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RESPONSE OF DRY SEASON OKRA *[Abelmorchus esculentus(L.)Moench]* TO TIMING OF FERTILIZER APPLICATION ON SANDY-LOAM SOIL

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ABSTRACT

Application of NPK fertiliser enhances okra fruit yield, but the lack of information on the proper time of application in dry season okra production has not enable farmers realize its optimum yield potential. Hence, this study assessed the appropriate time of applying NPK 15-15-15 fertiliser in dry season okra production under loamy-sand soil condition. Two field cropping of okra trials were conducted to evaluate the timing of 60 kg/ha NPK fertiliser application on okra performance. The treatments involved no fertilizer (NFA), fertilizer applications at 0, 2, 4 and 6 Weeks After Sowing (WAS). Treatments were laid out in Randomized Complete Block Design replicated three times. The results showed that significantly($\alpha_{0.05}$) lowerokra growth performances were observed in the NFA, while fertilizer application at 0, 2 and 4 WAS gave higher values. Fresh fruits weights at first cropping harvest ranged from 1733 – 2936±16.7g/2.5 m^2, with significant increasein application at 2 and 4 WAS compared toother treatments. In the second (residual) harvest, okra fruits yield ranged from 1344 - 2847±12.4 g/2.5 m^2, with significantly higherdifference observed at 0 WAS (2847±12.4 g/2.5 m^2) compared to the other treatments, while significantly lower values were observed at 6 WAS (1344±7.2 g/2.5 m^2)and NFA (1321±7.2 g/2.5 m^2).Number of fruitsper plot were similar in trend with fresh okra fruits yields. The highest cumulative fresh okra fruits yieldwas observed fertilizer application at0 WAS. In conclusion, application of NPK fertiliser in dry season okra production should be done at 0or 2 weeks after sowing on sand-loam soil.
Keywords: Timing of application, NPK fertiliser, Dry season,loamy-sand soil,Okra yield,

INTRODUCTION

Okra [Abelmoschusesculentus (L.)Moench]belongs to the family Malvaceae, an indigenous crop in Africa (AdeOluwa and Kehinde, 2011). It is a major economic crop in the West African sub-region owing to its health benefits and as a component of various recipes in many local cuisines and delicacies (Sanni et al., 2015).

The young green fruit is a nutritious vegetable containing 86.1% moisture, 9.7% carbohydrate, 2.2% protein, 0.2% fat, 1.0% fiber and 0.8% ash (Babatola and Olaniyi, 2013). Among health benefits derive from regular consumption of okra is ability to stabilize level of blood sugar and helps to regulate the rate of sugar absorbed by the body. In addition, okra mucilage has also been identified as an efficient tablet binder, plasma substitute and blood volume expander with tremendous potential for increasing renal function, alleviating kidney disease and reducing*proteinuria* (Bhat and Thoranathan, 2013). It is widely cultivated in West and Central Africa for its immature fruit used as vegetable. Immature or young okra fruit is eaten raw or cooked form.

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The dietary fibres and the seed provide protein, lycine and tryptophan amino acid. It is a common fruit vegetable crop with considerable areas under cultivation in Nigeria (Akanbi*et al.*, 2010). Depending on the cultivar, the frequency or period of harvesting, soil fertility status and agronomic practices, yield ranging from 2000 to 3000 kg ha^{-1} has been reported for okra(Asare-Bediako*et al*., 2014). Moreover, dry season okra production (which command premium price) faces the challenge of soil moisture as many farmers in west Africa practice rain fed okra production (Okunade*et al*., 2009; Chattopadhyay *et al*., 2011). There are several agronomic practices such as the use of different tillage practices, mulching with different materials and application of organic fertilisers which may reduce the demand for irrigation water, particularly in the rain-fed vegetable production. However, Water stress is usually the main physical limitation of the yield and growth of vegetables(Akbari*et al*., 2011). It has significant impact on forage growth, development and quality of okra yield especially in upland vegetable production. The problem of water in dry season okra production when prices are usually very highis a limiting factor of production and consequentially affects the supply and demand of vegetables in dry season (Abdul-El-Kader *et al.,* 2010). Where this is subdued, the period of fertiliser application for optimal yield of okra among the local farmers is limiting (Babatola, 2013). Similarly,there are numerous cultivars of okra with varying physiological attributes and may response differently to fertiliser(AdeOluwa and Kehinde, 2011; Estheit and Brisibe, 2015).

