Yield and nutrient uptake of white yam as affected by organo-mineral fertilizer in Ikenne, Southwestern Nigeria

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ABSTRACT

Information is scanty on the optimum level of fertilizer requirement for the production in yam production in relation to yield and nutrient uptake. This study was conducted to evaluate the effects of different levels of organic and mineral fertilizers, singly and in combination, on yield and nutrient uptake of white yam in 2004 and 2005 at Ikenne, Southwestern Nigeria. Four cultivars of white yam (Adaka, Amula, Danacha and Omiefun) were subjected to 10 fertilizer treatments comprising, sole organic fertilizer (OF), mineral (NPK 12-12-12) fertilizers combinations of the two (organo-mineral) and control, at the rate of 2.5 and 5.0 t/ha OF; 0.15, 0.3 and 0.45 t/ha NPK; 1.75 t/ha OF+0.15 t/ha NPK; 2.5 t/ha OF+0.15 t /ha NPK; 2.5 t/ha OF+0.3 t/ha NPK and 5.0 t/ha OF+0.3 t/ha NPK. The trials were conducted at Ikenne, Southwestern Nigeria. The experiment was a split-plot fitted into randomized complete block design with four replicates. White yam cultivars and fertilizer rates were main and sub-plot treatments respectively. Tuber yield and nutrient uptake were assessed. Data obtained over two years were pulled together and analyzed using analyses of variance and in the differences treatment means were separated using Duncan's multiple range test at 5% probability level. Four fertilizer treatments (5.0 t/ha OF, 0.45 t/ha NPK, 2.5 t/ha OF+0.3 t/ha NPK, 5.0 t/ha OF+0.3 t/ha NPK) significantly ($P < 0.05$) improved the growth and yield of white yam compared to the control. Fertilizer treatment at 5.0 t/ha OF + 0.15 t/ha NPK produced the highest tuber yield of 22.0 t/ha in 2004 and 17.9 t/ha in 2005. They were significantly ($P<0.05$) higher than the control plots in the two years. Similarly, the same fertilizer treatment had the highest N, P and K uptake of 48.4, 15.9 and 64.7 g/plant respectively in 2004. There were N, P and K uptakes of 42.9, 15.8 and 62.6 g/plant respectively in 2005 and were significantly ($P< 0.05$) higher than the control. Fertilizer treatment at 5.0 t/ha OF+0.3 t/ha NPK was the best with reference to tuber yield and nutrient uptake. Amula had the highest tuber yield of 21.5 and 10.7 t/ha in 2004 and 2005 respectively.

Keywords: *Dioscorea rotundata*, Fertilizers, Tuber- yield, Nutrient uptake.

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INTRODUCTION

Yams (*Dioscorea* spp.) are important staple food crops widely cultivated worldwide where, they constitute major source of calories and vitamin C in the diet of people (Obigbesan, 1981). Yams are cultivated in an area of about 2.5 million hectares in the world, producing about 23.5 million metric tonnes of tubers (FAO, 1999; 2004). Africa alone produces about 90% of yam tubers and covers about 95% of the area of production. Beside Africa, it is also grown on large scale in countries like China, Japan, Oceania and other Caribbean countries (Ghosh *et al*., 1988). Most of the yams are produced from the yam zone of West Africa (Cameroon, Nigeria, Benin, Togo, Ghana, and Cote d'Ivoire) and to a lesser extent, the neighbouring countries (Chad, Burkina Faso, Mali and Guinea). These areas account for about 92 percent of the total world production (FAO, 1999; Wilfried and Lutaladio, 1999; Chukwu and Ikwelle, 2000). In Nigeria about 2.5 million hectares of land is put into yam production annually, with the bulk production in the middle belt and southern part of Nigeria (Rai and Yadav, 2005).Yams are very important in local commerce in Africa and account for about 32% of farm income earned from crops. As a source of foreign exchange, they are exported from Caribbean countries to Europe and North America (FAO, 1999) primarily to meet the needs of Africans and African descendants in these regions.

