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Growth and Yield Responses of Okra (*Abelmoschus Esculentus*) and Soil Fertility Status to NPK Fertilizer Application Regimes

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Abstract: *There is a dire need to determine the most critical time of fertilizer application when demand for nutrients is highest in the growth cycle of crops in order to achieve the objective of increased crop yield, associated with fertilization. Consequent upon this, a two – year field experiment was carried out at the Teaching and Research Farm of the Ekiti State University, Ado – Ekiti, Ekiti State, Nigeria, during 2013 and 2014 cropping seasons to determine the effects of timing of NPK fertilizer application on the yield and yield parameters of okra (Abelmoschus esculentus) and soil fertility status. The experiment was laid out in a randomized complete block design with three replicates. The NPK fertilizer application regimes included: no fertilizer application (NFA), which served as control or check; application at 3, 6 and 9 weeks after planting (WAP). The results obtained indicated existence of significant (P = 0.05) differences among the NPK fertilizer application regimes with respect to their effects on soil nutrient status and okra growth and fruit yield. At the end of 2013 cropping season, NPK fertilizer application regimes resulted in significant increases in soil organic carbon (SOC) from 0.21 g kg^{-1} for NFA to 0.30, 0.41 and 0.50 g kg^{-1} for application at 3, 6, and 9 WAP. Similarly, at the end of 2014 cropping season, NPK fertilizer application regimes resulted in significant increases in SOC from 0.16 g kg^{-1} for NFA to 0.24, 0.35 and 0.42 g kg^{-1} for application at 3, 6, and 9 WAP. At the end of 2013 cropping season, NPK fertilizer application regimes resulted in significant increases in total N from 0.20 g kg^{-1} for NFA to 0.19, 0.25 and 0.33 g kg^{-1} for application at 3, 6, and 9 WAP. At the end of 2014 cropping season, NPK fertilizer application regimes resulted in significant increases in total N from 0.10 g kg^{-1} for NFA to 0.15, 0.22 and 0.28 g kg^{-1} for application at 3, 6, and 9 WAP. Mean values of okra fruit yield data across the two years of experimentation indicated that, NPK fertilizer application regimes significantly increased okra fruit yield from 0.37 t ha^{-1} for NFA to 1.15, 1.02 and 0.83 t ha^{-1} for the respective application at 3, 6 and 9 WAP.*

Keywords: *Fertilizer, nutrients, okra, soil, yield.*

1. INTRODUCTION

The inherently low fertility status of tropical soils, characterized by low activity clay, organic matter, nitrogen, phosphorus and exchangeable bases, has necessitated growing search for professionally sound soil fertility improvement practices, which in recent time, have included adoption of appropriate and adequate fertilizer packages, involving the use of organic and / or inorganic fertilizers (Atete, 2012; Lege, 2012; Wabaza, 2013). The use of inorganic or mineral fertilizers in improving and maintaining soil fertility has been reported to be ineffective, due to certain limitations. Some of these limitations include: low efficiency (due to loss of nutrients through volatilization and leaching), declined soil organic matter content, nutrient imbalance, soil acidification, as well as soil physical degradation and attendant increased incidence of soil erosion (Kader, 2012; Lege, 2012; Sekar, 2013). Asides, high cost and occasional scarcity of mineral fertilizers have posed a lot of problem to their use as nutrient sources (Guman, 2011; Exma, 2012).

Nitrogen, as well as phosphorus, plays an important role in fruiting, seeding and good quality development of okra plants (NIHORT, 1985). Potassium promotes formation of strong straw, with resultant decreased incidence of lodging in plants (NIHORT, 1985).

Previous studies (Atavil, 2011; Weil, 2012; Sosal, 2013; Ologun, 2013; Emezu, 2013) had demonstrated significant responses of okra growth and yield as well as soil nutrient status to time of NPK fertilizer application. In all the studies, significant differences in time of NPK fertilizer application treatments, as regards their effects on okra yield performance and soil fertility status were reported.

The principal objective of applying fertilizers to the soil is to improve the soil fertility, thus, raising the level of crop yield on farmers' farms. However, to achieve this objective of increased crop yield, associated with fertilization, there is a dire need to determine the most critical time of fertilizer application when demand for nutrients is highest in the growth cycle of crops. Consequent upon this, a two – year field experiment was carried out to determine the effects of timing of NPK fertilizer application on the yield and yield parameters of okra and soil fertility.