Despite the various advantages of the okra and the beneficial effect of synthetic fertilizers on its development and quality, there is a death of information on the appropriate timeto apply NPK fertiliser after sowing for optimal yield. There are various ways of applying fertilisers for okra production; such as side dressing, placement and broadcasting methods. For organic fertilisers, these are best applied 2 to 3 weeks deeply ploughed into the soil during tillage operation before sowing of the okra seed (Adediran*et al*., 2015).However, the effective timing of inorganic fertilizers application during periods of higher nutrient demand is essential for maximum plant growth, enhance yields and nutrient use efficiency, thereby improving net profit for the producer.In Nigeria, the limiting factors in okra production and other vegetable includespoor culturalpractices and low yielding varieties(AdeOluwa and Kehinde, 2011). Fertiliser application among the various agronomic practices also influences the growth and yield of green pod in okra. However, the specific time of chemical fertilisers application spelt a challenge among the small-scale farmers in Nigeria. Hence, this study focused on the assessment of the response of okra plant to various period of NPK fertiliser application to okra.

MATERIALS AND METHODS

Experimental site: The study was carried out at the School Farm of Koder Divine Comprehensive College, Imokun, Epe, Lagos State. The experiment was conducted on the field in mid-December, 2015 to March, 2016 on a sand-loamy soil which has previously been under continuous cultivation of different vegetables for two years.

Soil sample collection for laboratory analysis: Soil samples from the study site were collected before and after the experiment. The collected soil samples were bulked into composite separately, air-dried, crushed and sieved with 0.5mm mesh for soil physical and chemical laboratory analyses. The chemical properties analyzed for were nitrogen, phosphorus andexchangeable bases, while the particles size distribution was also determinedusing standard procedure described by IITA (1982) laboratory manual. The soil chemical and physical propertiesused before and after the studies are summarized in Table 1.

Experimental treatments and layout: The experiment plots and the treatments were laid in Randomize Complete Block Design (RCBD) with three replicates. The period of NPK fertiliser application formed the main factors (treatments) of the experiment. The NPK 15 – 15- 15 fertiliser (60 kg/ha) was applied at the following period intervals: 0 week after sowing (at sowing); 2 WAS; 4 WAS; 6 WAS and No Fertiliser Application (NFA).

Experimental land and planting operations: The land was manually cleared and tilled and beds were prepared, each measuring 2.5 m x 1.0 m (2.5 m^2) with 1 m betweenbeds and 2.0 m between blocks. Two seeds of *Bansatti* 447 okra variety were sown per hole at a spacing of 0.4 m x 0.6 m and seedlings were later thinned to one plant per stand to give a total plant population of ten (10) seedlings per bed (41,666 okra plants ha^{-1}),

The experimental materials: The materials used were okra seeds *Bansatti* 447 variety (sourced from Songhai Farm, Republic of Benin, Port Norvo), NPK 15-15-15 fertiliser; obtained from Agricultural Education Department, Michael Otedola College of Primary Education Noforija, Lagos State (MOCPED). It was a dry season okra production and was manually irrigated throughout the experiment.

The second cropping (residual trial) was established immediately after the first trial was terminated. The experimental layout and design were as in first trial and no fertiliser was applied.
Weed control: Weed control was carried out manually in the plots at 4 weeks after emergence and at early flowering using a hand-held hoe.
Harvesting: The harvest of Okra pods started 45 days after planting and proceeded until the conclusion of the trial.

