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The Response of *Dioscorea rotundata* to NPK Fertilizer Application in Edo State, Nigeria

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Abstract: The influence of NPK 15:15:15 fertilizer application on *Dioscorea rotundata* cv "Obiaoturugo" was carried at Evboneka in Edo State to determine the optimum level of NPK fertilizer application on yam in the forest zone. The investigations were carried in 2004 and 2005 at Evboneka (forest zone) and involved five treatments (0, 100, 200, 300 and 400 kg of NPK fertilizer ha^{-1}) which was arranged in randomized complete block design in three replicates. Results from the fertilizer trials showed that vine length, number of leaves and leaf area index significantly increased as fertilizer application increased thereby resulting in higher tuber yield. The averaged tuber yield for 2004 (15.60t ha^{-1}) was higher than the averaged yield of 2005 (14.70t ha^{-1}). The optimum tuber yield was obtained in both years with the application of 300kg ha^{-1} of NPK.

Keywords: *Dioscorea rotundata*, forest zone, tuber, yield and NPK fertilizer

INTRODUCTION

West Africa is the most important region for yam production in the world with about 96% of global production[1]. The main producer as reported[1] is Nigeria which produces about 71% of world output with Ghana, Cote d'lovrie, Benin and Togo following in that order.

Yam provides the staple foodstuff for millions of people in many tropical and sub-tropical countries[2]. According to[3], yam is the third only in important to cereal and cassava as a global source of carbohydrate.

In Edo State, Nigeria and under traditional land use and cropping system, yam is usually the first crop to be planted after the land has been cleared[2]. This is due to the high fertility requirement of the crop; it has relatively long seasonal growth[4]. Under this practice, therefore, yam has the advantage of utilising the mineral reserve accumulated when the soil is rested or after burning of vegetation.

Under crop rotation, yam is usually planted after a legume but care must be taken to ensure that it does not follow a legume crop that favour the build-up of nematode in the soil[5]. To stimulate the forest land fertility level and ensure continued high yield, previously cultivated lands are allowed to fallow period of about ten years depending on population pressure and availability of land[6].

Rising population pressure and increased demands on land for non-agricultural purposes have made soil fertility maintenance through prolonged fallows an untenable proposition, leaving maintenance of soil fertility through fertilizer usage the only viable alternative. The poor tuber yields obtained from farmers' plots[7] further suggest that soils involved in the production of yams need supplementary application of fertilizers if they are to do well. However, lack of knowledge and information on fertilizer use and their importance in yam production and inability of farmers to afford them, constitute a constraint to their use by resource-poor farmers.

Conflicting results and the benefits of fertilizers and organic manures have however been found in literatures[8]. This is to be expected due to lack of uniformity over a wide range of ecological conditions, especially soil types, under which yams are grown[9].

In view of this constraint, the overall goal of the present study is the determination of the optimum levels of NPK fertilizer application as a guide to developing more efficient and practical yam fertilizer programme in the rainforest zone.

MATERIALS AND METHODS

The trial was conducted at Evboneka ($5^0$45'N, $5^0$4'E) in the forest zone of Edo State. Weather data during the trial periods were obtained from the Nigerian Institute for Oil Pam Research (NIFOR), Benin City. The data are presented in Table 1. Composite soil sample was collected before cropping from site, analysed for its physical and chemical properties and presented in Table 2.

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Table 1: Climate data at Evboneka (Forest zone)

