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EFFECT OF STAKE LENGTH AND NPK FIERTILIZER ON WHITE YAM (*Dioscorea rotundata*) MINISETT IN UMUDIKE, SOUTH-EAST, NIGERIA

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Abstract
Staking and soil fertility are critical factors that affect yam production in the humid forest zone of South-East, Nigeria; where high rainfalls and cloud cover are prevalent. Field experiments were conducted at Umudike, South-East, Nigeria in the 2016 and 2017 cropping seasons, to study the effects of stake length and NPK fertilizer on the minisett of white yam cultivar *Yandu*. The experiment was laid out as a 4× 5 factorial in a randomized complete block design (RCBD) with three replicates. Treatments consist of four levels of stake length (0, 1, 2 and 3m) and five levels of NPK (15:15:15) fertilizer (0, 200, 400, 600 and 800kg/ha). Stake of 2 and 3m lengths had significantly longer vine lengths at 3 and 4 months after planting (MAP) and leaf area index at 3MAP than no staking. Averaged across the two cropping seasons, staking did not affect tuber yield, but the 2 or 3m stakes in 2016 had significant higher tuber yields than the yields obtained in 2017 regardless of stake length. NPK fertilizer application did not significantly influence vine length, leaf area index, and tuber yield, but the application of fertilizer at 200kg/ha increased the number of tubers per plant in 2017. The non-significant effects of staking and NPK fertilizer on tuber yield were ascribed to high rainfall that caused flooding and leaching of nutrients.

Keywords: Stake length, NPK fertilizer,white yam, tuber yield, South-East Nigeria

Introduction

Yam (*Dioscorea species*) are important tuber crops in Nigeria and other parts of West Africa where the vines are usually trained on firm supports (Igwilo and Udeh, 1987). In West Africa, *Dioscorea rotundata,* also referred to as white yam or white guinea yam is the most widely cultivated. It is the most important source of food and income for millions of producers, processors, and consumers in West Africa. In 2012, world production of yam was estimated at 58.7 million tons, with West Africa producing more than 92% (FAOSTAT, 2014). Nigeria and Ghana together produced about 66% of the world's yam supply. The five major yam-producing countries in West Africa are Benin, Cote d'Ivoire, Ghana, Nigeria, and Togo (FAOSTAT, *ibid*). They account for 93% of world production. Nigeria alone accounts for 68% of global production (36 million tons on 3 million hectares).As food, yam plays an important role by providing cash and dietary carbohydrate to millions of people. The crop also makes substantial contribution to protein in the diet, ranking as the third most important source of supply (Ekanayake and Asiedu, 2003; IITA, 2013). Yam has a better keeping quality than most other tropical root and tuber crops because the tubers have an extended period of dormancy during which physiological activities are at a minimum. About 31.8% of the population in Nigeria and 26.2% in Ghana depend on yams for food and income security. Yam tuber is usually prepared for consumption in a variety of ways which include boiling, frying, baking, processing into flour for the preparation of "*amala*", processing into pounded yam and processing into pottage (Orkwor and Ekanayake, 1998).

Staking is carried out to help twining yam vines display their leaves to attract adequate solar energy for efficient photosynthesis (Orkwor and Asadu, *ibid*). Although staking add to the cost, it is nevertheless essential as yam is not a shade tolerant plant (Lebot, 2009). Tuber yield is a function of photosynthetic efficiency, crop growth duration, and the harvest index. The photosynthetic efficiency of yams is closely related to the effective spread of leaf area to ensure maximum light interception (Akoroda, 1993). Staking increases leaves exposure to light, light capture and therefore, enhances photosynthetic efficiency.The agroecology in which yam is cultivated is important in terms of the staking requirements of the crop and the availability of staking materials (Ekanayake and Asiedu, 2003). In a humid climate, where cloud can greatly limit the number of hours of sunshine, staking improves the photosynthesis of plants, prevents foliar diseases, and allows the cultivation of interim crops. The benefit of tall stakes appears to depend on the yield potential of individual plants (Okigbo, 1973). Yams growing unstaked, with a reduced leaf area produce lower yields than staked plants and this is thought to be due to mutual leaf shading and, consequently, a reduced light interception in unstaked plants (Lebot, 2009). However, the stake length or height may depend on the species or cultivar, size of planting material, and environment.