2. MATERIALS AND METHODS

2.1. Study Site

An experiment was carried out at the Teaching and Research Farm of the Ekiti State University, Ado – Ekiti, Ekiti State, Nigeria, during 2013 and 2014 cropping seasons. The soil in the study site belongs to the broad group Alfisol (SSS, 2003). The soil was highly leached, with low to medium organic matter, deep red – clay profile, with top sandy loam texture. The study site had been under continuous cultivation of a variety of arable crops, among which were cassava, maize, melon, cocoyam, sweet potato, prior to the commencement of this study.

2.2. Collection and Analysis of Soil Samples

Prior to planting, ten core soil samples, randomly collected from 0 – 15 cm soil depth, were bulked inside a plastic bucket to form a composite sample, which was analyzed for chemical properties. At the end of each year cropping, another set of soil samples was collected in each treatment plot and analyzed. The soil samples were air – dried, ground, and passed through a 2 mm sieve. The processed soil samples were analyzed in accordance with the soil and plant analytical procedures, outlined by the International Institute of Tropical Agriculture (IITA) (1989).

2.3. Experimental Design and Treatments

The experiment was laid out in a randomized complete block design with three replicates. The NPK fertilizer application regimes included: no fertilizer application (NFA), which served as control or check; application at 3, 6 and 9 weeks after planting (WAP). The NPK fertilizer was applied at the rate of 400 kg ha^{-1} (Exma, 2013). Each plot size was 3 m x 3 m.

2.4. Planting, Weeding, Collection and Analysis of Data

Planting of okra was carried out on May 1 and May 10 in 2013 and 2014, respectively. Three seeds of spineless Clemson variety were planted per hole, at a spacing of 60 cm x 30 cm, and later thinned off to one seedling per stand (55,556 okra plants ha^{-1}), four weeks after planting (WAP). Weeding was carried out manually at 4 and 8 WAP, using a hoe.

Data were collected on growth parameters, and at harvest, data were also collected on fruit yield and yield components. All the data were subjected to analysis of variance, and treatment means were compared, using the Duncan Multiple Range Test (DMRT) at 5% level of probability.

3. RESULTS

3.1. Chemical Properties of Soil in the Study Site Prior to Investigation

Table1. *The chemical properties of soil in the study site before investigation*

Soil properties	**Values**
pH	5.8
Organic carbon (g kg^{-1})	0.71
Total nitrogen (g kg^{-1})	0.41
Available phosphorus (mg kg^{-1})	0.61
Exchangeable	**Bases (cmolkg^{-1})**
Potassium	0.70
Calcium	0.65
Magnesium	0.59
Sodium	0.41
Exchangeable Acidity	0.29
Effective Cation Exchangeable Capacity (ECEC)	2.64

3.2. Changes in Soil Fertility Status After 2013 and 2014 Cropping Seasons

Tables 2 and 3 show soil fertility status as affected by NPK fertilizer application regimes at the end of 2013 and 2014 cropping seasons. At the end of 2013 cropping season, NPK fertilizer application regimes resulted in significant increases in pH of the soil from 3.0 for NFA to 3.6, 4.1 and 4.8 for application at 3, 6, and 9 WAP. Similarly, at the end of 2014 cropping season, NPK fertilizer application regimes resulted in significant increases in pH of the soil from 2.5 for NFA to 3.0, 3.6 and 4.2 for application at 3, 6, and 9 WAP. At the end of 2013 cropping season, NPK fertilizer application regimes resulted in significant increases in SOC from 0.21 g kg^{-1} for NFA to 0.30, 0.41 and 0.50 g kg^{-1} for application at 3, 6, and 9 WAP. At the end of 2014 cropping season, NPK fertilizer application regimes resulted in significant increases in SOC from 0.16 g kg^{-1} for NFA to 0.24, 0.35 and 0.42 g kg^{-1} for application at 3, 6, and 9 WAP. At the end of 2013 cropping season, NPK fertilizer application regimes resulted in significant increases in total N from 0.20 g kg^{-1} for NFA to 0.19, 0.25 and 0.33 g kg^{-1} for application at 3, 6, and 9 WAP. At the end of 2014 cropping season, NPK fertilizer application regimes resulted in significant increases in total N from 0.10 g kg^{-1} for NFA to 0.15, 0.22 and 0.28 g kg^{-1} for application at 3, 6, and 9 WAP.