Data collection and analysis: Four (4) okra plants were pre-tagged from each bed and were used for data collection. The following growth parameters were observed; plant height, stem girth (circumference), number of leaves, number of fruits and fresh fruit weight. All the data collected were analyzed using analysis of variance (ANOVA) and the means were separated using Duncan Multiple range tests (DMRT) at$\alpha_{0.05}$

RESULTS AND DISCUSSION
The chemical properties of the soil used for the experiment was slightly acidic with moderate organic carbon and low nitrogen and high P as recommended for okra (Omotoso and Shittu, 2008). The exchangeable bases, K, Ca, Na and Mg were low with exception of Ca. The soil is classified under low nutrient status based on these chemical dynamics. The physical characteristics of the same soil, with high level of sand (726 g/kg) with low levels of clay and silt 140 and 134 g/kg respectively, both properties descried the soil to be sandy loam soil. The textural classification showed that the soil is well drained and suitable for cultivation (Omotoso andShittu, 2008).The high level of sand revealed that the physical properties of the soil remained the same after okra cultivation. However, there were slight changes in the organic carbon, total nitrogen and the pH. Similarly, the N, P and exchangeable bases were reduced in content with exception of sodium (Na) that increased by 5% (Table 1). The reductions in the soil nutrients after the first cropping may be attributed to uptake by the crop. This was in support of Omotoso andShittu(2008) that okra use soil nutrient for growth and development.

Table 1: The Values of chemical and physical properties of soil used before and after the experiment

Parameters	before the experiment	after the experiment
pH (Cl)	6.4	5.5
Organic C (g kg^{-1})	1.4	1.2
Total N (g kg^{-1})	0.34	0.29
Available P (mg kg^{-1})	55.1	50.9
Exchangeable Bases (cmol kg^{-1})		
K	0.65	0.54
Ca	26.50	24.50
Na	0.38	0.40
Mg	2.82	2.22
Particle size distribution (g kg^{-1})		
Sand	726.0	726.0
Clay	140.0	140.0
Silt	134.0	134.0
Textural class	*Sandy loam*	*Sandy loam*

Plant height at two weeks after sowing ranged from 13.4 to 21.1 cm (Table 2). The highest plant height was observed when fertiliser application was applied at sowing. However, this was not significantly different from the treatment involving fertilizer application at 2 or 4 WAS. Nevertheless, these treatments gave significantlyhigher plant height compared fertilizer application at 6 WAS which was also significantly higher than no fertiliser application. Similarly, the stem girth followed the same trend as observed in the plant height, withno significantly difference among treatments as the values ranged from 2.1 to 2.5 cm. No fertiliser (NFA) treatment gave was significantly low number of okra leaves compared to other timing of fertiliser application. The highest number of okra leaves was observed when fertiliser was applied at 4 WAS. However, at the 2 and 6 WAS of fertiliser application, the number of leaf (7.0) was the same.

Table 2: Response of okra plants to different time of fertiliser application at two weeks after sowing (2 WAS)

Timeof fertiliser application	Plant height (cm)	Stem girth (cm)	Number of leaves
0 WAS	21.1	2.5	6.7
2 WAS	20.3	2.4	7.0
4 WAS	21.0	2.4	8.0
6 WAS	16.1	2.1	7.0
NFA	13.4	2.1	4.7
S.E (df = 14)	±1.3	ns	±0.4

0 WAS, applied at sowing; 2 WAS, two weeks after sowing; 4 WAS, four weeks after sowing; 6 WAS, six weeks after sowing; NFA, No Fertiliser Application.

At 4 WAS,okra plant height was significantly high (38.2 cm) under fertiliser application at 4 WAS (Table 3) compared to the other treatments.Significantly reduced plant height was observed when no fertiliser was applied (NFA) compared to the other timing of fertiliser application. However, there is no significant difference between the plant height between fertiliser application at 0WAS and 2 WAS. The stem girth at 4 WAS ranged from 2.6 to 3.1 cm. Stem girth were higher and similar among 0, 2 and NFA but not significantly different from the other treatments. Similarly, the number of leaves at the 4 WAS were higher in the treatments involving 0 and 6 WAS okra seeds, while significantly lower number of leaves was observed in the NFA plants.

Table 3: Response of okra plants at four weeks after sowing (4 WAS) to different timing of fertiliser application

Timeof fertiliser application	Plant height (cm)	Stem girth (cm)	Number of leaves
0 WAS	36.2	3.1	10.7
2 WAS	36.5	3.1	9.7
4 WAS	38.2	2.6	10.0
6 WAS	34.5	2.8	10.7
NFA	26.6	3.1	7.7
S.E (df = 14)	±1.2	ns	±0.6

0 WAS, applied at sowing; 2 WAS, two weeks after sowing; 4 WAS, four weeks after sowing; 6 WAS, six weeks after sowing; NFA, No Fertiliser Application.

