Available online at www.notulaebotanicae.ro

Print ISSN 0255-965X; Electronic ISSN 1842-4309

Not. Bot. Hort. Agrobot. Cluj 37 (1) 2009, 165-170

Notulae Botanicae Horti Agrobotanici Cluj-Napoca

Yield and Distribution/Uptake of Nutrients of *Dioscorea rotundata* Influenced by NPK Fertilizer Application

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Abstract

Two field trials were conducted in 2005 and 2006 at Evboneka to determine the optimum level of NPK requirement for yield and nutrient composition of *D. rotundata* for the forest ultisol location. Fresh tuber yield, dry matter accumulation, percentage of nitrogen (N), phosphorus (P) and potassium (K) content of leaves and tubers at various stages and crude protein content of harvested tubers were evaluated under five levels (0, 100, 200, 300 and 400 kilogramme per hectare (kg ha^{-1}) of NPK fertilizer using randomized complete block design. NPK fertilizer application significantly increased all the tested parameters. The optimum level of NPK for successful production of white guinea yam was 300 (45 kg N + 20.37 kg P + 37.35 kg K) kg ha^{-1} in a forest ultisol that been under cultivation for at least two years.

Keywords: Crude protein content, dry matter accumulation, fresh tuber yield, NPK fertilizer application and nutrient uptake

Introduction

The yield and uptake of nutrients by crops is largely governed by the nutrient supply system of the soil through native and applied sources and their losses through leaching, weed infestation, etc (Kannaiyan, 1999). However, the native soil fertility of most tropical soils is low owing to the increased frequency of cultivation of land as demand for food increases, unsustainable nature of the bush fallow practices of naturally restoring the fertility status of the soil due to reduced fallow period occasioned by high population pressure and other human activities (Steiner, 1991), coupled with erosion, volatilization and immobilization (Law-Ogbomo and Remison, 2008).

Under continuous cropping, the native nutrient content of the soil is usually supplemented with inorganic NPK fertilizer if the crop planted is to do well (Alam *et al*. 2004). N, P and K are primary nutrient in the soil because of their acute deficiencies in most light-textured soil and their application in the soil form the basis of applying the secondary and the trace nutrients in the soil (Law-Ogbomo and Remison, 2007). Inorganic NPK fertilizer plays an importance role in the uptake of nutrient, nutrient contents and yield of crop plants (Kumar *et al*. 1995). The response of yam to nutrient is almost universal. In spite of considerable increase in fertilizer use, multiple nutrient deficiencies particularly that of NPK is on the increase in Nigerian Agriculture and is posing problem to sustained yam productivity (Ibeawuchi *et al*. 2006). Conflicting results about the benefits and adverse effects of fertilizer have been reported in literature (Osagie, 1997). This could probably due to differences in the pre-cropping nutrient status (Stephen, 1980) and partly due to difficulty in interpreting the results of soil analysis. Plant analysis is a useful supplement to soil analysis where the soil analysis presents difficulties in assessing available nutrients.

The study of nutrient flow in the plant organs with age will give some ideas about the uptake pattern of plants at different crop stages. Hence, the need to know the nutrient content of leaf and tuber at various age become very important. This investigation is an account of the influence of NPK fertilizer on yield, nutrient uptake and nutrient content of *Dioscorea rotundata*.

Materials and methods

This study was conducted at Benin City (7°30' E and 5°45' N). Although, the site had been under cultivation for two years, there was no evidence of fertilizer use. Composite samples from field were taken to determine the nutrient status of the soil before each cropping. The experiments were laid down in randomized complete block design of five plots, with three replications.