	2004							2005						
Month	Rainfall	Sunshine	Relative humidity (%)		Solar radiation	Temperature (%)		Rainfall	Sunshine	Relative humidity (%)		Solar Radiation	Temperature (%)	
	(mm)	(hours)	900H	1500H		Max.	Min.	(mm)	(hours)	900H	1500H		Max.	Min.
January	35.200	224.80	78.40	50.70	365.10	33.30	21.60	0.00	NA	61.70	45.00	NA	33.30	19.60
February	13.50	101.70	72.80	50.40	406.80	35.60	22.50	15.70	NA	79.80	52.40	NA	35.10	24.10
March	55.30	33.00	72.60	50.60	392.20	30.60	24.40	167.20	NA	81.70	65.20	NA	33.70	22.00
April	104.40	109.20	83.30	69.00	369.90	33.50	22.60	114.40	NA	81.80	67.10	NA	34.60	22.00
May	323.40	139.50	84.80	67.00	384.90	31.50	23.00	132.90	NA	83.40	68.20	NA	31.90	20.90
June	355.70	126.60	89.80	65.20	359.60	30.70	22.80	292.76	NA	85.90	75.50	NA	31.60	2..8
July	214.30	83.40	87.50	79.30	294.30	30.70	21.60	409.80	NA	86.40	81.00	NA	27.40	19.90
August	298.60	41.00	90.00	85.20	294.80	29.80	21.80	80.90	NA	89.00	68.00	NA	27.70	20.90
September	251.10	67.10	86.10	75.10	324.60	30.40	21.50	177.30	NA	86.30	73.80	NA	29.40	21.60
October	247.00	111.50	82.90	70.30	379.30	31.30	22.10	167.20	NA	84.80	69.10	NA	32.30	19.60
November	28.30	162.10	82.50	64.80	386.00	32.40	22.70	33.90	NA	80.10	56.40	NA	32.00	20.90
December	0.00	154.70	82.90	56.30	396.10	33.70	22.80	0.00	NA	83.40	61.50	NA	32.90	21.10
Total	1928.80	1493.80	991.60	783.90	4353.60	383.50	270.00	1595.00	NA	984.00	794.00	NA	381.90	253.40
Mean	160.70	124.50	82.60	65.30	362.80	32.00	22.5	132.90	NA	82.03	66.20	NA	31.80	21.10

Source: Documentation and Information Department, Nigerian Institute for Oil Palm Research, NIFOR.

Table 2: Soil physical and chemical properties of the experimental sites before cropping with yams during 2004 and 2005 cropping seasons

Soil properties	Experimental sites	
	Evboneka I	Evboneka II
pH (H_2O)	5.70	6.30
Organic carbon (%)	1.62	1.66
Total nitrogen (%)	0.18	0.18
Available phosphorus (mg kg^{-1})	7.30	1.10
Calcium (cmol kg^{-1})	7.80	5.75
Magnesium (cmol kg^{-1})	0.60	1.75
Potassium (cmol kg^{-1})	0.40	0.27
Clay (%)	11.00	22.6
Silt (%)	11.00	23.40
Sand (%)	78.00	54.40
Textural class	Loam sand	Sandy loam

Keys: Evboneka I - NPK fertilizer trial site for 2004 plants Evboneka II - NPK fertilizer trial site for 2005 yam plants

The trial consisted of five levels of NPK 15:15:15 (0, 100, 200, 300 and 400 kg ha^{-1}) in randomized complete block design with three replicates. *D. rotundata* cv "Obiaoturugo" commenced on the 24th of April, 2004 and 2005 at a spacing of 100cm on ridges and 100cm apart. As far as possible, the sett type: head, middle and tail were evenly distributed among plots. Since[10] found that the position of the sett in the parent tuber influences the rate of spouting and yield of tuber. Plots were mulched with dry grasses as described by[11] immediately after planting. The gross plot size was 7m x 6m and the net plot 6m x 5m. Six weeks after planting (WAP), five levels of NPK 15:15:15 fertilizer (0,100, 200, 300 and 400 kg ha^{-1}) were applied about 5cm deep, 20cm from the base of each plant. The vines were supported on stakes and the plots were weeded manually. Conventional growth techniques as indicated through vine length, internode length, number of leaves, number of vines and vine girth at monthly intervals were determined *in-situ* from two random samples per plot. The internode length was measured on the middle three internodes of each plot in the experimental site.

The yams were harvested at 33 WAP on December 2004 and 2005 when all the leaves had dried out and vines had withered and there was no more vegetative growth. At harvest, tuber length, tuber diameter and tuber weight were determined using[12] procedure.

Data collected were subjected to analysis of variance (ANOVA) with GENTSTAT programme, version 8.1 and significant differences among treatment means were evaluated using least significant difference (LSD).