Okra response to timing of fertiliser application at the 6th week after sowingshowed the okra plant height ranged from 38.5 to 42 cm (Table 4).The highest value observedin plants treated with fertiliser at sowing (0WAS).The significantlylowest plant height was observed in the no fertiliser application (NFA) treatment. Stem girth ranged from 3.1 to 3.6 cm and showed no significant difference among the treatments. Number of okra leaveswas highest in the 2 WAS fertilizer treatment. This value was not significantly higher than the treatment involving other fertilizer applications, except the no fertilizer application (NFA) treatment.

Table 4: Influence of different time of fertilizer application on okra plants at six weeks after sowing (6 WAS)

Timeof fertiliser application	Plant height (cm)	Stem girth (cm)	Number of leaves
0 WAS	42.3_a	3.6	15.7
2 WAS	41.2_b	3.4	16.3
4 WAS	41.5_b	3.4	16.0
6 WAS	40.0_b	3.1	15.0
NFA	38.5_c	3.3	11.3
S.E (df = 14)	±1.4	ns	±0.5

0 WAS, applied at sowing; 2 WAS, two weeks after sowing; 4 WAS, four weeks after sowing; 6 WAS, six weeks after sowing; NFA, No Fertiliser Application.

Crop performance is known to be associated with ability of the crop to acquire essential nutrients at the right time and in sufficient quantity to support growth and development prior to nutrient remobilization for enhanced yield (Marschner and Rengel, 2012). Hence, the improved okra plant height and stem girth across the period of observation must have been the resultant effect of early application of fertilizer at sowing compared to the other time of applications.According to Marschner and Rengel (2012),the acquisition of mineral nutrients begins with their movement from the surrounding soil to the root surface.

The early application of fertilizer to the crop, especially at sowing and 2 WAS must have triggered the movement of nutrients towards the crop root thereby favouring growth of the okra plant compared to the response observed in the delayed fertilizer application.Similarly, the early application of fertiliser to the okra plant is likely to have enhanced the root development to improve the plant nutrition relative to the delayed fertilizer application. This theory was explained by Marschner and Rengel (2012) that in response to enriched nutrient zones, root systems increase its levels of branching. Such proliferations around bands of fertilizer must have ensuredthe plants maximum nutrient uptake at the least possible costs to plant development. This assumptioncan be explained byReich (2002) optimal partitioning theory that plants react to environmental variations by dividing biomass between plant organs in order to optimize the acquisition of nutrients, light, water and carbon to enhance plant growth. Therefore, under low nutrient conditions, plants can bring more resources into growing roots and less for shoot growth(Reich, 2002). This probably explained the poor growth observed in the no fertilizer treatment compared to the other time of fertilizer applications. As explained by Reich (2002) and Morgan and Connolly (2013), young roots that are formed due to availability of nutrients, absorbs nutrients faster than old roots. Consequently, new roots supply plants with extensive sites for nutrient uptake, especially during establishment.Hence, the better growth observed in the treatment with nutrient application at sowing than nutrient application at 2 WAS.

At the first harvest (Table 5), the average fresh okra fruit yield when fertiliser was applied at 0, 2 and 4 (0WAS, 2 WAS and 4 WAS) weeks after sowing were 2936, 2933 and 2533 g/2.5 m^2 respectively, these yields were significantly different from fresh okra yield obtained when no fertiliser was applied (NFA). The least yield (1734 g/2.5 m^2) was observed when no fertiliser was applied. The number of fruits per plant followed the same pattern as observed in fruit yield.

