN	EMAUDO
pH	5.30	5.36
Organic Carbon (g/kg)	8.0	7.7
Organic matter (g/kg)	13.8	13.3
Available P (mg/kg)	4.37	4.78
Total Nitrogen (N) (g/kg)	0.72	0.58
Exchangeable Ca (Cmol/kg)	2.48	1.60
Exchangeable Na (Cmol/kg)	0.63	0.15
Exchangeable k (Cmol/kg)	0.16	0.18
Hydrogen (H^-) Cmol/kg	0.50	0.80
Aluminum (Al^{3+}) Cmol/kg	0.10	0.20
ECEC Cmol/kg	3.72	3.33
Clay (g/kg)	149.70	40.40
Silt (g/kg)	89.50	59.50
Sand (g/kg)	760.80	900.10
Textural class	SL	S

tassium and sodium and are below the critical nutrient element levels given for most crops of this region (Sobulo and Osiname, 1981; Adeoye and Agboola, 1985; Agboola and Corey, 1973; and Agboola and Obigbesan, 1974). The textural classes were sandy loam and sand.

Higher application of nitrogen significantly affected the maize plant growth rate with N:K applied ratios 4:1 having the highest growth rate in terms of maize plant height, stem girth, leaf area and number of leaves at 4 and 8 weeks after planting (WAP) for both experimental sites (tables 2, 3, 4 and 5). Although this was not significantly different from what were obtained from the applications at N:K ratios 1:1, 2:1 and 3:1 and as such, applying at N:K ratio 4:1 can be referred to as Excessive application of fertilizer, as opined by Smaling and Braun (1996).

TABLE 2: EFFECT OF VARIATION IN N:K RATIO ON MAIZE MEAN PLANT HEIGHT, STEM GIRTH, LEAF AREA AND NUMBER OF LEAVES AT 4 WAP (EMAUDO).

Adjusted N:K ratio in soils	Plant height (cm)	Stem girth (cm)	Leaf area (cm^2)	Number of leaves
0:0	17.10_{b}	0.83_{ab}	72.80	7.67
1:1	22.77_{ab}	1.20_{a}	106.38	8.67
1:2	19.03_{ab}	0.97_{ab}	79.59	8.00
1:3	17.60b	0.77b	68.85	7.67
1:4	17.97_{b}	0.93_{ab}	78.18	7.67
1:5	15.97_{b}	0.77_{b}	67.25	7.33
2:1	21.13_{ab}	1.10_{ab}	87.33	8.33
3:1	22.77_{ab}	1.20_{a}	106.38	8 67
4:1	25.77_{a}	1.20_{a}	108.27	8.67
5:1	19.80_{ab}	0.80_{ab}	73.59	7.33
SE. (P<0.05)	2.29	0.13	NS	NS

NS: Not significant
Means within the same vertical column having the same small letter(s) are not significantly different from each other.

TABLE 3: EFFECT OF VARIATION IN N:K RATIOS ON MAIZE MEAN PLANT HEIGHT, STEM GIRTH, LEAF AREA AND NUMBER OF LEAVES AT 8 WAP (EMAUDO).

Adjusted N:K ratio in soils	Plant height (cm)	Stem girth (cm)	Leaf area (cm^2)	Number of leaves
0:0	46.67_{c}	1.20_{c}	188.89_{b}	13.67
1:1	83.25_{ab}	1.73_{ab}	380.46_{a}	14.33
1:2	73.77cb	1.67ab	395.67a	15.00
1:3	73.60cb	1.73ah	429.65a	14.33
1:4	72.30_{cb}	1.73_{ab}	362.05_{a}	13.67
1:5	57.37_{cb}	1.67_{ab}	391.26_{a}	15.00
2:1	83.27_{ab}	1.67_{ab}	391.26_{a}	15.00
3:1	90.13_{ab}	1.67_{ab}	424.15_{a}	15.00
4:1	107.13_{a}	1.77_{a}	466.70_{a}	15.00
5:1	64.27_{cb}	1.43_{bc}	301.31_{ab}	15.00
SE. (P<0.05)	11.14	0.10	56.2	NS

NS: Not significant
Means within the same vertical column having the same small letter(s) are not significantly different from each other.

