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YIELD RESPONSE OF MAIZE (*Zea mays* L.) AND SOIL NUTRIENTS TO TIME AND METHODS OF NPK APPLICATION

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ABSTRACT

A study was carried out at the Teaching and Research Farm of the University of Ado-Ekiti, Nigeria, during early 2008 and 2009 cropping seasons to determine the effects of time and methods of NPK fertilizer application on yield of maize (*Zea mays* L.) and soil nutrients. The design was split – plot, laid out in a Randomized Complete Block, with three replicates. Time of NPK fertilizer application constituted the main – plot treatments, while the method of NPK fertilizer application was the sub-plot treatment. The main-plot treatments were: no fertilizer application (NFA) i.e. control, single early application (SEA) at four weeks after planting (WAP), two split applications (SA), with half applied at 4 WAP, and the rest half at 8 WAP and single late application (SLA) at 8 WAP. The methods of NPK fertilizer application were band placement and broadcast methods. The results indicated that there were significant (P – 0.05) differences between the two treatments as regards their effects on yield and yield components of maize. The percentage decreases in soil organic carbon (SOC), adduced to time of NPK fertilizer application were 38, 44, 48 and 40 for NFA, SEA, SA and SLA respectively. SLA resulted in a 60% increase in total N, contrasting decreases of 36, 26 and 29% for NFA, SEA and SA respectively. Similarly, SLA resulted in a 62% increase in available P, as against decreases of 26, 16 and 21% for NFA, SEA and SA respectively. Time of NPK fertilizer application significantly (P = 0.05) increased maize grain yield from 2.79 t ha^{-1} for NFA to 4.15, 4,43 and 3.13 t ha^{-1} for SEA, SA and SLA, respectively. Band placement of NPK fertilizer gave 4.10 t ha^{-1} maize grain yield, which was significantly higher than 3.75 t ha^{-1} obtained for the broadcast method counterpart.

Key words: Yield, time, method, fertilizer, soil, nutrients.

INTRODUCTION

One of the major constraints to crop production in the tropics is inherently low soil fertility status, characterized by low levels of activity clay, organic matter, nitrogen, phosphorus and exchangeable cations. (Awodun and Olafusi, 2007; Adenle, 2010). Since food production, a dependent factor of soil fertility, is the necessity of man hence, proper management of soil fertility, which is a pre-requisite for continuous food production and sustainability of the resources is imperative (Risse, 2007; Adenle, 2010).

In recent time, many soil fertility improvement techniques have been recommended, which included adoption of appropriate and adequate fertility packages, involving the use of organic and/or inorganic fertilizer (Tankou, 2000). The use of inorganic fertilizer in maintaining soil fertility has been reported to be ineffective due

to certain limitations, such as declined soil organic matter content, nutrient imbalance, soil acidification, as well as soil physical degradation with resultant increased incidence of soil erosion (Adenle, 2010).

Previous studies (Adepetu, 2007; Boyer, 2009; Morr, 2010) have demonstrated significant effects of time of NPK fertilizer application on maize yield and soil nutrients. Similarly, significant response of maize yield and soil nutrients to methods of NPK fertilizer application have been demonstrated by studies of (Ologunja 2006; Mahal, 2008; Kemper 2010). In all these studies, it was reported that banding of NPK fertilizer was superior to broadcast method with respect to their effects on maize yield and soil nutrient. However, Beadle (2003) and Khan (2009), obtained non-significant difference between band placement and broadcast methods of NPK fertilizer application as regards their influence on maize yield.

Although, in Southwestern Nigeria, N, P and K nutrition of maize has been accorded adequate research attention, information is inadequate concerning the effects of time and method of NPK fertilizer application on major soil nutrients and performance of maize. Therefore, this study examined influence of time and methods of NPK fertilizer application on maize grain yield and soil nutrients.