Table 5: The effects of time of fertiliser application on number and weight (g/2.5 m^2) of fresh okra fruits at first and second (residual) production

Time of fertiliser Application	First harvest		Second (residual) harvest	
	Fresh fruit Weight	Number of fruits	Fresh fruit Weight	Numberof fruits
0 WAS	2533_b	168	2847_a	168_a
2 WAS	2933_a	180	1856_b	111_c
4 WAS	2936_a	183	1783_b	112_b
6 WAS	2133_c	143	1344_c	113_{bc}
NFA	1734_d	123	1321_c	109_c
S.E (df = 14)	±16.7	ns	±12.4	±0.6

0 WAS, applied at sowing; 2 WAS, two weeks after sowing; 4 WAS, four weeks after sowing; 6 WAS, six weeks after sowing; NFA, No Fertiliser Application. ns = no significant difference

At the second trial (residual experiment), the fresh okra fruit ranged from1321 to 2847 g/2.5 m^2. When fertiliser was applied at 2 and 4 weeks (2 WAS and 4 WAS), the fruit yields were1856g and 1783g/2.5 m^2 which were not significantly different. Similarly, the number of fruit per okra plant with the fruit number per plant ranging from 109 to 168; the least was recorded under 0WAS- when fertiliser was applied at point of okra seeds sowing. This showed that the nutrient content of the fertiliser were no longer adequately available for plant use due to some factors such as timeliness of its application, volatilization of the element like N and leaching (Table 5).

The availability of nutrient at the growth stage of plant development have impact on crop yield. Yield improvement in okra through fertilizer application is well documented (Iyagba*et al*., 2013; Fagwalawa and Yahaya, 2016; Bhandari *et al*., 2019). In essence, the improvement in root proliferation resulting from fertilizer application is likely to accounts for the yield increase in okra. This is finding is in support of previous reports by Iyagba*et al*. (2013), Fagwalawa and Yahaya (2016) and Bhandari *et al*. (2019) that the application of fertiliser increased the yield of okra. This is evident in the results obtained from the study. In that, all the treatments invol-ving fertilizer application improved the yields of okra plants. However, the variations in responses to time of application must have been responsible for the differences in yields, since they all received the same amount of fertilizer application. Thus, the earliness to nutrient acquisition must be responsible for deferential increases in the overall yield component and yield of the crop. This result agrees with the findings ofAmali and Namo (2015) that delay in fertiliser application reduced the yield of maize. They found in their study that; the mean number of barrenplants increased with delay in fertilizer application at six weeks after planting.

Crop performance under residual cropping is a function of the left-over nutrients from the initial cropping. Reports have shown the favourable response of crops to the major nutrients applied to a previous crop (Akintomide and Osundare, 2015). The findings in this study indicated that the residual of fertiliser differs with time difference. The longer the delay in fertiliser application, the higher the okra plants performance in the residual. This imply that nutrients were not adequately absorbed and utilized by the roots of the first okra plant to promote growth and yield. Hence, the leftover nutrients favoured the residual crop performance rather than the first cropping of okra.This is in agreement with Law-Ogbomo, (2013) and Akintomide and Osundare (2015) findings who reported that delayed application of fertiliser leads to retention of nutrients resulting from low efficiency in crop nutrient uptake (Roy *et al*., 2006), because the okra plants did not have adequate time to use them until the end of their life cycles or until they were harvested.Nutrient application toward the time of crop flowering may not be adequately utilized as absorption by crop is generally reduced during the initiation of nutrient remobilization for fruit formation. Similarly, the delay in nutrient N application does not imply its availability in the residual cropping. Also, due to low solubility of P in the soil, it requires considerable time to mineralize for crop uptake. These may attribute to the poor performance in the okra plants treated with 6 WAS fertilizer application. The left-over nutrient is likely to have been lost through the heat of dry season. The lower yield component and yield of okra in the second cropping can be attributed to reduced level of nutrient that resulted from the first cropping. This was in support of Law-Ogbomo (2013) on the effects of residual application of fertiliser on okra, that the yield of okra from residual application of fertilisers is lower that obtained from the first cropping.

CONCLUSION

The performance of okra on sand-loam soil depends on the timeliness of NPK fertiliser application. It was deduced that the performance of okrawith respect to fresh fruit yield and number of fruits were improved by time of fertilizer application. The application NPK fertiliser during dry season okra production should be applied at sowing or not later than two (2) weeks after sowing on sand-loam soil. Late application of mineral fertiliser at the first cropping did not favour okra performance. However, subsequent to late fertiliser application a second okra cropping should be encouraged.

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