The effect of applied ratios (N:K) on dry matter yield (DMY), nutrient concentrations, and uptake of maize plant screen house in soils of Emaudo and RRIN are shown on Tables 6 and 7, while Correlation coefficient matrix showing the effect of applied N:K ratios in soils on the relationship between nutrient concentrations, uptake and DMY of maize in these soils are shown on tables 8 and 9, respectively. In Emaudo soils, the concentration of N in the ear leaf

TABLE 4: EFFECT OF VARIATION IN N:K RATIOS ON MAIZE MEAN PLANT HEIGHT, STEM GIRTH, LEAF AREA AND NUMBER OF LEAVES AT 4 WAP (RRIN)

Adjusted N:K ratio in soils	Plant height (cm)	Stem girth (cm)	Leaf area (cm^2)	Number of leave
0:0	24.00_b	0.73_c	170.4c	6.33
1:1	27.33_{ab}	0.87_{abc}	207.4bc	7.67
1:2	27.00_{ab}	0.82_{abc}	203.6bc	7.00
1:3	27.00ab	0.79bc	198.0bc	7.67
1:4	24.67_b	0.79_{ab}	194.3c	7.67
1:5	24.67_b	0.79_b	174.7c	6.67
2:1	29.67_{ab}	0.90_{ab}	222.8bc	7.67
3:1	30.00_{ab}	0.92_{ab}	259.4ab	7.67
4:1	32.33_a	0.96_a	282.7a	8.00
5:1	28.00_{ab}	0.80_{ab}	218.2bc	7.33
SE. (P<0.05)	2.29	0.13	19.17	NS

NS: Not significant
Means within the same vertical column having the same common small letter(s) are not significantly different from each other.

increased with increase in N application. The highest N concentration was obtained from applied N:K ratio 4:1, this was closely followed by 3:1 and 2:1, respectively. The highest K concentration was obtained from applied N: K ratio 1:5. The highest N uptake was from applied N: K ratio 1:5. The highest K uptake was also obtained from applied N: K ratio 4:1. Nitrogen concentration in the earleaf was nagatively and significantly correlated with K with 'r' values of

TABLE 5: EFFECT OF VARIATION IN N:K RATIOS ON MAIZE MEAN PLANT HEIGHT, STEM GIRTH, LEAF AREA AND NUMBER OF LEAVES AT 8 WAP (RRIN).

Adjusted N:K ratio in soils	Plant height (cm)	Stem girth (cm)	Leaf area (cm^2)	Number of leave
0:0	102.0e	1.03	385.4_b	11.00c
1:1	159.0bcd	1.40	525.9_{ab}	12.33abc
1:2	159.0bcd	1.40	486.3ab	12.33abc
1:3	151.0cd	1.37	481.0ab	12.00abc
1:4	146.3cd	1.27	470.2ab	12.00abc
1:5	138.7d	1.03	456.8ab	11.33bc
2:1	169.0abc	1.47	560.8_{ab}	12.67ab
3:1	178.3ab	1.53	575.3_{ab}	13.00a
4:1	184.7a	1.60	587.0_a	13.33a
5:1	160.7abcd	1.43	537.7_{ab}	12.67ab
SE. (P<0.05)	7.66	NS	58.3	0.49

NS: Not significant
Means within the same vertical column having the same small letter(s) are not significantly different from each other.

TABLE 6: EFFECT OF VARIATION IN N:K RATIOS ON PLANT NUTRIENT CONCENTRATIONS, UPTAKE AND DRY MATTER YIELD OF MAIZE IN THE SCREEN HOUSE IN SOILS OF EMAUDO

Adjusted N:K ratio in soil	D.M.Y. (g/pot)	conc of nutrients in plant N (Conc) (%)	K (Conc) (%)	uptake of nutrients N(Uptak) mg/kg	K(Uptak) mg/kg
0 : 0	1.13	1.49	1.65	17.68	22.20
1 : 1	1.57	1.50	1.87	23.55	29.36
1 : 2	1.52	1.54	2.1	16.94	23.10
1 : 3	1.29	1.69	2.14	46.14	58.42
1 : 4	1.28	1.74	2.29	22.62	29.77
1 : 5	1.20	1.77	2.43	28.85	39.61
2 : 1	1.76	2.13	1.61	24.07	18.19
3 : 1	1.80	3.15	1.51	38.70	27.18
4 : 1	2.75	3.18	1.24	33.35	18.97
5 : 1	1.20	3.32	1.17	37.12	18.72

-0.749* and Nitrogen uptake in the earleaf was positively but not significantly correlated with K uptake with 'r' values of 0.512 respectively. In RRIN soils, the concentration of N in the ear leaf increased with increase in N application. The highest N concentration was obtained from applied N:K ratio 4:1, this was closely followed by 3:1 and 2:1, respectively. The highest K concentration was obtained from applied N: K ratio 1:5. The highest N uptake was from applied N: K ratio 1:5. The highest K uptake was also obtained from applied N: K ratio 1:4. Nitrogen concentration in the earleaf was negatively and significantly correlated with K with 'r' values of -0.755* and Nitrogen uptake in the earleaf was positively and also significantly correlated with K uptake with 'r' values of 0.977** respectively.