RESULTS AND DISCUSSIONS

Results: The means of vegetative characters obtained from each treatment at 4 and 8 WAP are shown in Tables 3 and 4 respectively. At 4 WAP, no significant differences existed among the treatment means in both years. The number of vines $stand^{-1}$ varied from 1.00 to 2.17 in both years, but there was no definite sequence (Table 3). The vine girth showed a range 2.17 – 2.50 and followed the same trend as the number of vine $stand^{-1}$. The vine length varied from 0.36 to 2.20m and followed the same trend as the previous two parameters. The internode length and the number of nodes like the number of vines had no definite trend and varied from 3.33 to 13.83cm for internode length and 5.00 to 10.00 for number of nodes.

At 8 WAP, a significant difference existed among treatment means in both years for number of leaves but for vine length $stand^{-1}$, it was only significant at 2004 planting season. Generally, vine girth increased with increasing rate of NPK fertilizer application, but there was no significant difference among treatment means. The unfertilized plots had the least mean value for vine girth except during 2005 planting season where the mean value for 400kg NPK fertilizer applied plots was the least (1.33cm). The highest was 2.50cm with 300kg NPK fertilizer during 2004 planting season but it was 1.67cm with 100kg NPK fertilizer during 2005 planting season.

The number of leaves increased as the quantity of applied fertilizer increased in both cropping years at 8 WAP. In both cropping years, unfertilized plots had the least with 52.80 and 104.80 leaves respectively, for 2004 and 2005. In 2004, plots fortified with 400kg NPK fertilizer had the highest number of leaves (109.80) but the highest number of leaves was 245.30 in 2005 from the same level of NPK fertilizer application.

The vine length followed the same trend as the number of leaves at 8 WAP. However, the vine length was higher in 2004 cropping season than the 2005 cropping season. The longest vines were obtained from 400kg NPK fertilizer treatment in both years with 4.07m and 3.00m for 2004 and 2005 respectively. The shortest vines were obtained from the unfertilized plots in both seasons.

There was no significant difference among the treatment means in respect of the number of nodes $stand^{-1}$ at 8 WAP (Table 4). The trend was not different from that of 4 WAP and ranged from 20.75-24.80 nodes $stand^{-1}$.

The effect of fertilizer application on the number of leaves of *D. rotundata* at 16 and 24 WAP are shown in Table 5. Significantly differences were recorded at 16 and 24 WAP. There was a significant variation between the cropping seasons with 2005 plants having highest numbers of leaves at all application levels. 2005 plants with 400kg NPK ha^{-1} had the highest number of leaves (548.00) recorded at 16 WAP in both years and the least was observed in 2004 planting without fertilizer treatment (197.00) at 16 WAP. The number of leaves was directly proportional to the quantity of fertilizer applied and the number increased with increased in fertilizer application rate in both years.

The effects of NPK fertilizer on plant growth are presented in Table 6. The application of NPK fertilizer had significant effects on leaf area index (LAI) at 16 WAP. LAI increased with increased in fertilizer application rate. At 24 WAP, LAI increased significantly with the application. The 2004 plants had higher LAI at all fertilizer application levels than 2005 plants.

The response of NPK application on tuber yield and yield components in the two cropping seasons is shown in Table 7. The fresh tuber yield ranged between 10.36 and 19.57t ha^{-1}. Generally, there was increased in tuber yield as the level of fertilizer increased up to 300kg ha^{-1} and declined at 400kg ha^{-1} in both cropping seasons. Comparatively, lower tuber yields were obtained in 2004 cropping season but in 2005 there was no definite sequence.

Table 3: Effects of NPK 15:15:15 fertilizer application on vegetative characters of *D. rotundata* at 4 WAP.

Cropping year	NPK (kg ha^{-1})	No. of vines $Stand^{-1}$	Vine girth (cm)	Vine length (m)	Internode length (cm)	No. of leaves $Stand^{-1}$	No. of nodes $Stand^{-1}$
2004	0	1.83	2.33	2.20	13.83	0.00	10.00
	100	1.83	2.50	1.85	5.83	0.00	8.67
	200	2.00	2.17	2.12	3.33	0.00	9.33
	300	2.17	2.42	2.23	6.17	0.00	9.33
	400	2.17	2.62	1.71	4.00	0.00	8.00
Mean		2.00	2.41	2.02	6.60	0.00	9.07
LSD(0.05)		ns	ns	ns	ns	ns	ns
2005	0	1.17	2.25	0.36	9.89	0.00	5.17
	100	1.17	2.53	0.41	12.50	0.00	6.50
	200	1.00	2.25	0.45	10.25	0.00	5.00
	300	1.17	2.25	0.44	9.22	0.00	6.06
	400	1.17	2.50	0.58	12.55	0.00	6.67
Mean		1.13	2.36	0.45	10.80	0.00	5.88
LSD(0.05)		ns	ns	ns	ns	ns	ns