Prior to the advent of shifting cultivation system of farming, tropical and subtropical soils could guarantee sustainable production of arable crops (such as yams, maize, cowpea etc.) without external input of nutrients. Presently there is problem of widespread nutrient deficiency that limit crop uptake, growth and yield due to land degradation and nutrient fixation in the soil (Akinrinde, 2006). Most of the plant essential nutrients especially nitrogen (N), phosphorus (P) and potassium (K) are not readily available to plants due to erosion, leaching and fixation. According to Akinrinde and Okeleye (2005), crops have become so expensive to produce that nutrient deficiency should not be allowed to limit their yields. However, this goal is far from reality. The use of mineral fertilizer (e.g. NPK) is beyond the reach of peasant farmers due to high cost and procurement difficulties especially in developing countries. Apart from this, continuous use of mineral fertilizer alone leads to soil acidity, nutrient imbalance and declining crop yield (Tendon, 1992).

In recent times, alternatives to the use of mineral fertilizers are being sought. This is because, apart from the ability of organic manure to neutralize soil acidity, it could also provide some essential macronutrients (N, P, K, Ca, Mg) and micro nutrient (Zn, B, Cu etc.) for crop production and lead to increased crop growth, nutrient uptake and yield (Brower and Powel, 1995). This is because organic manure holds in check (in-situ within the root zone) the movement of mineral nutrients due to leaching and erosion. In the case of low activity clay of most tropical soils, organic manure makes available cation exchange sites to augment the normal property of clay, which is lacking thereby enhancing nutrient uptake, and hence use efficiency. It also increases crop yield quality, which enhances shelf-life (Kpello *et al.*, 1981). Organic fertilizers also have long-term residual effects, which maintain soil fertility in continuous cropping. Studies carried out on the use of organic manure alone and in conjunction with mineral fertilizers on yam in humid forest zone of Nigeria produced excellent results (Agboola and Obigbesan, 1975; Adeoye *et al.*, 1991). Dearth of recent information exists on the nutrient uptake and tuber yield of white guinea yam from plants grown with organic with or without-mineral fertilizers. This study was conducted to evaluate the yield and NPK uptake of white yam grown with different fertilizer treatments in Ibadan.

MATERIALS AND METHODS

Field trials were conducted in Ibadan (Longitude 3^0 42'E and Latitude 6^0 54'N) on an alfisol (Oxic Kandiustalf), in the lowland forest zone of Nigeria in 2004 and 2005. The 2004 and 2005 sites were under natural and mucuna fallow for a year respectively before cropping. The composted organic fertilizer used in the experiment was analyzed for total N, P, K and exchangeable bases as in IITA (1981). In pre and post cropping soil analysis, total N was estimated by Micro Kjeldahl method of Black (1965). Available P was determined by first extracting with Bray- P1, and then read colorimetrically with spectrophotometer (Bray and Kurtz, 1945). Exchangeable K, Ca, Mg and Na were determined by extraction with IN ammonium acetate (Murphy and Riley, 1962). Soil pH was determined by pH meter with glass electrode. Organic carbon was determined by the wet oxidation method of Walkley and Black (1934) and particle size distribution was determined by method of Bouyoucos (1962). The experiment was laid down in a split plot arrangement in randomized complete block design replicated four times. Fifty to sixty grams sett sizes of four landrace cultivars of *Dioscorea rotundata* (CV. Adaka, Danacha, Omiefun and Amula) were planted in April each year on ridges at a spacing of 1 m X 0.5 m. Alleys 2 m wide separated the plots to prevent flow of fertilizer from one plot to another and tangling of vines between the adjacent plots. Six weeks after planting, 10 fertilizer treatments were applied, comprising: control (no fertilizer), 2.5 t/ha organic fertilizer (OF), 5.0 t/ha OF, 0.15 t/ha NPK 12-12-12(NPK), 0.3 t/ha NPK, 0.45 t/ha NPK, 1.75 t/ha OF+0.15 t/ha NPK,2.5 t/ha OF+0.15 t/ha NPK, 2.5 t /ha OF+0.3 t/ha NPK and 5.0 t/ha OF+0.3 t/ha NPK. The fertilizers were applied in a groove about 5 cm deep and 10 cm from the base of each plant. The yams were staked and weeded manually after initial pre-emergence application of herbicide. Sampling was done monthly for data collection from one month after fertilizer application till the start of senescence of yam plants. Harvesting was done in December each year. Three yam plants/plot were carefully uprooted, washed and separated into leaves (petiole plus lamina), vines, tuber and roots. They were weighed and dried in oven at 70 ^{0}C for 72 hours for dry matter determination and the nutrient uptakes were calculated by multiplying the dry matter weight by the plant's nutrient contents. Five plants were harvested in the net plot and weighed for tuber yield. Data obtained over the two years were pulled together and analyzed using analyses of variance and differences treatment means were separated using Duncan's multiple range test at 5% probability level. Statistical analysis software, SAS version 9.1 (2003) was used for the analysis.

