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Full-Length Research Paper

Response of Okra (*Abelmoschus esculentus* (L.) Moench) to N and K Fertilizer in a Ultisol

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ABSTRACT: A factorial experiment was set out in a randomized complete block design to determine the effects of four rates of N (0, 60, 80 and 100 kg N/ha) and four rates of K (0, 50, 70 and 90 kg K/ha) on growth and yield of okra were studied. Weight per pod was increased by 26% when 60 kg N/ha was applied than the control or by 44% when 100 kg N/ha was applied than when not. Plant height and dry matter accumulation increased significantly ($P < 0.05$) with incremental application of nitrogen. Nitrogen fertilizer application showed no significant effect on leaf area and the number of branches and leaves. Application of 70 kg K/ha was optimum for vegetative growth of okra under the conditions. Pod yield (t/ha) was raised by 21% when K was applied at 70 kg K/ha compared with where it was not applied. Combined application of 100 kg N/ha and 70 kg K/ha gave optimum vegetative growth, while a combination of 80 kg N/ha and 70 kg K/ha proved optimum for pod and seed yields.

Keywords: Okra, pod and seed yields, N and K fertilizer, dry matter, growth

INTRODUCTION

In Nigeria, Okra (*Abelmoschus esculentus* L.) is considered as a local vegetable grown as rain fed or irrigated crop (Tiamiyu *et al*., 2010). It is generally a multipurpose versatile crop with the leaves, pods and flowers eaten. The slimy, fresh pods are rich in vitamin A and C. The young tender fruits are usually prepared into pieces for use in sauce to be served with starchy diets like maize, rice, sorghum, yam, cassava etc. (Omeje *et al*., 2013). The seed by-product is also used for formulating animal feed (Martin, 1982). In spite of the popularity of okra as a vegetable crop, and as a crop that almost all its parts can be put to economic use, it has not been given the attention it deserves in research for increased yield. Okra production in Nigeria is primarily at a back yard home garden for which few attention has been given by commercial farmers, researchers and consumers despite its nutritional value, income and employment generation and potential (Omeje *et al*., 2013). In Nigeria, the crop is cultivated in over 1.5 million hectares (Majanbu *et al*., 1986), but low yields are often recorded. This low yield experienced has been attributed to poor soil fertility and soil deficiency in important mineral nutrients. Soil productivity maintenance is a major constraint of tropical agriculture (Akande *et al*., 2010). With a shift away from bush fallow system to an intensive agricultural system, there are problems of adequate plant nutrition with a consequent progressive depression in yields. It has become important to apply organic manure and fertilizer for optimum crop performance. The Nsukka soil on which the present work was done is a typical ultisol low in fertility. Nitrogen and K are the two major elements that are often in short supply. This limitation can be overcome by supplying these elements through inorganic fertilization. The optimum rates for good yields are necessary to be known through a well planned investigation. The current study was therefore conducted to determine the growth and yield responses of okra to nitrogen and potassium fertilizers in

ultisol at Nsukka, Nigeria.

MATERIALSAND METHODS

The experiment was conducted under field conditions to study responses of okra to N and K fertilizer application in an ultisol at Nsukka. The experiment was conducted in the Teaching and Research farm of the Department of Crop Science, University of Nigeria, Nsukka, atitude 06° 52'N, longitude 07° 24'E, and on an altitude of 447.20 m above sea level (University of Nigeria, Nsukka Meteorological Station). The soil was generally characterized as an ultisol of Nkpologwu soil series. The area was previously under a two-year cassava plot before it was cleared and used for the experiment.

Land preparation

The experimental site was ploughed and harrowed. Soil sample to a depth of 0 - 15 cm was taken with soil auger from 10 different representative locations of the site. Those were then bulked and the composite sample used for mechanical and chemical analyses of the soil. The field was marked, limed with cement flue dust at the rate of 1.0 t/ha to raise the soil pH from 4.6 to 6.5. A total of 48 raised beds were made, each measured 3 m x 3 m in 2 and 1.0 m apart. The total area of the field of the experimental site was 0.0594 ha.