ns- not significant

Table 4: Effects of NPK 15:15:15 fertilizer application on vegetative characters of *D. rotundata* at 8 WAP.

Cropping year	NPK (kg ha^{-1})	No. of vines $Stand^{-1}$	Vine girth (cm)	Vine length (m)	Internode length (cm)	No. of leaves $Stand^{-1}$	No. of nodes $Stand^{-1}$
2004	0	1.83	2.15	3.18	27.67	52.80	21.70
	100	1.83	2.25	3.40	30.00	69.80	23.80
	200	2.00	2.30	3.57	25.67	85.30	20.30
	300	2.17	2.50	3.82	23.17	105.70	24.80
	400	2.33	2.43	4.07	19.33	109.80	21.00
Mean		2.03	2.39	3.61	25.20	87.40	22.30
LSD(0.05)		ns	ns	0.523	ns	26.532	ns
2005	0	1.33	1.60	2.47	10.67	104.80	21.33
	100	1.17	1.67	2.83	13.17	160.20	19.00
	200	1.17	1.53	2.77	9.57	194.70	19.50
	300	1.17	1.43	2.97	12.00	231.60	22.10
	400	1.17	1.33	3.00	10.80	245.30	21.83
Mean		1.20	1.51	2.87	11.24	187.30	20.75
LSD(0.05)		ns	ns	ns	ns	54.112	ns

ns- not significant

The relative tuber yield ranged from 1.00 to 2.42 and was significantly increased by fertilizer application in both cropping seasons. It followed the same trend with tuber yield as it increased with fertilizer application up to 300kg NPK ha^{-1} and then declined at 400kg NPK fertilizer ha^{-1}. In both years, the highest relative tuber yields were 2.42 and 1.94 in 2004 and 2005 respectively with the application of 300kg NPK ha^{-1}.

Discussion: The results of this trial showed that NPK fertilizer application increased tuber yield. This is a confirmation of the fact that fertilization for efficient nutrient use by plants has been identified as a necessary cultural input for improving growth and yield of the crop. The applied NPK fertilizer to yam had positive effects on the performance of the crop in the two cropping seasons.

Table 5: Effects of NPK 15:15:15 fertilizer application on number of leaves of *D. rotundata* at 16 and 24 WAP

Cropping year	NPK (kg ha^{-1})	Number of leaves stand^{-1}	
		16 WAP	24 WAP
2004	0	197.00	366.00
	100	247.00	541.00
	200	290.00	606.00
	300	456.00	686.00
	400	523.00	764.00
Mean		342.00	592.00
LSD(0.05)		56.000	133.600
2005	0	315.00	226.00
	100	362.00	288.00
	200	432.00	339.00
	300	488.00	358.00
	400	548.00	458.00
Mean		429.00	329.00
LSD(0.05)		115.400	110.900

Table 6: Effects of different levels of NPK 15:15:15 fertilizer application on leaf area index of *D. rotundata* at 16 and 24 WAP.

Cropping Year	NPK (kg ha^{-1})	LAI	
		16 WAP	24 WAP
2004	0	0.99	2.27
	100	1.10	2.97
	200	1.35	3.69
	300	2.20	4.12
	400	2.21	4.25
Mean		1.57	3.55
LSD(0.05)	0.680	0.87	
2005	0	1.74	2.48
	100	2.15	2.78
	200	2.30	3.00
	300	2.45	3.36
	400	2.88	3.41
Mean		2.30	3.01
LSD(0.05)		0.670	0.45

The non-significant response by any of the vegetative parameters at 4 WAP, before fertilizer application, suggested that the plots were most probably homogenous. Application of NPK fertilizer was made at 6 WAP for effective uptake by the crop as recommended by[4] and[13,4] had reported the dependence of young yam plants for nourishment from the mother setts in the first six weeks of growth while[13] who studied sprouting and growth habit of yams showed that from 6 WAP, plants grew independently of the mother setts.