MATERIALS AND METHODS

Studies site: The two-year experiment was carried out at the Teaching and Research Farm of the University of Ado-Ekiti, Nigeria, during 2008 and 2009 cropping seasons. The soil of the study site belongs to the broad group Alfisols (SSS, 2002) of the basement complex. The soil was highly leached, with low to medium organic matter content. The study site had earlier been cultivated to a variety of arable crops, among which were cassava, cocoyam, sweet potato and maize before it was fallowed for three years prior to the commencement of this study. The fallow vegetation was manually slashed, and thereafter, the land was ploughed and harrowed.

Collection and analysis of soil samples: Prior to planting, ten core soil samples, randomly collected from 0-15 cm top-soil were mixed to form a composite, which was analysed for physical and chemical properties. At the end of the second cropping season, another set of soil samples was collected and analysed. The soil samples were air-dried, ground, and passed through a 2mm sieve. The sieved samples were then analysed for pH by using glass electrode pH meter. Bray P -1 extractant was used to extract available P, while organic C and total N were determined by the Walkey, Black oxidation and kjeldahl digestions, techniques, respectively. Exchangeable bases K, Ca, Mg and Na were extracted by neutral normal ammonium acetate. K, Ca, and Na were determined by flame photometry, while Mg was by Atomic Absorption spectrophotometry. Effective cation exchange capacity (ECEC) was obtained by summation method (sum of K, Ca, Mg, Na and exchangeable acidity). The determination of exchangeable acidity was by extraction-titration method described by Mclean (1965). Particle size distribution was done by the hydrometer method of soil mechanical analysis as outlined by Bouyoucos (1951).

Experimental design and treatments: The design was split–plot, laid out in a Randomized Complete Block, with three replicates. Time of NPK fertilizer application constituted the main –plot treatment, while the method of NPK fertilizer application was the sub-plot treatment. The main–plot treatment were: no fertilizer application (NFA) ie. Control, single early application (SA), with half applied at 4 WAP, and the rest half at 8 WAP and single late application (SLA) at 8 WAP. The methods of NPK fertilizer application were band placement and broadcast methods. The NPK fertilizer was applied at the rate of 400 kg ha^{-1} (Fondufe, 1995).The main-plot size was 4m x 2m, while

the sub-plot size was 2m x 1m.

Planting, collection and analysis of data:
In 2008 and 2009, planting was done on March 16 and April, respectively. Seeds of Oba super 1 maize variety dressed with Apron Plus were planted at 100 cm x 50 cm (20,000 plants ha^{-1}). Weeding was done manually at 3, 6 and weeks after planting. At harvest, data were collected on length and diameter of cob, and dry seed weight was determined using a Metler weighing balance. All the data were subjected to analysis of variance (ANOVA) and treatment means were compared, using the Least Significant Difference (LSD) at 5% (0.05) level of probability.

RESULTS

Table 1 shows the physical and chemical properties of soil in the study site prior to cropping. The soil was sandy loam in texture, with a pH of 5.4. The soil organic carbon (SOC) and total nitrogen were 2.91 and 1,87g kg^{-1}**,** respectively. The available phosphorus was 1.61 mg kg^{-1}. The exchangeable bases i.e. K, Ca, Mg and Na were 1.98, 1.56, and 1.28 cmol $kg^{-1,}$ respectively. The exchangeable acidity and effective cation exchange capacity were 0.61 and 6.38 cmol kg^{-1}, respectively.

Table 1: The physical and chemical properties of soil in the study site prior to cropping

Parameters	**Values**
pH	5.4
Organic carbon (g kg^{-1})	2.91
Total nitrogen (g kg^{-1})	1.87
Available phosphorus (mg kg^{-1})	1.61
Exchangeable K (cmol kg^{-1})	1.48
Exchangeable Ca (cmol kg^{-1})	1.56
Exchangeable Mg (cmol kg^{-1})	1.45
Exchangeable Na (cmol kg^{-1})	1.28
Exchangeable Acidity (cmol kg^{-1})	0.61
Effective cation exchange capacity	6.38
Particle size analysis (g kg^{-1})	
Sand	650
Silt	200
Clay	130

