Growth and yield of white guinea yam (*Dioscorea rotundata* Poir.) influenced by NPK fertilization on a forest site in Nigeria

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Abstract

Two field experiments were conducted at Evboneka in Edo State, Nigeria to determine the optimum fertilizer requirement of white guinea yam (*Dioscorea rotundata* Poir) and to develop an efficient fertilization strategy for yam production in the rainforest locations of Nigeria. We examined the dry matter production and yield, besides growth parameters under five levels of NPK in 2005 and 2006. The treatments (0, 100, 200, 300, and 400 kg 15:15:15 NPK ha^{-1}) were arranged in a randomized complete block design with three replications. Leaf area index (LAI) and dry matter content increased significantly as the quantities of fertilizer applied increased. LAI values ranged from 1.24 to 5.73 at 16 week after planting (WAP) and 2.77 to 6.37 at 24 WAP respectively for the unfertilized and 400 NPK kg ha^{-1} plots. The corresponding values for dry matter accumulation were 1.29 to 3.70 t ha^{-1} and 6.0 to 8.77 t ha^{-1} at 16 and 24 WAP respectively. These parameters resulted in higher crop growth rate for the fertilized plants giving higher tuber yield and relative yields. The maximum tuber yield of 24 t ha^{-1} and a relative yield 2.16 were obtained at 300 kg ha^{-1} of NPK, implying the adequacy of this fertilizer dose.

Keywords: Crop growth rate, Leaf area index, Total dry matter yield.

Introduction

Nigeria, the largest producer of yams in the world, has a total production of 18.3 million Mg from 1.5 million ha (FAO, 2004). Average tuber yield (12.2 Mg ha^{-1}), however, is low, mainly due to unscientific production practices. For instance, relying on bush fallow practices to restore soil fertility, loss of site productivity on account of bush burning, intensive cropping often without nutrient supplementation, overgrazing, and soil erosion are important factors that affect yam productivity in Nigeria (Okonkwo, 1995). Although experimental studies on fertilizer application showed increased yam productivity (Ige et al., 2005), blanket fertilizer recommendations (e.g., 200 to 400 kg NPK mixed fertilizer ha^{-1}; Anon, 1987) has obvious limitations. Moreover, crop species and cultivars, besides site characteristics, may vary substantially in their response to fertilizer treatments (Nwinyi and Odurukwe, 1988). Chemical fertilizer is also becoming a major cost factor in yam production, and its price has been increasing steadily, besides having potentially undesirable effects on the environment. Hence there is a need to optimize the fertilizer requirement of white guinea yam (*Dioscorea rotundata* Poir.) grown on various sites. The present study was aimed at determining the optimum fertilizer needs of *D. rotundata* on a forest location in Nigeria and to explain the physiological basis underlying better performance of plants treated with NPK 15:15:15 fertilizer mixture.

Materials and Methods

Two field trials were conducted in 2005 and 2006 at Evboneka, Nigeria located in a humid rainforest zone. Soils of the experimental sites (0 to 30 cm) were Ultisols (acidic sandy loam) with low nutrient status (Table 1). The land was cleared of the existing vegetation and ridges constructed using hoes after the site had been deep-

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Table 1. Soil physico-chemical properties (0 to 30 cm) of the two experimental sites (Ultisols) at Evboneka, Nigeria prior to cropping with yams during 2005 and 2006 cropping seasons.

Soil properties	Experimental sites	
	Evboneka 1	Evboneka II
pH (H_2O)	5.0	4.8
Organic C (%)	0.76	0.79
Total N (%)	0.09	0.07
Available P (mg kg^{-1})	4.67	3.85
Exchangeable cations		
Ca (cmol kg^{-1})	0.80	0.70
Mg (cmol kg^{-1})	0.60	0.60
K (cmol kg^{-1})	0.15	0.15
Clay (%)	25.0	31.0
Silt (%)	17.0	22.0
Sand (%)	58.0	47.0
Textural class	Sandy loam	Sandy loam

Evboneka 1: 2005 trial site; Evboneka II: 2006 trial site.