Traditionally, farmers produce yams on fertile soils after long periods of fallow because of the high nutrient demand of the crop. However, rising population pressure and increased demands on land for non-agricultural purposes have made soil fertility maintenance through prolonged fallows an untenable proposition, leaving the maintenance of soil fertility through fertilizer use the only viable alternative (Law-Ogbomo and Remison, 2007). The poor tuber yields obtained from farmers' plots (IITA, 2002) suggest that soils currently used for yam production need supplementary fertilizer applicationto sustain prodution. In most production systems, yam yields are reported to decline sharply when grown after short fallow of about 1-3 years duration (Watson and Goldsworthy, 1964). In a similar vein, strong yield declines have been observed under continuous yam cultivation (Kowal and Kassam, 1978) due to soil fertility depletion. Yam responds to fertilizer applications under various agronomic conditions (Irizarry *et al*, 1995) and extracts large quantities of nutrients from the soil. For example, a yam yield of 29t/ha removed 133kg N, 10kg P, and 85kg K from the soil (Sobulo, 1972). According to reports on trends of resource management constraints in high-intensity yam growing areas in Nigeria, 72% of the fields had worsening soil fertility conditions, whereas, only 3% of the fields had improved fertility status (IITA, 1999). Based on the data on the amounts of nutrient elements absorbed from the soil, the critical nutrient elements in yam production are nitrogen and potassium (Okigbo, 1980).

Conflicting results on the benefits of fertilizers on yam have been reported (Okwuowulu, 1995). Kang *et al*. (1981) reported no significant effect of NPK (15:15:15) fertilizer on tuber yield in all three locations where their experiments were conducted. Compound fertilizer (NPK 15:15:15) at the rate of 400 – 500 kg/ha was recommended for acid sandy loam soils in southern Nigeria for seed yam production (NRCRI, 1985), while Yayock (1980) made blanket recommendations of 400 – 600 kg/ha for yam production in South-East States. Igwilo (1989), reported that NPK fertilizer application had no significant effect on staked plants of Nwopoko and Obiaoturugo varieties (*Dioscorea rotundata*), but reduced the yield of unstaked plants of these varieties. Law-Ogbomo and Remison (2007) investigated the effects of five rates of NPK 15:15:15 fertilizer on white yam (*Dioscorea rotundata* cv. Obiaoturugo) and found that vine length, number of leaves, and leaf area index significantly increased, as fertilizer application increased, while optimum tuber yield was obtained at 300 kg/ha. Okpara *et al* (2014) studied the effect of NPK fertilizer on white yam micro-sett and observed that mean tuber yield increased significantly in response to NPK fertilizer application up to 600kg/ ha. Although effects varied, yam response to fertilizer is related to the soil fertility status, species, or cultivar (Asiedu, 2003). The objective of this study was to evaluate the effects of stake length and NPK fertilizer on the growth and yield of *Yandu* white yam cultivar in aultisol of South-East Nigeria. The treatment was conducted to resolve the question of whether varying stake lengths and NPK fertilizer rates had no effects on white yam minisett growth and tuber yield in the region.

Materials and Methods

The study was conducted in the 2016 and 2017 cropping seasons at the National Root Crops Research Institute (NRCRI), Umudike, South-East, Nigeria. Umudike is located at Latitude 5° 29' N, Longitude 7° 33' E, and on altitude of 122m above sea level. Each year, the experiment was planted on a different site that had been under fallow for one year. The land used for the experiment was slashed, ploughed, harrowed, and ridged. A composite soil sample was obtained with soil auger to a depth of 20cm from six representative locations in the field plot and used for the determination of physico-chemical properties of the soils in the two seasons The sand, silt and clay fractions were determined using Bouyoucos method (Bouyoucos, 1962). Soil pH (water) was determined in a soil-water ratio of 1: 2.5 using a pH meter. (Udo *et al,* 2009). Organic carbon content was determined by walkley-black method (Nelson and Sommers, 1996). Total nitrogen was determined by Microkjeldahls' method (Bremner, 1996). Available phosphorus was determined by Bray-1 method (IITA,1979). Exchangeable potassium was determined using flame photometer, while calcium and magnesium were determined using atomic absorption spectrophotometer (Thomas, 1982).