Changes in soil nutrient status after cropping. Table 2 shows the influence of time and methods of NPK fertilizer application on major soil nutrients after cropping. The percentage decreases in SOC, adduced to time of NPK fertilizer application were 38,44, 48 and 40 for NFA, SEA, AS and SLA, respectively. SLA resulted in a 62% increase in available P, compared to decreases of 26, 16 and 21% for NFA, SEA and SA, respectively. Similarly, SLA resulted in a 60% increase in total N, contrasting decreases of 36, 26 and 29 % for NFA, SEA and SA, respectively. SLA resulted in a 69 % increase in exchangeable K, as against decreases of 47, 41 and 49 % for NFA, SEA and SA, respectively. Band placement of NPK fertilizer decreased SOC by 31%, compared to increase of 57, 80 and 76 % for N, P and K, respectively. Broadcast method of NPK fertilizer application resulted in decrease of SOC, N, P and K.

Table 2: Effects of time and methods of NPK fertilizer application on major soil nutrients after cropping.

Treatment	Org C (gkg^{-1})				Total N (gkg^{-1})				Available P ($mgkg^{-1}$)				Exchangeable K ($cmolkg^{-1}$)			
	Initial	Final	*change	%change	Initial	Final	*change	%change	Initial	Final	*change	%change	Initial	Final	*change	%change
Time of NPK fertilizer application																
No fertilizer	2.91	1.80	-1.11	38	1.87	1.20	-0.67	36	1.61	1.20	-0.41	26	1.48	0.79	-0.69	47
Single early application	2.91	1.63	-1.28	44	1.87	1.38	-0.49	26	1.61	1.35	-0.26	16	1.48	0.88	-0.60	41
Split application	2.91	1.52	-1.39	48	1.87	1.33	-0.54	29	1.61	1.28	-0.33	21	1.48	0.75	-0.73	49
Single late application	2.91	1.75	-1.16	40	1.87	2.99	1.12	60	1.61	2.60	0.99	62	1.48	2.50	1.02	69
Methods of NPK fertilizer application																
Band placement	2.91	2.00	-0.91	31	1.87	2.93	1.06	57	1.61	2.90	1.29	80	1.48	2.60	1.12	76
Broadcast method	2.91	2.25	-0.66	23	1.87	1.18	-0.69	37	1.61	1.08	-0.53	33	1.48	0.89	-0.59	40

*Change in soil nutrient status after cropping = final – initial values

Table 3: Effects of time and methods of NPK fertilizer application on grain yield, length and diameter of maize cob at harvest

Treatments	Maize grain yield ($t\ ha^{-1}$)			Maize cob length (cm)			Maize cob diameter (cm)		
	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean
Time of NPK fertilizer application									
No fertilizer (control)	2.88d	2.69d	2.79	10.08d	9.94d	10.01	5.11d	5.04d	5.08
Single early application	4.19b	4.10b	4.15	13.11b	12.99b	13.05	7.21b	7.11b	7.16
Split application	4.4a	4.40a	4.43	14.70a	14.58a	14.64	8.59a	8.47a	8.53
Single late application	3.17c	3.08c	3.13	11.27c	11.18c	11.23	6.21c	6.13c	6.17
Methods of NPK fertilizer application									
Band placement	4.16a	4.03a	4.10	13.51a	13.42	13.47	1.63a	7.55a	7.59
Broadcast method	3.80b	3.69b	3.75	1.86b	12.74b	12.80	7.00b	6.89b	6.95

Values followed by the same letter in the same column under each treatment are not significantly different at P = 0.05.

Maize grain and yield components:
Grain yield and yield components of maize at harvest as affected by time and methods of NPK fertilizer application are presented in Table 3. Time of NPK fertilizer application was high, split or late application resulted in significant increases in maize grain yield from 2.79 t ha^{-1} for the control NFA to 4.15, 4.43 and 3.13 t ha^{-1} for SEA, SA and SLA, respectively. Similarly, NPK fertilizer application resulted in significant increases in maize cob length from 10.01 cm for NFA to 13.05, 14.64 and 11.23 cm for SEA, SA and SLA, respectively. NPK fertilizer application significantly increased maize cob diameter from 5.08 cm for NFA to 7.16, 8.53 and 6.17 cm for SEA, SA and SLA, respectively. Band placement of NPK fertilizer gave 4.10 t ha^{-1} maize grain yield, which was significantly higher than 3.75 tha^{-1} for the broadcast method. Band placement gave 7.59 cm cob diameter, which was significantly higher than 6.95 cm for the broadcast method.