ploughed with a tractor drawn disc plough. The ridges were 6 m long and 1 m apart. *D. rotundata* cv. 'Obiaoturugo' (average 250 g setts) was planted on April 21 each year at 1 x 1 m spacing to have a population density of 10 000 plants ha^{-1}. The design for the trial was randomized complete block design with five treatments (0, 100, 200, 300, and 400 kg ha^{-1} of NPK fertilizer 15:15:15) and three replications. After planting, each plot was mulched with dry grasses/leaves to conserve soil moisture. Staking was done with one stake per stand. Plots were of gross size 7 x 6 m and net size of 6 x 5 m and were weeded at 4, 6, 11, and 17 weeks after planting (WAP). Fertilizer was applied at 6 WAP. The fertilizer used was a branded fertilizer mixture, manufactured by the National Fertilizer Company of Nigeria (Onne, Port Harcourt, Nigeria). Crop growth was assessed through morphological parameters such as vine length, stem girth, internode length, and the number of nodes, leaves, and vine per plant. All parameters were determined *in-situ* on two randomly sampled plants per plot. Leaf discs were punched out with a cork borer and the relationship between area and dry weight of the disc was used to estimate leaf area. Total dry weight was determined at 16 and 24 WAP following the ISTA (1993) procedures. The process involved separately uprooting two plants per plot including the underground portions (tuber) and oven-drying the tubers, vines, and leaves after chopping them into bits at 70°C for 72 h. Leaf area index, harvest index, and crop growth rate were computed as described by Remison (1997). The yam tubers were harvested plot-wise at 33 WAP after large scale drying up of leaves and the data on tuber yield per plant were collected. The plot yield was expanded to a per ha basis and the relative tuber yield (RTY) computed as yield in treated plots over that of control.

Year-wise data were analyzed using analysis of variance, followed by combined analysis over the two years in SAS version 8.2. Means were compared using Tukey's test (0.05). Linear correlations linking variables were also computed in SAS. The data were further subjected to pooled statistical analysis to ascertain whether the differences between fertilized and unfertilized plants were due to sampling error or not (Snedcor and Cochran, 1993).

Results and Discussion

Yam growth and assimilate partitioning

Fertilized plots witnessed greater vine length and number of leaves compared to unfertilized plants (Table 2). Mean number of leaves ranged from 350 to 1011 and 541 to 965 at 16 and 24 WAP respectively. Untreated plants were almost stunted due to poor soil nutrient supplies (Table 1). Vine girth and number of leaves (r = 0.63) and number and the rate of fertilizer applied (r = 0.60 to 0.72) were positively correlated (p>0.05). Leaf area index (LAI) ranged between 1.24 (unfertilized plants) to 5.73 (400 kg NPK ha^{-1}) at 16 WAP (Table 2). As expected, LAI increased with plant age and it ranged from 6.15 (unfertilized) to 8.77 (400 kg NPK ha^{-1}) at 24 WAP. Higher LAI associated with fertilized plants signifies greater leaf production rates, leaf area expansion, and leaf area duration. The unfertilized plants had substantially lower LAI due to fewer leaves presumably resulting from premature leaf fall and early vine senescence, which is consistent with the findings of Igwilo (1989).

Total plant dry weight (TDW) varied from 1.29 (unfertilized) to 3.70 t ha^{-1} (400 kg NPK ha^{-1}) at 16

Table 2. Effects of different levels of NPK 15:15:15 fertilizer application on growth of *Dioscorea rotundata* at a forest location in Evboneka, Nigeria at 8, 16, and 24weeks after planting (WAP).