RESULTS AND DISCUSSION

Physical and chemical properties of the study sites

The chemical and physical properties of the two experimental soils are presented in Table 1. The soils of the two sites were sandy loam. Soil pH was 5.7 in 2004 and 5.9 in 2005. The soils were slightly acidic. The organic carbon content ranged from 0.67 g/kg in 2004 and 0.62 g/kg in 2005 while total N content ranged from 1.58 g/kg in 2004 and 1.08 g/kg in 2005. The total N and organic carbon contents were high in 2004 but low in 2005 based on the critical value of 1.5-2.0g/kg, (Sobulo and Osiname, 1981). The available P was 15.70 mg/kg in 2004 and 8.43 mg/kg in 2005 representing sufficiency and marginal deficiency levels, considering the 10-16mg/kg as being critical for crop production (Sobulo and Osiname, 1981; Adeoye and Agboola, 1985). The exchangeable K was 0.38 cmol/kg in 2004 and 0.15 cmol/kg in 2005. The soils were generally rich in K, considering the 0.16-0.25cmol/kg critical level (Adeoye and Agboola, 1985). This indicates the need for additional nutrient supply to the soils. The soils silt, clay and sand contents of between 160-170, 100 and 730-740 g/kg respectively (Table 1) are optimal to retain adequate water for normal yam growth.

Table 1. Pre-cropping chemical and physical properties of soils of the experimental sites in 2004 and 2005

Soil Properties	**2004**	**2005**
pH (H_2O)(1:1)	5.7	5.9
pH (KCl) (1:1)	4.1	4.7
Total N (g kg^{-1})	1.58	1.08
Organic carbon (g kg^{-1})	0.67	0.62
Available P (mg kg^{-1})	15.7	8.43
Exchangeable cations (cmol kg^{-1})		
Ca^{2+}	1.47	4.81
Mg^{2+}	0.32	1.05
K^{+}	0.38	0.15
Na^{+}	0.34	0.08
$Al^{3+} + H^{++}$	4.30	4.10
ECEC (cmol kg^{-1})	6.86	10.18
Base saturation (%)	68.2	85.3
Extractible micronutrients mg kg^{-1}		
Iron	69.9	38.0
Zinc	0.83	3.48
Copper	0.89	1.89
Manganese	92.9	83.0
Soil texture (g kg^{-1})		
Sand	740	730
Silt	100	100
Clay	160	170
Classification (USDA 1994)	Typic Paleudalfs Sandy loam	