Exprimental treatments

Treatments comprised four levels of nitrogen and four levels of potassium fertilizers. Nitrogen was applied as urea (46% N) and potassium as muriate of potash (60% K20). The N levels were 0 (zero), 60, 80 and 100 kg N/ha while the K levels were o (zero), 50, 70 and 90 kg K/ha. All the possible combinations of the 4 levels of N and 4 levels of K gave 16 treatment combinations. The design of the experiment was a 4 x 4 factorial in a randomized complete block design (RCBD) with three replications. The treatments were allocated to plots in each of the 3 replicates at random, using a table of random numbers.

Planting

Before planting, the seeds were soaked overnight in water to enhance imbibition. The okra variety used was NHAe47-4; the seeds were sown at a spacing of 60 cm x 60 cm. Two seeds were sown per hole at a depth of about 2 cm. After germination, the seedlings were thinned down to one plant per stand.

Fertilizer application

Fertilizer was applied in two splits. By that, the appropriate fertilizer rate for each plot was divided into two equal parts. The first split was applied at 13 days after planting (DAP) while the second split was at 38 DAP which coincided with the time of floral bud initiation. Basal dressing of 30 kg/ha of P_2O_5 as single superphosphate was applied to every plot at the time of the first split application only. The fertilizers were applied by ring method of application. Weeding by hoeing was done three times at 13, 38 and 55 DAP.

Records

At 90 DAP, the following agronomic measurements were made on two plants per plot: Number of leaves/plant; number of branches/plant; leaf area/plant; number of pods/plant and plant height. Stem diameter was measured using veneer calipers while plant height was measured in situ with meter rule. Other parameters taken include: Average pod weight (g/plant); total pod yield (t/ha); pod diameter/plant and pod length/plant.

Destructive sampling

At 101 DAP; two plants per plot were randomly selected for destructive sampling. The plants were carefully dug up making sure to recover the roots as much as possible. The dug up plants were separated into the fractions of leaf, stem and root, which were wrapped separately and dried in an oven at 80°C to a constant weight. The dry weights of the fractions were recorded. Before drying, the leaf area measurements were made with an automatic leaf area meter of Delta-T model.

Seed yield estimation at maturity

Two plants per plot were left un-harvested and used for seed yield estimation. The pods on plants that were reserved for seeds were harvested at 120 DAP when they were already dry. They were sun-dried again for 7 days and the following records were taken: Number of dry pods/plant; length of pods/plant (cm); circumference of pod at the widest portion (cm); number of seeds/plant; seed yield/plant (g); and shelling percentage.

Meteorological records

Weather records were obtained from the University of

Nigeria agro meteorological station during the period of the experiment.

Methods of laboratory soil analysis

The bulked soil sample collected from the experimental site was analyzed for the mechanical and chemical properties of the soil.

Statistical analysis

All the data were analyzed according to the procedure for a factorial experiment in a randomized complete block design (RCBD) as outlined by Steel and Torrie (1980). Mean separation for significant effects was done using the method of least significant differences (LSD) as described by Obi (1986).