NPK (kg ha^{-1})	Growth at 8 WAP		Growth at 16 WAP				Growth at 24 WAP				
	Vine length (m)	No. of leaves Plant^{-1}	No. of leaves	Leaf area index	Total dry weight (Mg ha^{-1})	Harvest index	No. of leaves	Leaf area index	Total dry weight (Mg ha^{-1})	Harvest index	Crop growth rate (g m^{-2} wk^{-1})
0	3.28^{bc}	52^{d}	350^{d}	1.24^{c}	1.29^{c}	0.10^{b}	541^{d}	2.77^{d}	6.15^{b}	0.60^{b}	0.61^{ab}
100	3.52^{bc}	98^{c}	585^{c}	2.63^{b}	2.48^{b}	0.29^{ab}	665^{c}	4.35^{c}	7.49^{a}	0.67^{ab}	0.53^{b}
200	3.65^{b}	142^{b}	573^{c}	2.80^{b}	2.34^{b}	0.32^{a}	832^{b}	4.16^{c}	8.28^{a}	0.58^{b}	0.74^{ab}
300	3.85^{ab}	157^{ab}	660^{b}	3.50^{b}	2.75^{b}	0.25^{a}	977^{a}	5.51^{a}	8.77^{a}	0.71^{ab}	0.75^{a}
400	4.20^{a}	167^{a}	1011^{a}	5.73^{a}	3.70^{a}	0.17^{b}	965^{a}	6.37^{a}	6.00^{b}	0.75^{a}	0.29^{c}

Means with the same superscript do not differ significantly.

WAP (Table 2). It increased as the fertilizer rate increased (r= 0.64; p<0.05). As expected, the dry matter accumulation increased with time and at 24 WAP, the highest values were noted for 300 kg NPK ha^{-1} (8.77 Mg ha^{-1}). Further increases in fertilizer dose (e.g., 400 kg NPK ha^{-1}), however, resulted in a decline in dry matter accumulation signifying a curvilinear response pattern. The significant increase in TDW as a result of fertilizer application also paralleled increases in leaf number and LAI, which may have ensured better utilization of the solar radiation (Okwuowulu, 1995; Law-Ogbomo, 2007). Apparently, more vegetative growth was observed at 400 kg ha^{-1} (e.g., greater number of vines, shorter internodes, longer vines, more leaves, and higher LAI; Table 2) compared to its next lower dose, implying that vegetative growth occurred at the expense of tuberization at very high NPK doses.

Harvest index (HI) varied from 0.10 to 0.32 at 16 WAP and 0.58 to 0.75 at 24 WAP (Table 2). Unfertilized plants had the lowest HI at 16 WAP, while the highest values were noted for the 200 kg NPK ha^{-1} treatment. At 24 WAP, however, the highest HI was obtained for plants fertilized at the rate of 400 kg NPK ha^{-1} and the lowest for plants fertilized with 200 kg NPK ha^{-1}. HI was significantly correlated with fertilizer rates at both 16 and 24 WAP (r = 0.68 and 0.59 respectively; p<0.05). The consistently positive correlation of HI with fertilizer application is an indication of the enhanced translocation of assimilates to the tuber in the fertilized plots. This also resulted in greater bulking ability as fertilizer application increased up to 300 kg ha^{-1} of NPK.

The crop growth rate (CGR) showed a trend similar to that of HI. It ranged from 0.29 to 0.75 g m^{-2} wk^{-1} with an average of 0.60 g m^{-2} wk^{-1}. CGR also was significantly correlated with fertilizer rates and the number of leaves with correlation coefficients of 0.57 and 0.61, respectively (p<0.05). The significant correlation between CGR and LAI (r=0.66; p<0.05) further demonstrates the effectiveness of higher LAI resulting from fertilizer application in influencing plant growth and vigour.

Tuber yield

Fresh tuber yield ranged from 1.18 to 2.41 kg plant^{-1} (Table 3). In general, tuber yield per plant increased as fertilizer application increased up to 300 kg ha^{-1}, but declined thereafter (e.g., 400 kg ha^{-1}). Tuber yield per hectare also followed a similar pattern (Table 3). Higher white guinea yam yields with fertilizer application noted in the present study is consistent with the report of Yayock et al. (1988) who showed yields up to 25 Mg ha^{-1} under improved management from West Indies. The significant correlation between fresh tuber yield and number of tuber (r=0.65; p<0.05) revealed that tuber yield increase associated with fertilizer application was probably due to an increase in the number of tubers.

Average tuber size in fertilizer treatment was also greater than that of the unfertilized plants (range 0.70 to 1.37 kg per tuber; Table 3). Furthermore, average tuber size and number of tuber (r = 0.58; p<0.05) and fertilizer rates (r = 0.68; p<0.05) were significantly correlated. Relative yield was highest (2.16) for 300 kg NPK ha^{-1} treatment

Table 3. Effects of different levels of NPK 15:15:15 fertilizer application on yield and yield components of *Dioscorea rotundata* at Evboneka, Nigeria (forest location).