At the end of 2013 cropping season, NPK fertilizer application regimes resulted in significant increases in available P from 0.24 mg kg^{-1} for NFA to 0.31, 0.38 and 0.44 mg kg^{-1} for application at 3, 6, and 9 WAP. At the end of 2014 cropping season, NPK fertilizer application regimes resulted in significant increases in available P from 0.20 mg kg^{-1} for NFA to 0.27, 0.32 and 0.38 mg kg^{-1} for application at 3, 6, and 9 WAP. At the end of 2013 cropping season, NPK fertilizer application regimes resulted in significant increases in exchangeable K from 0.20 cmol kg^{-1} for NFA to 0.34, 0.42 and 0.56 cmol kg^{-1} for application at 3, 6, and 9 WAP. At the end of 2014 cropping season, NPK fertilizer application regimes resulted in significant increases in exchangeable K from 0.13 cmol kg^{-1} for NFA to 0.28, 0.35 and 0.49 cmol kg^{-1} for application at 3, 6, and 9 WAP. At the end of 2013 cropping season, NPK fertilizer application regimes resulted in significant increases in exchangeable Ca from 0.25 cmol kg^{-1} for NFA to 0.29, 0.36 and 0.48 cmol kg^{-1} for application at 3, 6, and 9 WAP. At the end of 2014 cropping season, NPK fertilizer application regimes resulted in significant increases in exchangeable Ca from 0.19 cmol kg^{-1} for NFA to 0.24, 0.29 and 0.40 cmol kg^{-1} for application at 3, 6, and 9 WAP.

At the end of 2013 cropping season, NPK fertilizer application regimes resulted in significant increases in exchangeable Mg from 0.20 cmol kg^{-1} for NFA to 0.32, 0.41 and 0.49 cmol kg^{-1} the respective application at 3, 6, and 9 WAP. At the end of 2014 cropping season, NPK fertilizer application regimes resulted in significant increases in exchangeable Mg from 0.17 cmol kg^{-1} for NFA to 0.27, 0.34 and 0.40 cmol kg^{-1} for the respective application at 3, 6, and 9 WAP. At the end of 2013 cropping season, NPK fertilizer application regimes resulted in significant increases in exchangeable Na from 0.25 cmol kg^{-1} for NFA to 0.22, 0.29 and 0.34 cmol kg^{-1} for the respective application at 3, 6, and 9 WAP. At the end of 2014 cropping season, NPK fertilizer application regimes resulted in significant increases in exchangeable Na from 0.19 cmol kg^{-1} for NFA to 0.16, 0.23 and 0.30 cmol kg^{-1} for the respective application at 3, 6, and 9 WAP.

Table2.*Soil nutrient status as affected by NPK fertilizer application regimes after 2013 cropping season*

Treatments (NPK fertilizer Application regimes)	**pH**	**Org. C (g kg^{-1})**	**Total N (g kg^{-1})**	**Avail. P (mg kg^{-1})**	**Exchangeable bases (cmol kg^{-1})**			
					K	**Ca**	**Mg**	**Na**
NFA	3.0d	0.21d	0.20d	0.24d	0.20d	0.25d	0.20d	0.25d
3 WAP	3.6c	0.30c	0.19c	0.31c	0.34c	0.29c	0.32c	0.22c
6 WAP	4.1b	0.41b	0.25b	0.38b	0.42b	0.36b	0.41b	0.29b
9 WAP	4.8a	0.50a	0.33a	0.44a	0.56a	0.48a	0.49a	0.34a

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT).WAP = weeks after planting; NFA = no fertilizer application.