RESULTS

The period of July to October during which the experiment was performed was characterized by high total rainfall and frequent rains (Table 1). Radiation was considered generally high and adequate throughout the period, although it was lower in July and October compared with the other months. The soil of the experimental site was texturally sandy clay loam (Table 2). It was acidic and considered generally low in nutrients. The number of leaves produced per plant and the leaf area were not significantly influenced by fertilization with N or K at 90 DAP (Table 3). However, leaf area seemed highest with 70 kg K/ha or 100 kg N/ha. A combination of 100 kg N/ha with 70 kg K/ha or 80 kg N/ha with 90kg K/ha gave significantly the highest leaf area per plant. Incremental nitrogen or potassium rates increased plant height (Table 4). Higher number of branches with increased rates of N and K did not show statistical significance. Interaction of N and P did not show a consistent trend. The number of harvested pods was not clearly influenced by N and K Fertilization although a combination of 100 kg N/ha and 70 kg K/ha gave the highest number of pods harvested (Table 5). Average weight per pod increased with increased N application but not beyond the rate of 80 kg N/ha, while the influence of K treatment was not significant. However, a combination of 80 kg N/ha and 70 Kg K/ha gave significantly the highest weight per pod and also the highest pod yield (t/ha). Nitrogen and K treatments on average did not influence pod diameter much (Table 6). However, 80 kg N/ha gave the longest pods. Accumulation of dry matter in plant fractions was always highest at 80 kg N/ha or 70 kg K/ha but not beyond those rates (Table 7). A combination of 100 kg N/ha and 70 kg K/ha or 80 kg N/ha and 90 kg K/ha appeared most satisfactory in generating the greatest dry matter accumulation in plant parts. At dry maturity, long pods were produced at fertilizer rate of 50 Kg K/ha (Table 8), also 80 kg N/ha produced longer dry pods than others. There was no significant effect of either nitrogen or potassium on dry pod diameter but a combination of 90 kg K/ha and 100 kg N/ha gave the widest dry pod diameter. At dry maturity of pods, 70 kg K/ha application produced more number of dry pods than other K rates except 90 kg K/ha (Table 9). There was no significant effect of potassium on the number of seeds produced and on shelling percentage. Seed yield/plant increased as the potassium level increased. As the nitrogen level increased, the number of pods produced and the seed yield (g/plant) increased but not beyond the N rate of 80 kg N/ha. The combination of 70 kg K/ha and 80 kg N/ha gave the highest shelling percentage.

DISCUSSION

Fertilizer is one of the most important inputs contributing to crop production because it increases productivity and improves yield (Akande *et al*., 2010). Increased plant height and dry matter accumulation with incremental application of nitrogen was consistent with the usual response of crops under deficiency conditions. Firoz (2009) observed that plant height in okra was enhanced by N fertilizer up to 120 kg N/ha and reported that the higher dose of N might have enhanced cell division and formation of more tissues resulting in luxuriant vegetative growth and thereby increased plant height. The increase in number of branches and leaves and in leaf area were not significant with N application although Firoz (2009) reported that application of N up to 120 kg N/ha remarkably enhanced number of branches per plant, internode length and number of fruits per plant in okra. There was increase in number of pods per plant, average weight per pod yield (t/ha) with N application. Weight per pod was increased by 26% when 60 kg N/ha was applied than when no N was applied, or by 44% when 100 kg N/ha was applied than when not. Ahmed and Mohamed (2015) also reported yield increase in okra with fertilizer N application. Under the conditions of the experiment, pod yield was optimum at 80 kg N/ha as no further significant yield increase was obtained beyond that rate. Potassium application increased plant height, branching, leaf number, leaf area and dry matter accumulation only at 70 kg t/ha compared with no K application, showing that 70 kg K/ha was optimum for vegetative growth of okra under the conditions. Pod yield (t/ha) was raised by 21% when K was applied at 70 kg K/ha compared with where it was not applied while a further higher rate tended to depress

Table 1: Total monthly rainfall, rain days, radiation and soil and air temperatures at Nsukka.

Total rainfall (mm)	0	0	47	111	209	126	116	80	457	177	61	0.0
Rain days	0	0	2	4	12	12	18	19	19	12	3	0
Radiation (cal/cm^2/day)	667	822	641	706	645	523	464	416	511	569	-	760
Max soil temp (ºC)	37.2	42.5	40.0	38.5	35.2	32.6	31.6	29.9	30.9	31.3	-	27.5
Min soil temp (ºC)	30.5	32.8	32.7	31.5	30.2	28.3	25.9	25.1	27.1	28.7	29.3	31.2
Max air temp (ºC)	30.5	32.8	32.7	31.5	30.2	28.3	25.9	25.1	27.1	28.7	29.3	31.2
Min air temp (ºC)	19.1	20.3	20.5	21.1	21.1	20.8	20.5	20.3	20.3	20.3	19.2	17.4
Day length (hrs)	11.5	11.5	12.0	12.1	12.3	12.3	12.3	12.2	12.1	12.0	11.5	11.5

Note: (-) = value not available

Table 2: Results of mechanical analysis and chemical composition of the top 15 cm of soil.