DISCUSSION

The decrease in SOC (or soil organic matter, SOM) obtained for single early application, split application and single late application of NPK fertilizer are in conformity with the findings of Adepetu (2007), Boyer (2009) and Morr (2010), who noted decrease in SOM after cropping, regardless of timing of NPK fertilizer application. This observation was due, perhaps, to the fact that application of NPK fertilizer may have resulted in the provision of conducive conditions for microbial activities which resulted to accelerated organic matter decomposition, hence, SOC depletion. The decreases in N, P and K associated with single early application and split application of NPK fertilizer can be ascribed to high uptake of these three nutrient elements for synthesis of certain organic compounds which are required for vegetative growth in the early growing period. Boyer (2009) and Morr (2010), have also reported that the rate of nutrient uptake is faster in the early growing period than at a later stage.

Much as the decreases in N, P and K after cropping, can be attributed to high uptake by maize plants, however, another factor that can be implicated for the decrease in N, P and K is the decrease in SOM. Previous studies (Adepetu, 2007 and Adenle, 2010), have established reduction in SOM and degradation of soil physical properties, following NPK fertilization with resultant incidence of leaching and erosion. So, the decrease in SOM, occasioned by NPK fertilization may have resulted in the decrease in N, and K, as these nutrient elements, like other nutrients, are integrally tied to SOM (Robinson *et al.*, 1994).

Single late application of NPK fertilizer resulted in increases in N, P and K after cropping, implying that maize plants did not make use of all the nutrients applied at eight weeks after planting before the completion of their growth-cycle. The decreases in N, P and K after cropping, associated with broadcast method can be ascribed to wastage of the fertilizer. This is because most of the NPK fertilizer was washed away by erosion, and so the little that eventually got into the soil may have been used up by maize plants.

The higher maize grain yield that attended split NPK fertilizer application agreed with the findings of Adepetu (2007); Boyer (2009) and Morr (2010). These authors reported significantly higher values of grain yield and yield components of maize under split than those for single early and single late application counterparts. The better NPK fertilizer utilization may have boosted up initial growth rate in maize plants, by accelerating the development of good vegetative structures. Thus, the rapid initial growth rate may have promoted photosynthetic activities in maize plants, with resultant high carbohydrate production during

fruiting, based on the premise that the growth of plants is positively correlated with their yields (Nyende *et al.,* 2001). This implies that, as far as maize is concerned, at least, two split doses of NPK fertilizer are required.

The lowest values of maize grain yield consistently recorded for single late NPK fertilizer application suggested that, maize plants did not benefit immensely from the NPK fertilizer applied at eight weeks after planting before the completion of their life-cycle. From the findings of this study, it is apparent that, for a good maize performance to be achieved, emphasis should not only be placed on the number of applications, rather, on timing of fertilizer application to coincide with plant nutrient demand, especially, at the most critical stages of growth. In view of the benefits that maize plants derived from early NPK fertilization, the recommendation of properly timed NPK fertilizer application, especially at four weeks after planting is imperative.

Band placement of NPK fertilizer gave significantly higher values of yield and yield components of maize than the broadcast method, suggesting more nutrients availability in the former than the latter. The higher nutrient availability associated with band placement was evident in increases in soil N, P and K after cropping, as against decreases in these three nutrients under broadcast method.

CONCLUSION

Single early and split application of NPK fertilizer resulted in decreases in SOC, N, P and K after cropping. However, single late application of NPK fertilizer resulted in increases in N, P and K after cropping. Band placement increased N, P and K after cropping, contrasting decreases of these three nutrients by the broadcast method of application. Similarly, band placement gave significantly higher values of maize yield and yield components than the broadcast method.

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