TABLE 7: EFFECT OF VARIATION IN N:K RATIOS ON PLANT NUTRIENT CONCENTRATIONS, UPTAKE AND DRY MATTER YIELD OF MAIZE IN THE SCREEN HOUSE IN SOILS OF RRIN

Adjusted N:K ratio in soil	D.M.Y. (g/pot)	conc of nutrients in plant N (Conc) (%)	K (Conc) (%)	uptake of nutrients N(Uptak) mg/kg	K(Uptak) mg/kg
0 : 0	0.54	1.71	1.61	9.21	9.74
1 : 1	1.17	1.72	1.65	20.11	21.69
1 : 2	1.09	1.782	1.91	21.92	23.47
1 : 3	0.95	1.84	1.94	22.82	24.04
1 : 4	0.70	1.99	2.05	26.45	27.20
1 : 5	0.53	1.92	2.17	49.72	56.32
2 : 1	1.24	1.92	1.95	20.93	20.13
3 : 1	1.33	2.87	1.81	21.54	16.05
4 : 1	2.60	2.93	1.72	16.10	11.00
5 : 1	1.23	3.54	1.31	13.46	6.94

TABLE 8: CORRELATION COEFFICIENT MATRIX SHOWING THE EFFECT OF APPLIED N:K RATIOS IN SOILS ON THE RELATIONSHIP BETWEEN N:K CONCENTRATIONS, UPTAKE AND DMY OF MAIZE PLANT IN THE SCREEN HOUSE (SOILS OF EMAUDO)

	D.M.Y.	*N(Conc)*	*k(Conc)*	*N(Uptak)*	*k(Uptak)*
D M Y	1				
N(conc)	0.048	1			
K(conc)	0.088	-0.749*	1		
N(uptake	0.870**	0.528	-0.303	1	
K(uptake)	0.835**	-0.376	0.618	0.512	1

*, **- significant at 5 and 1% respectively

TABLE 9: CORRELATION COEFFICIENT MATRIX SHOWING THE EFFECT OF APPLIED N:K RATIOS IN SOILS ON THE RELATIONSHIP BETWEEN N:K CONCENTRATIONS, UPTAKE AND DMY OF MAIZE PLANT IN THE SCREEN HOUSE (SOILS OF RRIN)

	D.M.Y.	*N(Conc)*	*k(Conc)*	*N(Uptak)*	*k(Uptak)*
D.M.Y.	1				
N(Conc)	-0.340	1			
k(Conc)	0.789**	-0.755*	1		
N(Uptak)	0.983**	-0.172	0.701*	1	
k(Uptak)	0.998**	-0.368	0.810**	0.977**	1

*, **- significant at 5 and 1% respectively

The positive correlation between the uptake of N and K probably is an indication of synergistic relationship. This was in agreement with the findings of Heathcote (1972). In the N/K ratio experiment, there was a significant effect of applied ratio on earleaf DMY in both soils of RRIN and Emaudo. The DMY and concentrations of N and K where highest at N/K ra-

tio 4:1 in both soils. Eghball and Power (1999) observed that fertilizer fortified with Nitrogen increases the concentrations of nitrogen and phosphorus as well as potassium concentration in plant tissue. This could be the probable reason while K concentration in the plant tissue was high with higher N application. Nitrogen/ Potassium application of varying ratios affected maize vegetative growth significantly in some stages of growth. However, Howeler and Spain (1980) found at carimagua that the crop did not respond to N unless K was applied in the right proportion. With grain yield (table 10), applied N/K ratio 4:1 recorded the highest in both soils of RRIN and Emaudo although not significant. The highest cob yield was also obtained from the same applied ratio in both soils. Gething (1993) of the international potash institute stated that in Asia the N: K ratio usage approaches 10: 1 compared with around 2: 1 in Europe and North America and some other parts of the world. This implies that with soils of RRIN and Emaudo, N:K ratios 4:1 could probably be the best ratio for maize production, hence its recommendation. Nitrogen and Potassium concentrations in the earleaf at silk at this particular N/K ratio application level were within the sufficiency ranges based on values given by Jones and Eck, (1973).

TABLE 10: EFFECT OF SOIL NITROGEN:POTASSIUM RATIOS ON THE YIELD OF MAIZE (COB AND GRAIN) IN SOILS OF RRIN AND EMAUDO.

	RRIN		EMAUDO	
Adjusted N:K Ratio in Soils	COB FIELD WEIGHT (ton/ha)	GRAIN YIELD (ton/ha)	COB FIELD WEIGHT (ton/ha)	GRAIN YIELD (ton/ha)
0:0	6.11d	2.16	5.12c	2.07
1:1	7.46b	3.06	7.62b	3.01
1:2	7.46b	2.60	7.61b	2.71
1:3	7.32c	2.45	6.81c	2.62
1:4	6.47c	2.34	6.35c	2.33
1:5	6.14d	2.28	6.11c	2.21
2:1	8.22a	3.12	7.71b	3.07
3:1	8.63a	3.37	8.71a	3.11
4:1	9.92a	3.46	9.33a	3.33
5:1	6.79c	2.36	6.52c	2.46
SE(.05)	0.011	NS	0.049	NS

Means within the same vertical column having the same common small letter(s) are not significantly different from each other.

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