Table 2. Nutrient content of the fertilizer materials

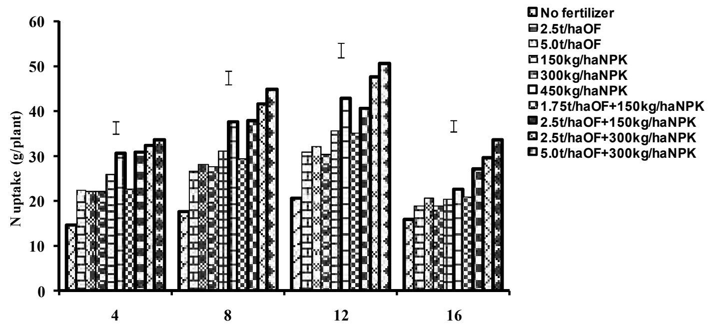
Properties	Fertilizer materials OF*	Urea	TSP	MOP
N (%)	1.09	46	-	-
P ”	0.70	-	60	-
K ”	1.27	-	-	60
Ca ”	1.48	-	-	-
Mg ”	0.58	-	-	-
C/N ratio (g/kg)	8.97	-	-	-
Na (cmol kg^{-1})	2.75	-	-	-
Fe (mg kg^{-1})	95.0	-	-	-
Mn ”	346	-	-	-
Cu ”	48.3	-	-	-
Zn ”	287	-	-	-

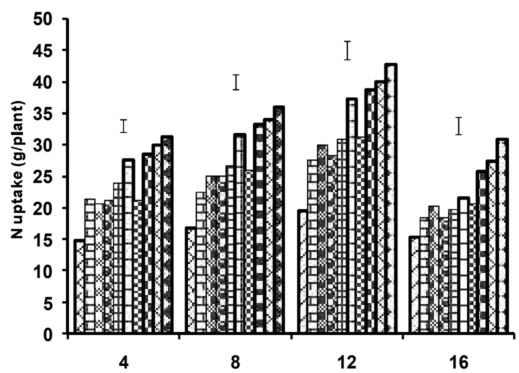
*OF = Organic fertilizer, TSP = triple super phosphate,MOP = Muriate of potash

Table 3: Effects of different fertilizer treatments on tuber yield of of white yam at Ikenne in 2004 and 2005 cropping season

Fertilizer treatment	**Tuber yields (t/ha)**	
	2004	**2005**
No fertilizer	18.46ab	8.08e
2.5tha^{-1}OF	19.88ab	9.36de
5.0tha^{-1} OF	22.60a	12.37bc
150$kgha^{-1}$NPK 12-12-12	20.69ab	11.88cd
300$kgha^{-1}$NPK 12-12-12	21.31a	12.53bc
450$kgha^{-1}$NPK12-12-12	19.20a	17.34a
1.75tha^{-1}OF+150$kgha^{-1}$NPK	19.14ab	14.24bc
2.5tha^{-1}OF+150$kgha^{-1}$NPK	20.58a	16.60b
2.5tha^{-1}OF+300$kgha^{-1}$NPK	21.65a	17.94a
5.0tha^{-1}OF+300$kgha^{-1}$NPK	21.98a	18.22a

Means in the column followed by the same letters are not significantly different by Duncan Multiple Range Test (DMRT).