The experiment was a factorial type, laid out in a randomized complete block design (RCBD) with three replicates. Stake lengths were at four levels (0, 1, 2, and 3m), while NPK fertilizer rates were at five levels (0, 200, 400, 600, and 800 kg/ha).The treatment combinations were twenty and comprised: LoF_0, LoF_2, LoF_4, LoF_6, LoF_8, L_1F_0, L_1F_2, L_1F_4, L_1F_6, L_1F_8, L_2F_0, L_2F_2, L_2F_4, L_2F_6, L_2F_8, L_3F_0, L_3F_2, L_3F_4, L_3F_6, L_3F_8 (Lo, L_1, L_2, L_3=zero, 1m, 2m and 3m stake lengths respectively; F_0, F_2, F_4, F_6, F_8 = zero, 200, 400, 600 and 800kg/ha NPK respectively; each plot size measured 4m x 2m =8m^2). Planting was done at a spacing of 1m x 0.3m which gave a plant population of 33,333 plants per hectare. A tuber sett-size of 50g was planted per hole on 19 June 2016 and 29 June 2017. NPK (15:15:15) fertilizer was applied using the band method at 8WAP to approperate plots. Inorganic fertilizer NPK (15:15:15) was applied at different rates using the band placement method in appropriate plots at 8WAP. Pre-emergence herbicide (Diuron) was applied immediately after planting in 2016 and 2017 and was complemented with manual weeding at 4, 8, and 12 weeks after planting (WAP).

The growth parameters measured include; vine length and leaf area index at 3 and 4 MAP from four randomly selected plants per plot. Leaf area (cm^2) per plant was obtained using the correction leaf factor from the formular: Y=0.46+0.194X, where Y=total leaf area determined by grid method and linear regression analysis. Leaf area index was determined using the formular: LAI= Leaf area of plant (cm^2)/Land area covered by plant (cm^2) (Akonye and Nwauzoma, 2003). At plant maturity (360 days after planting), records on yield and yield components were taken on number of tubers per plant, tuber weight per plant, and tuber yield (t/ha). The data obtained were subjected to analysis of variance (ANOVA) according to the procedure for a randomized complete block design using GENSTAT Discovery Edition 3 Statistical Package (2007). The comparison of the treatment means for significance was done by the use of least significant difference (LSD) procedure at 5% level of probability.

Results and Discusion

The soil of the experimental site was loamy sand in 2016 and sandy clay loam in 2017, with a pH of 5.1 in 2016 and 4.8 in 2017 (Table 1). The soils were low in organic matter and nitrogen in 2016 and 2017. Soil potassium content was low in 2016, but high in 2017. In both years, the phosphorus content of the soils was high. The total annual rainfalls for 2016 and 2017 were 2323mm and 2080mm, respectively. Rainfall pattern was bimodal with peaks in June and August in 2016, and July and September in 2017 (Table 1). In general, stakes of 2 or 3m lengths at 3 and 4 MAP in 2016 produced significantly higher vine length than no staking (Table 2). At 3 MAP, the 3m stake had longer vines than 1m stake, while at 4 MAP, 2m stake had longer vines than 1m stake. Application of NPK fertilizer did not significantly affect vine length of yam minisett at 3 and 4 MAP. Leaf area index values at 3 MAP in 2016 were similar for 2m and 3m stakes, but significantly higher than that of no staking (Table 3). There were no effects of staking on leaf area index later in crop growth at 4 MAP. NPK fertilizer did not significantly affect leaf area index at 3 and 4 MAP. In 2016, stake length, NPK fertilizer,and the interactive effects of stake length and NPK fertilizer did not significantly affect the number of harvested tubers per plant (Table 4). In contrast, in 2017, the application of NPK fertilizer at 200kg/ha produced significantly more tubers than no fertilizer or the application of NPK at the higher rates of 600 and 800kg/ha. Also, no staking produced higher number of tubers than the use of 1, 2, or 3m stakes. Interactions were significant in 2017, such that no staking and NPK fertilizer at 200kg/ha produced the highest number of tubers per plant. The use of 3m stake in 2016 produced significantly higher tuber weight than no staking (Table 5). In both years, NPK fertilizer application did not significantlyinfluence tuber weight. In the 2017 cropping season, there were significant NPK x Staking height interactions. The use of 2m stake and 200kg/ha NPK or no staking and 600kg NPK produced the highest tuber weight. Averaged across the two cropping seasons, stake length, NPK fertilizer, and interactions of both factors had no significant effects on tuber yield (Table 6). Three-way interactions of stake length x NPK fertilizer x year were not significant but two-way interactions between staking and year, significantly affected tuber yield (Table 7). The 2 and 3m stakes in 2016 produced significantly higher tuber yields than all stake lengths in 2017. Overall, tuber yield in 2016 was almost double that of 2017.