Table 3.*Soil nutrient status as affected by NPK fertilizer application regimes after 2014 cropping season*

Treatments (NPK fertilizer Application regimes)	**pH**	**Org. C (g kg^{-1})**	**Total N (g kg^{-1})**	**Avail. P (mg kg^{-1})**	**Exchangeable bases (cmol kg^{-1})**			
					K	**Ca**	**Mg**	**Na**
NFA	2.5d	0.16d	0.10d	0.20d	0.13d	0.19d	0.17d	0.19d
3 WAP	3.0c	0.24c	0.15c	0.27c	0.28c	0.24c	0.27c	0.16c
6 WAP	3.6b	0.35b	0.22b	0.32b	0.35b	0.29b	0.34b	0.23b
9 WAP	4.2a	0.42a	0.28a	0.38a	0.49a	0.40a	0.40a	0.30a

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). WAP = weeks after planting; NFA = no fertilizer application.

3.3. Okra Leaf Area

Okra leaf area as affected by different NPK fertilizer application regimes in 2013 and 2014 cropping seasons is presented in Table 4. Mean values of okra leaf area data across the two years of experimentation indicated that, NPK fertilizer application regimes significantly increased okra leaf area from 0.68 m^2 $plant^{-1}$ for NFA to 1.32, 1.08 and 0.79 m^2 $plant^{-1}$ for NPK fertilizer application at 3, 6 and 9 WAP, respectively.

Table4.*Okra leaf area as affected by different NPK fertilizer application regimes in 2013 and 2014 cropping seasons*

Treatments (NPK fertilizer Application regimes)	Okra leaf area (m^2 $plant^{-1}$)						
	4 WAP		8 WAP		10 WAP		
	2013	2014	2013	2014	2013	2014	Mean
NFA	0.39b	0.34b	0.81c	0.74c	0.94d	0.88d	0.68
3 WAP	0.51a	0.45a	1.69a	1.62a	1.86a	1.80a	1.32
6 WAP	0.37b	0.32b	1.21b	1.16b	1.72b	1.67b	1.08
9 WAP	0.38b	0.33b	0.83c	0.75c	1.26c	1.20c	0.79

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT).WAP = weeks after planting; NFA = no fertilizer application.

3.4. Okra Fruit Yield and Yield Attributes

Table 5 shows the effects of different NPK fertilizer application regimes on okra fruit yield and yield components at harvest. Mean values of okra fruit yield data across the two years of experimentation indicated that, NPK fertilizer application regimes significantly increased okra fruit yield from 0.37 t ha^{-1} for NFA to 1.15, 1.02 and 0.83 t ha^{-1} for NPK fertilizer application at 3, 6 and 9 WAP, respectively. Similarly, NPK fertilizer application regimes significantly increased okra fruit length from 4.71 cm for NFA to 8.56, 7.91 and 6.58 cm for the respective NPK fertilizer application at 3, 6 and 9 WAP. NPK fertilizer application regimes significantly increased okra fruit diameter from 3.84 cm for NFA to 7.47, 6.80 and 5.47 cm for the respective NPK fertilizer application at 3, 6 and 9 WAP.

Table5. *Okra fruit yield and yield attributes as affected by different NPK fertilizer application regimes in 2013 and 2014 cropping seasons.*

Treatments (NPK fertilizer application regimes)	Okra fruit yield (t ha^{-1})			Okra fruit length (cm)			Okra fruit diameter (cm)		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
NFA	0.40d	0.33d	0.37	4.73d	4.68d	4.71	3.88d	3.80d	3084
3 WAP	1.20a	1.10a	1.15	8.60a	8.52a	8.56	7.51a	7.42a	7.47
6 WAP	1.07b	0.96b	1.02	7.94b	7.87b	7.91	6.83b	6.76b	6.80
9 WAP	0.88c	0.77c	0.83	6.61c	6.55c	6.58	5.50c	5.44c	5.47

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT).WAP = weeks after planting; NFA = no fertilizer application.

4. Discussion

The chemical properties of soil in the study site, prior to cropping, indicated that the soil was slightly acidic, with a pH of 5.8. The soil organic carbon (SOC) value of 0.71 g kg^{-1} was below the critical level of 0.91 g kg^{-1} for soils in Southwestern Nigeria (Wabaza, 2013; Ologun, 2013). The total nitrogen content of 0.41 g kg^{-1} was below the critical level of 0.80 g kg^{-1}, according to Ologun (2013) and Sekar (2013). The K status of 0.70 cmol kg^{-1} was above the critical level of 0.45 cmol kg^{-1} (Emezu, 2013). The Ca, Mg and Na contents were all below the established critical levels for soils in Southwestern Nigeria (Guman, 2011).