Mechanical analysis	**(%)**
Coarse sand	60
Fine sand	12
Clay	26
Silt	2
Texture class	Sandy clay loam
Chemical composition	**(%)**
Nitrogen	0.06
Organic carbon	1.2
Organic matter	1.72
Exchangeable calcium meq/100)	0.60
Exchangeable magnesium (meq/100)	0.80
Available phosphorus (meq/100)	44
Potassium (meq/100)	0.20
C.E.C (meq/100)	6.5
Sodium (meq/100)	0.33
Soil pH	
pH (soil: water; 1:2.5)	4.6
pH (soil: 0.1 N KCl; 1:2.5)	4.2
pH after liming (soil: water; 1:2.5)	5.6

Table 3: Effect of nitrogen and potassium on number of leaves and leaf area per plant at 90 DAP.

	Potassium (kg/ha)				
Nitrogen (kg/ha)	**0**	**50**	**70**	**90**	**Mean**
Number of leaves/plant					
0	7.7	9.7	15.3	11.0	10.9
60	7.0	16.0	16.7	12.3	13.0
80	11.0	8.0	18.3	16.0	13.3
100	15.3	10.0	18.0	11.0	13.6
Mean	10.2	10.9	17.1	12.6	12.7
Leaf area/plant (cm^2)					
0	157.7	346.7	468.7	330.3	325.7
60	157.2	656.7	702.0	557.3	539.9
80	289.3	787.3	643.0	913.2	607.2
100	427.0	368.8	926.0	564.0	591.2
Mean	257.8	539.9	684.9	591.2	516.0

	No of Leaves	**Leaf area (cm^2)**
$LSD_{0.05}$ for 2 nitrogen means	NS	NS
$LSD_{0.05}$ for 2 potassium means	NS	NS
$LSD_{0.05}$ for 2 nitrogen x potassium means	10.7	675.0

DAP = Days after planting

Table 4: Effect of nitrogen and potassium on plant height and number of branches in okra plant at 90 DAP.

	Potassium (kg/ha)				
Nitrogen (kg/ha)	**0**	**50**	**70**	**90**	**Mean**
Plant height (cm)					
0	25.67	41.0	46.3	32.33	36.31
60	37.40	49.0	53.13	45.93	46.37
80	30.53	41.9	50.03	75.50	49.49
100	61.60	19.5	64.82	70.38	54.08
Mean	38.8	37.85	53.6	56.33	48.56
Number of branches/plant					
0	2.0	1.3	0.3	2.0	1.4
60	1.3	2.7	2.7	1.0	1.9
80	0.7	1.0	3.3	3.3	2.1
100	3.0	1.0	2.3	1.7	2.0
Mean	1.8	1.5	2.2	2.0	1.9

	Height (cm)	**branches**
$LSD_{0.05}$ for 2 nitrogen means	3.30	NS
$LSD_{0.05}$ for 2 nitrogen x potassium means	6.60	2.3

DAP = Days after planting

Table 5: Effect of nitrogen and potassium on number of pods/plant and pod yield (g/plant) of okra.