Average across two cropping seasons, staking did not significantly affect tuber yield of the white yam minisett; although the use of 2m stake increased vine length and leaf area index relative to no staking. The non-significant effect of staking on yield may be due to the high rainfall (2079.8-2322.7mm per annum) which caused flooding of some treatment plots. Earlier findings of Enyinnaya *et al.* (1983), and Igwilo, (1988) showed that yields of yam varieties were not significantly affected by the height of stakes. Igwilo and Ude (1987) and Igwilo (1989), reported that stakes function mainly to keep the yam vines away from floodwater, while Chapman (1965), stated that yam canopies supported on shorter stakes had wider girth than those on taller stakes for efficient distribution of solar radiation, indicating why stakes height did not affect tuber yield. Igwilo and Udeh (1987), also reported that waterlogging or flooding yam vines for 24 to 72 hours caused damage to the leaves, decay of apical bud, death of vines, and reduced tuber yield, especially if the plants had been treated with fertilizers. Despite the lack of effect of staking on tuber yield, the use of 2 or 3m stakes in 2016 resulted in higher yields than those obtained in 2017 regardless of stake length. On average, tuber yield in 2016 was higher than that of 2017 by 93.5% probably due to the more favorable soil reaction (at a pH of 5.1) which made nutrients more available in 2016. The use of small or short stakes (2m or less) for miniset vines in a humid environment had been recommended to keep yam vines away from floodwater and prevent foliar diseases that reduce yields when vines trail on the ground (Igwilo, 1988; Ekanayake and Asiedu, 2003).

In a similar vein, NPK fertilizer did not influence vine length, leaf area index, and tuber yield, primarily due to the flooding of some treatment plots. Fertilizer best management practices require the application of the correct fertilizer at an appropriate rate, time, and place (Baiyeri *et al.,* 2013). In this study, annual rainfall was particularly high and above 2000mm in 2016 and 2017, resulting in erosion and flooding and consequently loss of nutrients by leaching and denitrification. Leaching was thought to be partly responsible for low nitrogen recovery as heavy leaching of fertilizer (nitrogen) has been reported for loamy soils under similar rainfall conditions (Igbokwe, 1980). Nitrogen and potassium which are critical for tuber crops are easily lost in the soil through leaching, emission of gaseous nitrogen and possibility of potassium fixation (Nwinyi, 1988). Remison (1997) also ascribed the poor growth and yield of crops in wet soil to the development of toxic substances, insufficient oxygen for respiration, and lack of nitrate formation. Recent studies indicated that annual erosion losses in low-input production systems in sub-Saharan Africa are about 10kg N/ha, 2kg P/ha and 6kgK/ha, with losses greater in high-input systems or where rainfall is very high (Fairhurst, 2012). Igwilo (1989) observed that fertilizer application did not affect staked plants of white yam (Nwopoko and Obiaoturugo) and concluded that varietal differences in response to staking and no staking may arise from differences in canopy structure which, if it allows vines and leaves to contact flood water, lead to their early senescence and low yields.From this study, it appeared that *Yandu* white yam production could be improved by making use of short stakes, that is 2m or less stake, and managing with NPK 15:15:15 fertilizer at the rate of 200kg/ha.

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Table 1: Soil and monthly rainfall data of the site

	Soil physical properties												
	Sand (%)	Clay (%)	Silt (%)										
2016	84.2	9.4	6.4	Loamy	Sand								
2017	67.8	21.4	10.8	Sandy	clay	Loam							
			Soil	**chemical**	**properties**								
	Soil pH (water)	OM (%)	N (%)	P(mg/kg) (%)	K (cmol/kg)								
2016	5.1	1.62	0.084	34.2	0.113								
2017	4.8	1.66	0.095	10.8	0.3								
			Monthly	**Rainfall**	**(mm)**								
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
2016	0.0	0.0	257.7	129.3	278.4	354.1	268.7	396.2	312.6	273.4	45.0	7.3	2322.7
2017	51.0	0.0	76.7	188.3	134.2	298.1	493.3	222.4	400.0	184.2	31.0	0.0	2079.8

Table 2: Effect of Stake Length and NPK fertilizer on vine length (cm) of *Yandu* white yam cultivar at different sampling dates in 2016

	Months after planting(MAP)	
	3	**4**
Stake length (m)		
0.0	108.2	171.0
1.0	115.4	188.4
2.0	164.4	219.2
3.0	173.8	205.8
Mean	140.4	196.1
LSD(0.05)	**52.4**	**35.4**
NPK (kg/ha)		
0	155.6	185.1
200	136.5	194.4
400	118.1	188.9
600	139.6	195.9
800	152.4	216.2
Mean	140.4	196.1
LSD(0.05)	**NS**	