Weeks after Fertilizer application

Figure 1: Effects of fertilizer treatment on nitrogen

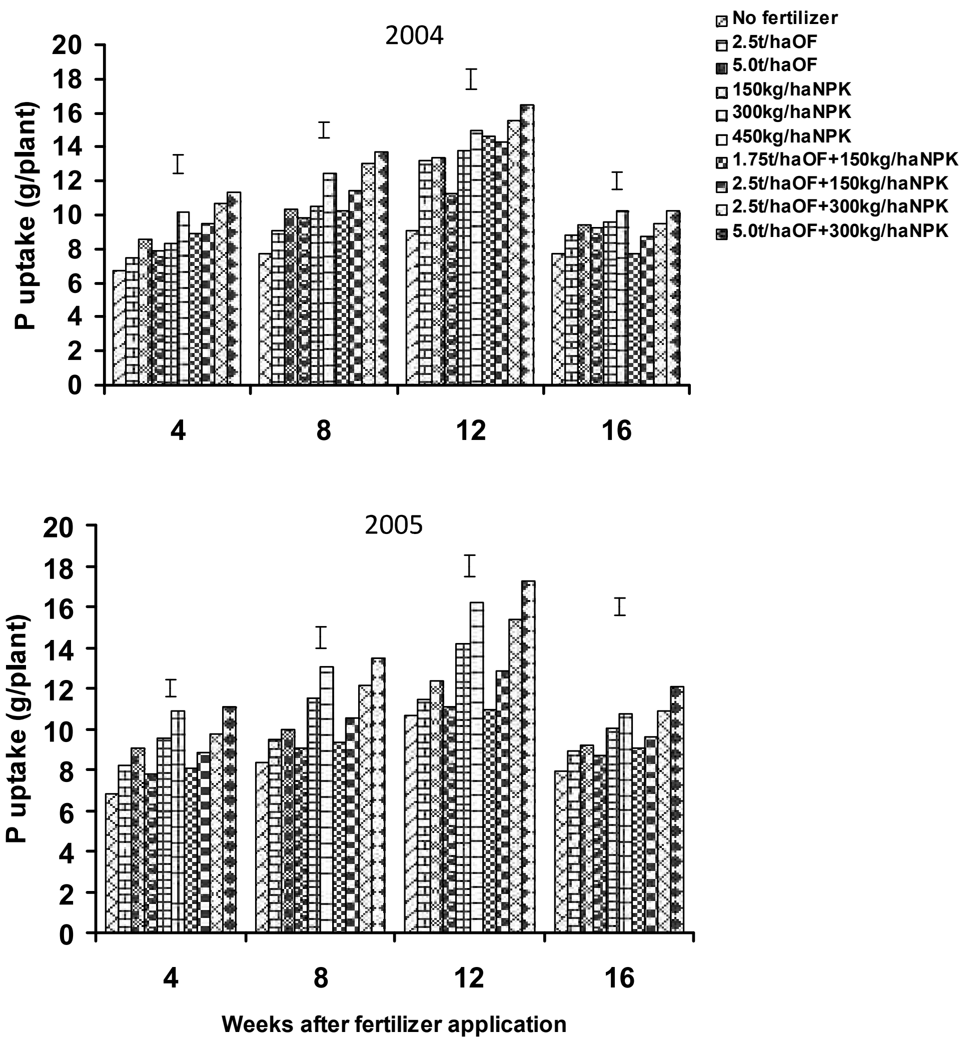


Figure 2: Effects of fertilizer treatment on phosphorus uptake of white yam at Ikenne in 2004 and 2005