Uptake and utilization of applied fertilizer in both years witness better responses in terms of number of sprouting loci, leaf number and vine girth compared with the non-fertilized plants. Increased in vine girth with fertilizer application resulted in the retention of appreciable amount of assimilates in the vine for node and leaf production. The increasing number of loci stand^{-1} could cause increase in the leaf number. Greater leaf number resulted in larger leaf area. Increase in the number and vines was a precursor to greater amount of assimilates and this allowing more translocation to the tuber as there was a significant correlation between number of leaves and leaf area.

The significant increase in vine length of yam plants with fertilizer treatment reflects the effects of

Table 7: Effects of different levels of NPK 15:15:15 fertilizer application on yield and yield components of *D. rotundata*

Cropping year	NPK (kg ha^{-1})	No. of tubers $Stand^{-1}$	Tuber yield		Average tuber size(kg)	Relative tuber Yield
			(kg $stand^{-1}$)	(t ha^{-1})		
2004	0	1.67	1.04	10.36	0.61	1.00
	100	2.11	1.77	17.72	0.86	1.90
	200	2.42	1.91	19.12	0.83	2.03
	300	2.78	2.18	19.16	0.89	2.42
	400	1.89	1.16	11.55	0.61	1.23
Mean		2.17	1.61	15.6	0.76	1.72
LSD(0.05)	ns	0.604	0.604	5.531	0.199	0.862
2005	0	1.53	1.03	10.4	0.68	1.00
	100	1.33	1.46	14.63	1.16	1.45
	200	1.90	1.62	16.2	0.86	1.58
	300	2.03	1.97	19.57	0.97	1.94
	400	2.40	1.4	13	0.58	1.35
Mean		1.84	1.5	14.7	0.85	1.46
LSD(0.05)		0.445	0.358	4.029	0.362	0.368

ns - not significant

fertilizer nutrients, N, P, and K. The untreated control plants were almost stunted in growth as they had to rely on the native soil fertility which, from the results of chemical analysis was deficient in these nutrients.

Changes in leaf number are bound to affect the overall performance of yams as the leaves serves as the photosynthetic organ of the plant. Increased leaf number leads to a greater dry matter accumulation per unit of land area, because of better utilization of solar radiation. Also a greater leaf number contributes to a better canopy favouring either photosynthesis or suppression of weeds; therefore more leaves possessed by the plants lead to an improved yield. There were significant differences among the treatments in response to LAI during the two sampling periods. LAI generally increased with NPK treated yam plants have been due to increased leaf production and leaf duration. AS a consequence, a high amount of radiation was intercepted contributing to an increase in tuber yield. LAI of any plant is an indicator of its photosynthesis capacity and translocation into tubers[14]. This would be reflected in plants growth and vigour. The untreated plants had lower LAI due fewer numbers of leaves resulting from premature leaf fall and vine senescence to reduction of tuber yield.

The effect of NPK 15:15:15 fertilizer on the tuber yield was significant and the application of 300kg had the highest yield in both cropping years. The 2004 yam plants had higher yield at all fertilizer levels except at 400kg NPK ha-1 and this was due to native soil fertility status and the prevailing atmospheric conditions during both cropping seasons. The positive response of yam tuber to NPK fertilizer application was due to the fact that it prolonged the vegetative growth phase leading to longer growth duration and ensuring higher yield.

Tuber yield was reduced when fertilizer was not applied. Significant increases in yield as a result of NPK 15:15:15 fertilizer application is likely to persuade resource-poor farmers to buy and use fertilizer on their yam farms as indicated by high tuber yield. Farmers' complain about the deleterious effects of chemical fertilizer; these undersirable effects include burning the plants, rendering the tuber susceptible to rot during storage and unpalatability of the tuber produced with fertilizer application as well high cost of fertilizer in Nigeria. These effects may be due to the fact that they conducted blanket application of chemical fertilizer without the benefit of soil testing and regard for laid down recommendation.

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