Table 3: Effect of Stake Length and NPK fertilizer on leaf area index of Yandu white yam cultivar at different sampling dates in 2016

	Months after planting (MAP)	
	3	**4**
Stake length (m)		
0.0	0.204	0.195
1.0	0.283	0.521
2.0	0.463	0.748
3.0	0.465	0.545
Mean	0.354	0.502
LSD(0.05)	**0.210**	**NS**
NPK (kg/ha)		
0	0.438	0.368
200	0.310	0.460
400	0.348	0.767
600	0.350	0.628
800	0.322	0.288
Mean	0.354	**0.502**
LSD(0.05)	**NS**	**NS**

Table 4: Effect of NPK fertilizer and Staking Length on number of tubers per plant of *Yandu* white Yam cultivar in 2016 and 2017

	Stake height (m)				
NPK fertilizer(kg/ha)	**0**	**1**	**2**	**3**	**Mean**
		2016			
0	1.48	1.51	1.30	1.56	**1.46**
200	1.58	1.46	1.70	1.19	**1.49**
400	1.77	1.60	1.69	1.62	**1.67**
600	1.87	2.05	1.36	1.55	**1.71**
800	1.59	1.90	1.40	1.72	**1.65**
Mean	**1.66**	**1.70**	**1.49**	**1.53**	
		2017			
0	1.43	1.14	1.33	1.30	**1.30**
200	3.51	1.20	1.10	1.21	**1.75**
400	1.30	1.56	1.13	1.38	**1.34**
600	0.86	1.41	1.17	1.13	**1.14**
800	1.23	1.35	1.42	1.22	**1.31**
Mean	**1.67**	**1.33**	**1.23**	**1.25**	

		2016	**2017**
LSD(0.05) for NPK (F) means	=	NS	0.43
LSD(0.05) for Staking (S) means	=	NS	0.38
LSD(0.05) for F x S means	=	NS	0.86

Table 5: Effect of NPK fertilizer and staking height on tuber weight (kg) of Yandu white Yam in 2016 and 2017.

	Stake length (m)				
NPK fertilizer(kg/ha)	0	1	2	3	Mean
		2016			
0	0.240	0.433	0.680	0.573	**0.482**
200	0.310	0.393	0.397	0.670	**0.443**
400	0.467	0.497	0.387	0.413	**0.441**
600	0.387	0.180	0.647	0.480	**0.423**
800	0.340	0.363	0.410	0.420	**0.383**
Mean	**0.349**	**0.373**	**0.504**	**0.511**	
		2017			
0	0.286	0.384	0.146	0.208	**0.256**
200	0.193	0.246	0.526	0.185	**0.288**
400	0.369	0.226	0.202	0.233	**0.258**
600	0.491	0.188	0.162	0.365	**0.301**
800	0.334	0.190	0.290	0.213	**0.257**
Mean	**0.335**	**0.247**	**0.265**	**0.241**	

		2016	**2017**
LSD(0.05) for sett NPK (F) means	=	NS	NS
LSD(0.05) for staking (S) means	=	0.157	NS
LSD(0.05) for F x S means	=	NS	0.236

Table 6: Effect of Stake Lengthand NPK fertilizer on mean tuber yield (t/ha) of *Yandu* white Yam (2016 and 2017)

	Stake length (m)				
NPK fertilizer(kg/ha)	**0**	**1**	**2**	**3**	**Mean**
0	12.39	15.86	17.96	18.61	**16.21**
200	18.33	14.62	20.61	17.35	**17.73**
400	23.27	19.57	14.28	16.02	**18.28**
600	17.82	9.74	17.07	18.28	**15.73**
800	15.89	14.53	16.63	16.32	**15.84**
Mean	**17.54**	**14.87**	**17.321**	**17.32**	

LSD(0.05) for staking (S) means	=	NS
LSD(0.05) for sett NPK (F) means	=	NS
LSD(0.05) for F x S means	=	NS

Table 7: Effect of year and stake length on tuber yield (t/ha) of Yandu white Yam cultivar

Year		**Stake length**	**(m)**		
	0	**1**	**2**	**3**	**Mean**
2016	19.94	19.76	24.10	24.59	22.10
2017	15.14	9.97	10.52	10.04	11.42
Mean	17.54	14.87	17.31	17.32	

LSD(0.05) for year (Y) means	=	10.52
LSD(0.05) for staking (S) means	=	NS
LSD(0.05) for Y x S means	=	8.04

*****LSD means Least Signiificant Difference***

*****NS means Not Significant***