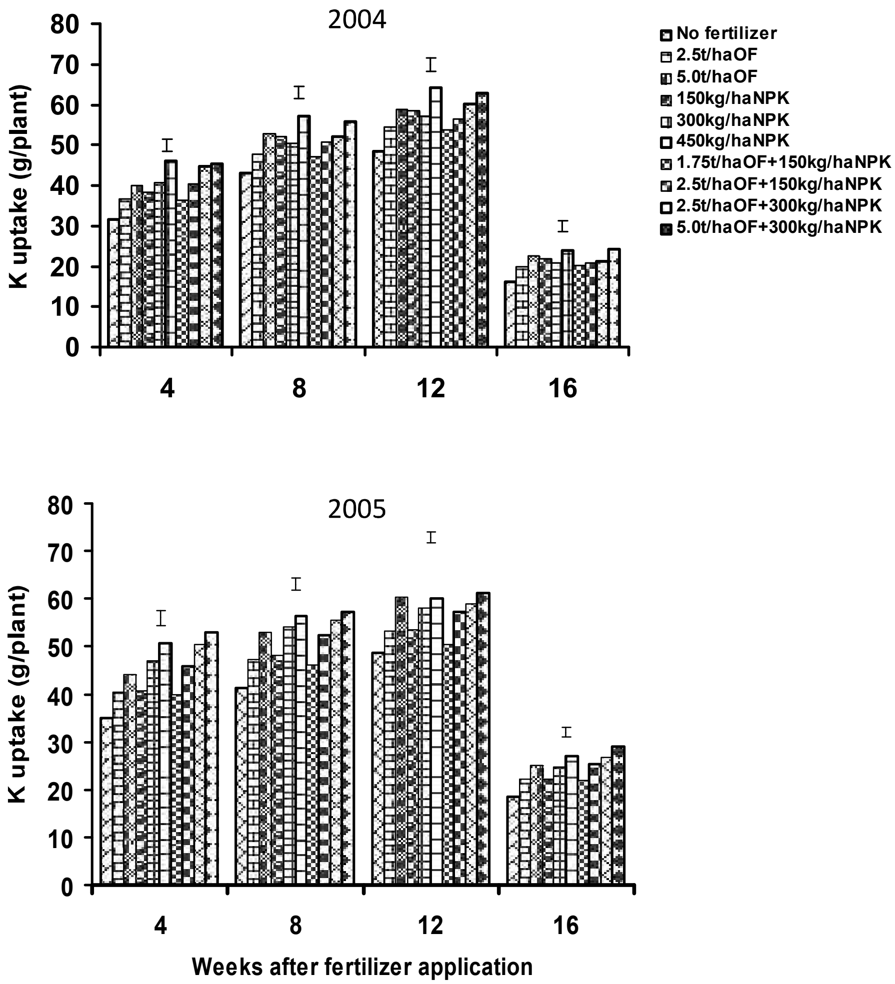


Figure 3: Effects of fertilizer treatment on Potassium uptake of white yam at Ikenne in 2004 and 2005

Organic fertilizer (Cowdung plus sorted city refuse) contained 1.09, 0.7, 1.27, 1.48 and 0.58% of N, P, K, Ca and Mg, respectively. Urea contained 46% N, TSP contained 60% P while MOP contained 60% K. The organic materials are rich in plant nutrients with C/N ratios of 8.97g/kg being adequate for quick nutrient release (Table 2).

Effect of different fertilizer treatments on nutrient uptake and tuber yield of white yam

The NPK uptake by the yam plants (Fig. 1 to 3) increases with increasing nutrient content of fertilizer materials. However, organo-mineral fertilizer enhanced better nutrient uptake compared to NPK fertilizer alone and the control. Fertilizer rate at 5.0 t/ha OF + 300 kg/ha NPK is superior to other fertilizer treatment in this study. The organic manure content of this fertilizer material must have enhanced appropriate release, availability and consumption of nutrient by the yam plants compared to the control. Also, the slow release of nutrients by organic manure coupled with the long period yam plants took to reach maturity made it easy for enhanced nutrient uptake by yam plants from the organic and organo-mineral fertilizer (Obigbesan, 1981) as compared to mineral fertilizer that releases its nutrients very fast or get leached out even before the plant could absorb it. Effects of different fertilizer treatments on tuber yield of white yam at in 2004 and 2005 is shown in Table 3. In 2004 and 2005, plots grown with 5.0 t ha^{-1} OF + 300 kg ha^{-1} NPK had significantly higher mean tuber yields of 18.46 t ha^{-1} and 8.08 t ha^{-1}), about 97.6% and 67% higher than tuber yield from the control plots (Table 3). There were significant ($P< 0.05$) differences in yields among the four white yam cultivars, with cv. 'Adaka' and 'Amula' having significantly higher mean yields of 16.58 t ha^{-1} and 16.89 t ha^{-1} relative to others only in 2005. There were no significant differences in tuber yields among the four yam cultivars in 2004 (Table 3).

The significant ($P<0.05$) increase in tuber yield and N, P, K uptakes with increasing nutrient content of fertilizer for both years indicated the important and positive effects of organic, inorganic and organo-mineral fertilizer on yam plants. This is expected because of the low native soil fertility status of the sites where the yam was grown. Many research findings on yam support the view that yams generally respond well to fertilizer application especially in an exhaustively cropped land (Agboola and Obigbesan, 1981; Adeoye *et al*., 1991). However among the fertilizer treatments those that received the combination of organic and inorganic fertilizers performed better. This observation is in accord with the findings of Agboola and Obigbesan (1975), Adeoye *et al*., (1991) and Adediran *et al.* (1999) on yams and other crops. They all asserted that combination of organic and inorganic fertilizer on crop production performed equally and in some cases even better than the use of either organic or inorganic fertilizer alone. The relatively poor performance of the control plots can be attributed to very low nutrient (NPK) status of the plots that can not sustain optimum yam production (Adeoye and Agboola, 1985; FFD/FMARD, 2002).

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