	Potassium (kg/ha)				
Nitrogen (kg/ha)	**0**	**50**	**70**	**90**	**Mean**
Number of pods/plant					
0	2.0	3.7	5.3	1.7	3.2
60	4.7	5.3	3.3	2.0	3.9
80	4.7	2.0	6.0	6.3	3.9
100	5.0	3.3	8.0	3.0	4.9
Mean	4.1	3.6	5.7	3.3	4.0
Average pod weight (g)/plant					
0	14.07	29.25	24.74	23.04	22.78
60	25.47	36.51	25.22	27.57	28.70
80	38.69	39.23	25.91	28.49	33.08
100	39.12	33.57	42.86	49.41	41.24
Mean	29.34	34.66	29.68	32.13	31.45
Total pod yield (t/ha)					
0	2.02	2.79	4.21	1.55	2.64
60	2.18	4.83	2.45	2.26	2.93
80	14.13	8.80	13.70	12.76	12.40
100	16.57	11.34	21.92	15.24	16.27
Mean	8.77	6.94	10.57	7.95	8.56

	Number of pods/plant	**Average pod weight**	**Pod yield (t/ha)**
$LSD_{0.05}$ for 2 nitrogen means	NS	9.27	5.65
$LSD_{0.05}$ for 2 potassium means	NS	NS	NS
$LSD_{0.05}$ for 2 nitrogen x potassium means	5.54	18.54	11.30

yields. Sulikari (1975) reported a depressed yield of okra at the potassium level above 40 kg K/ha. The disparity in the K requirement could be due to the difference in the native soil K for the two experiments in addition to other possible differences in the experimental conditions. Bid *et al*. (1971) also reported that combined application of 60 kg N/ha and 30 kg K/ha gave a better result than when the elements were applied singly. Results showed that a combination of 80 kg N/ha and 70 kg K/ha appeared optimum both for vegetative growth and for pod yield.

Table 6: Effect of nitrogen and potassium on average pod length (cm) and pod diameter.

	Potassium (kg/ha)				
Nitrogen (kg/ha)	**0**	**50**	**70**	**90**	**Mean**
Pod diameter (cm)					
0	3.06	3.36	3.06	2.08	2.89
60	2.09	3.36	2.95	2.91	2.83
80	2.92	3.32	3.08	3.17	3.13
100	3.34	2.27	2.94	3.78	3.33
Mean	2.85	3.33	3.01	2.99	3.04
Pod length (cm)					
0	7.99	7.68	7.49	5.63	7.20
60	7.51	9.49	7.26	7.11	7.84
80	10.71	10.02	8.25	8.85	9.48
100	7.8	9.98	6.96	10.45	8.78
Mean	8.50	9.27	7.49	8.01	8.32

	Pod diameter (cm)	Pod length (cm)
$LSD_{0.05}$ for 2 nitrogen means	NS	1.80
$LSD_{0.05}$ for 2 potassium means	NS	NS
$LSD_{0.05}$ for 2 nitrogen x potassium means	1.1	3.60

Table 7: Effect of nitrogen and potassium application on dry matter accumulation (g/plant) in okra plant fractions at 112 DAP.

	Potassium (kg/ha)				
Nitrogen (kg/ha)	**0**	**50**	**70**	**90**	**Mean**
Number of pods/plant					
0	6.47	6.22	5.82	10.61	7.28
60	4.03	9.69	14.55	11.40	9.92
80	8.32	13.06	16.19	13.54	12.78
100	9.21	7.49	12.39	13.11	10.55
Mean	7.01	9.11	12.24	12.16	10.13
Stem dry matter (DM)					
0	15.18	6.46	7.38	13.37	10.60
60	7.86	15.10	26.50	15.38	16.29
80	7.28	33.74	32.99	16.63	23.40
100	15.58	9.83	15.38	14.92	13.93
Mean	11.47	16.28	20.64	15.83	16.05
Root dry matter					
0	4.15	4.17	4.73	6.69	4.94
60	5.06	11.80	13.37	8.18	9.60
80	11.50	19.08	18.71	10.59	14.97
100	11.94	6.75	11.52	13.22	10.89
Mean	8.16	10.45	12.08	9.67	10.09
Inflorescence dry matter					
0	2.49	2.72	0.43	1.71	1.84
60	0.22	1.27	1.89	0.88	1.07
80	5.31	4.18	3.71	3.43	4.16
100	2.33	3.21	3.33	2.95	3.20
Mean	2.59	2.85	2.34	2.24	2.57
Total dry matter					
0	28.29	19.57	18.36	32.38	24.66
60	17.17	37.86	56.61	35.84	36.88
80	32.38	70.06	71.60	44.91	55.31
100	39.06	27.28	42.62	44.20	38.54
Mean	29.23	38.69	47.30	39.90	38.84