NPK levels (kg ha^{-1})	Tuber yield		Average tuber size (kg)	Relative tuber yield
	Per plant (kg)	Per hectare (Mg)		
0	1.18^{c}	11.80^{d}	0.70^{c}	1.00^{b}
100	1.86^{b}	18.57^{bc}	1.18^{ab}	1.68^{a}
200	2.02^{b}	20.23^{b}	1.32^{a}	1.81^{a}
300	2.41^{a}	24.07^{a}	1.37^{a}	2.16^{a}
400	1.72^{b}	17.03^{c}	0.94^{bc}	1.53^{ab}

Means with the same superscript do not differ significantly.

(Table 3), which was consistent with the trends in tuber yield. Implicit in this is that the economic optimum for tuber yield occurs at 300 kg NPK ha^{-1}.

Overall, this study confirms that NPK fertilizer application to white guinea yam is a necessary for improving crop productivity. Yield differences between unfertilized and fertilized plots have been attributed, among other factors to longer vines, leafiness, and efficient transfer of assimilates to the sink leading to greater total dry weight, which is consistent with a previous report on this crop (Anon, 1980). This has resulted in corresponding increases in growth and bulking rate of tuber resulting in higher yield. Application of 300 kg NPK ha^{-1} appeared adequate for maximizing tuber yield under the conditions of the present experiment. The NPK fertilizer rate, however, should be based on soil test response. This would probably alleviate the deleterious effects of chemical fertilizers, e.g., burning the plants, rendering the tuber susceptible to rot during storage, and unpalatability of the tuber especially under high fertilizer levels, as well as the high cost of chemical fertilizers.

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References

Anon. 1980. Nigeria: Nitrogen demand at record level, In: *Nitrogen*, No. 123, January-February, 1980. British Sulphur Corporation, pp 18–24.

Anon. 1987. Fertilizer use in crops. Bendel State Agricultural Development Programme, Benin City, Nigeria. 6p.

Food and Agriculture Organization (FAO) 2004. FAOSTAT. FAO Statistic Division, Rome.

Ige, D.W., Adepetu, J.A., and Obi, O.A. 2005. Effect of organic amendment on P release in soils of south western Nigeria. Ife J. Agric., 1: 1–70.

Igwilo, N.O. 1989. Response of yam cultivars to staking and fertilizer application. Trop. Agric., 66: 38-42.

ISTA 1993. International Rules for seed Testing Association. Seed Science and Technology, Supplementary Rules, 21: 13–33.

Law-Ogbomo, K.E. 2007. Agronomic evaluation of white yam (*Dioscorea rotundata* Poir) in different ecological zones of Edo State, Nigeria. Ph.D Thesis, University of Benin, Benin City, Nigeria. 154p.

Nwinyi, S.C.O. and Odurukwe, S.O. 1988. Optimum N.P.K. requirement of white yam (*Dioscorea rotundata).* Nig. Agric. J., 24: 63–70.

Okonkwo, S.N.C. 1995. Effect of pre-sprouting and planting depth of yam (*Dioscorea* spp) minisett on field establishment, tuber yield and net income in the southern Guinea savanna of Nigeria. Nig. Agric. J., 28: 1–8.

Okwuowulu, P.A. 1995. Yield response to edible yam (*Dioscorea* sp.) to time of fertilizer application and age at harvest in an Ultisol in the humid zone of Southeastern Nigeria. Afr. J. Root Tuber Crops, 1: 6–10.

Remison, S.U. 1997. *Basic Principles of Crop Physiology*. Sadoh Press (Nig.), Benin City, 163p.

Snedcor, G.W. and Cochran, W. G. 1993. *Statistical Methods.* 8th ed. Iowa State University Press. 503p.

Yayock, J.Y., Lombion, G., Owonubi, J.J., and Onazi, O.C. 1988. *Crop Science and Production in Warm Climates.* Macmillian Publisher Ltd, London, 215p.