Relative to the control treatment, the observed significant increases in soil pH, after cropping, adduced to NPK fertilizer application at 3, 6 and 9 weeks after planting, agree with the reports of Atavil (2011); Weil (2012) and Emezu (2013), who noted significantly higher pH values of soil in the plots of NPK fertilizer application at 3, 6 and 9 weeks after planting, relative to the control. The increases in soil pH, adduced to different NPK fertilizer application regimes, can be ascribed to increases in exchangeable basic cations at the exchange sites of soil in the plots of different NPK fertilizer application regimes. At the end of the second year (2014) cropping season, soil pH values for NPK fertilizer application at 3, 6 and 9 weeks after planting, were lower than what obtained at the end of the first year (2013) cropping season, suggesting increase in soil acidity under NPK fertilizer application regimes at the end of the second year. The increase in soil acidity, associated with NPK fertilizer application, can be attributed to acidifying effects of NPK fertilizer. The acidifying effects of NPK fertilizer can be ascribed to its acid – forming nature, due to its N and P content (Weil, 2012).

The significant increases in SOC that attended different NPK fertilizer application regimes, corroborate the findings of Sosal (2013) and Ologun (2013), who noted significant increases in SOC under NPK fertilizer application regimes, relative to the control. These observations can be ascribed to the significant increases in soil pH, associated with NPK fertilizer application regimes. This is because previous studies (Sosal, 2013; Ologun, 2013) had indicated that, the rate of organic matter decomposition, and hence, SOC turn over, depends on pH of the soil medium, with the rate of organic matter decomposition and SOC turn over, increasing with increasing pH (i. e. decreasing acidity).

The significantly higher total N, available P and exchangeable K values for the different NPK fertilizer application regimes, compared to the control, can be attributed to the release of N, P and K by NPK fertilizer. This implied that, not all the N, P and K, supplied through the NPK fertilizer application were utilized by okra plants. The highest values of all plant nutrients recorded in the plots of NPK fertilizer application at 9 weeks after planting, can be ascribed to accumulation of these nutrients, as the okra plants did not have enough time to utilize them before the completion of their life cycles or before they were harvested, unlike when the application was carried out at 3 and 6 weeks after planting. This implied that, of all the NPK fertilizer application regimes, NPK fertilizer application at 9 weeks after planting okra, resulted in highest residual effects of N, P and K.

At the end of the second year (2014) cropping activities, values of nutrients for all NPK fertilizer application regimes were lower than what obtained at the end of the first year (2013) cropping activities. These observations further confirmed the assertions of Guman (2011) and Exma (2013), who opined that soil fertility declined under continuous cropping with or without addition of inorganic or organic soil amendments. The lower values of soil nutrients, observed under NPK fertilizer application regimes at the end of the second year, was due perhaps, to lower SOC values recorded at the end of the second year under the NPK fertilizer application regimes. This is because soil organic matter (SOM) has been reported as a reservoir of other plant nutrients, that is, other plant nutrients are integrally tied to it, and hence, the maintenance of SOM is paramount in sustaining other soil quality factors (Robertson *et al.* 1994; Arena, 2012; Ase, 2014). These observations suggest that, soil fertility cannot be maintained or sustained on a long term basis through inorganic fertilization.

The significantly higher okra fruit yield and yield components, recorded for NPK fertilizer application regimes, compared to the control, are in agreement with the findings of Ologun (2013) and Sosal (2013), who reported significantly higher okra fruit yield and yield components under NPK fertilizer application regimes, relative to the check. These observations can be attributed to the release of N, P and K by the NPK fertilizer, unlike in the control plots where there was no nutrient release. The least values of okra fruit yield and yield parameters for NPK fertilizer application at 9 weeks after planting, suggested that, the okra plants did not benefit much from delayed application of the NPK fertilizer at 9 weeks after planting, unlike when the application was done at 3 and 6 weeks after planting.

The lower okra fruit yield and yield components recorded during the second year harvest, compared to the first year harvest, under NPK fertilizer application regimes, can be adduced to declined soil fertility during the second year, as a result of nutrient removal by okra during the first year cropping season.

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