	Leaf	Stem	Root	Inflorescence	Total DM
$LSD_{0.05}$ for 2 nitrogen means	4.03	9.44	4.85	2.21	11.65
$LSD_{0.05}$ for 2 potassium means	4.03	NS	NS	NS	NS
$LSD_{0.05}$ for 2 N x K means	8.06	18.88	9.70	4.41	23.30

Table 8: Effect of nitrogen and potassium on average length and diameter (cm) at dry maturity of pods.

	Potassium (kg/ha)				
Nitrogen (kg/ha)	**0**	**50**	**70**	**90**	**Mean**
Pod length (cm) per plant					
0	7.99	7.68	7.49	5.68	7.20
60	7.51	9.49	7.26	7.11	7.84
80	10.51	10.02	8.45	8.85	9.46
100	7.80	9.89	6.96	10.45	8.78
Mean	8.50	9.27	7.49	8.01	8.32
Pod diameter (cm) per plant					
0	3.06	3.36	3.06	2.08	2.89
60	2.09	3.36	2.95	2.91	3.13
80	2.93	3.32	3.08	3.17	3.13
100	3.34	3.26	2.94	3.78	3.33
Mean	2.85	3.33	3.01	2.99	3.04

	Pod length	Pod diameter
$LSD_{0.05}$ for 2 harvest frequency means (cm)	NS	NS
$LSD_{0.05}$ for 2 potassium means (cm)	1.78	NS
$LSD_{0.05}$ for 2 harvest frequency x potassium means	3.57	1.09

Table 9: Effect of nitrogen and potassium on number of dry okra pods, number of seeds/ pods, seed weight (g/plant) and shelling percentage at dry maturity of pods.

	Potassium (kg/ha)				
Nitrogen (kg/ha)	**0**	**50**	**70**	**90**	**Mean**
Number of dry pods per plant					
0	2.67	3.67	6.00	1.67	3.50
60	5.33	5.33	13.33	3.33	6.83
80	8.00	8.33	11.00	16.00	10.83
100	11.33	10.00	13.33	15.00	13.58
Mean	6.83	6.83	12.17	9.00	8.69
Total number of seeds/ plant					
0	37.00	42.17	78.00	93.50	62.87
60	83.00	108.35	189.17	156.17	134.17
80	153.67	183.17	214.33	222.17	193.84
100	178.33	195.33	200.17	170.50	186.08
Mean	113.00	132.76	170.42	160.59	144.19
Seed yield (g/plant)					
0	2.13	2.26	3.01	4.86	3.07
60	3.54	5.72	8.81	7.50	6.39
80	6.97	11.15	12.11	12.52	10.69
100	7.84	8.85	10.70	7.83	8.83
Mean	5.15	7.00	8.63	9.30	7.25
Shelling percentage					
0	36.62	33.51	28.34	37.72	34.05
60	40.00	39.95	45.22	46.10	42.62
80	50.00	61.95	63.79	57.78	58.38
100	51.91	53.64	55.79	67.59	52.23
Mean	44.63	47.07	48.79	50.91	46.82

	Pod number	Seed number	Seed weight	Shelling %
$LSD_{0.05}$ for 2 nitrogen means (cm)	4.54	NS	3.17	10.30
$LSD_{0.05}$ for 2 potassium means (cm)	4.54	NS	3.17	NS
$LSD_{0.05}$ for 2 N x K means	9.07	NS	6.34	20.61

Conclusion

The field investigation on okra responses to N and K fertilizer showed that a combination of 100 kg N/ha and 70 kg K/ha appeared to be the optimum for vegetative growth while a combination of 80 kg N/ha and 70 kg K/ha proved optimum for pod yield and also for mature seed production under the conditions of the topical ultisol of Nsukka.

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