D. rotundata (cv. Obiaoturugo) was planted by Mid-April during the two years from 2005 and 2006 at a spacing of 100 cm on ridges 100 cm apart. As far as possible, the sett type, head, middle and bottom were evenly distributed among plots. Plots were mulched with dry grass immediately after planting. The gross plot size was 7 x 6 m and the net plot was 6 x 5 m. Eight weeks after planting (WAP), five levels of NPK (0 (0 kg N + 0 kg P + 0 kg K), 100 (15 kg N + 6.79 kg P + 12.45 kg K), 200 (30 kg N + 13.58 kg P + 24.90 kg K), 300 (45 kg N + 20.37 kg P + 37.35 kg K) and 400 (60 kg N + 27.16 kg P + 49.80 kg K) kg ha-1) as

Tab. 1. Soil physical and chemical properties before cropping

Property	Year	
	2005	2006
pH (H2O)	4.10	4.60
Organic Carbon (%)	2.11	1.04
Total Nitrogen (%)	0.08	0.23
Available Phosphorus	8.00	4.00
Exchangeable cations (cmol kg-1)		
Potassium	0.06	0.05
Sodium	0.16	0.29
Magnesium	0.10	0.07
Calcium	0.55	0.30
Clay (%)	9.00	18.00
Silt (%)	2.00	1.00
Sand (%)	89.00	84.00
Textural Class	Sandy loam	Sandy loam

compound fertilizer was applied to the plots through basal placement.

The vines were staked singly using bamboo measuring two metre long and not tied together in four to avoid bias. Weeding operation, were done manually at 8, 12, 16 and 22 WAP. Harvesting was done at the beginning of December when all the leaves had dried out (leaf senescence) and vines had withered. 12 yam stands in each plot were harvested and data was on fresh tuber yield per hectare. Two tubers from each plot were then taken weighed and oven dried at 70°C for 48 hours to constant weight for dry matter content determination and for N, P and K determination at final harvest. The N content of the final harvested tubers were multiply by 6.25 to obtain the crude protein content of the tuber. 30 plants, two from a plot, were removed at random at 16 and 24 WAP, separately into leaves, vines and tubers, dried at 70° C for 72 hours to constant weight (ISTA, 1993). The various portions were sub-sampled and ground, and 0.2 g of the ground material ashed at 450°C four hours. The ash was digested in hot dilute hydrochloric acid and analyzed for P determined on the samples by the molybdenum blue method (Jackson, 1973) and potassium (K) on an flame photometer (Mylavarapus and Kennelley, 2002). The N was determined by the standard Micro-Kjeldal method as outlined by Mylavarapus and Kennelley (2002) using Tecator kjeltec auto analyzer. N, P and K uptake were determined by multiplying oven dry weight of the sample with the nutrient (N, P and K) content in the respective sample.

Analysis of variance was carried out on each of the observations recorded for each year of study, followed by combined analysis over two years. The Least Significant Difference (LSD) test was used for detecting significance differences between means at 5% level of probability.

Results and discussion

Soil native fertility

Pre-cropping chemical analysis of the 2005 and 2006 sites are presented in Tab. 1. The soil is acidic (pH 4.10 – 4.40) and textually sandy loam. The soils are classified as ultisols derived from coastal plain sand. The soils contain less than 1.50 – 2.00 % N, 25.00 mg kg^{-1} available P, exchangeable K of 0.40 cmol kg^{-1}, exchangeable Ca of 0.20 – 0.40 cmol kg^{-1} and exchangeable Mg of 0.40 cmol kg^{-1}. Soils below these critical levels are regarded as being low in these nutrients (Ibedu *et al*., 1988). Consequently, optimum growth and yield cannot be achieved without supplementary nutrients through organic manure and/or inorganic fertilizer.

Crop yield

The results of this trial showed that NPK application increased both fresh tuber yield and dry matter accumulation (biomass). From this study, the average fresh tuber yield varied from 10.38 to 13.36 t ha^{-1} between 0 and 300 kg ha^{-1} and declined at 400 kg ha^{-1} (Tab. 2). This is an indication that the 300kg ha^{-1} may be regarded as the optimum level of the nutrient elements while the 400 kg ha^{-1} may be said to be the toxic level, since it retarded growth (dry mat-

Tab. 2. Effects of different levels of NPK 15:15:15 fertilizer on the tuber yield and dry matter accumulation of *D. rotundata* at final harvest.

Nutrient applied	Fresh tuber yield (t ha^{-1})			Dry matter accumulation (t ha^{-1})		
(kg ha-1)	2005	2006	Combined	2005	2006	Combined
0	10.36	10.40	10.28	3.78	3.45	3.62
100	17.72	14.63	16.17	5.84	6.08	5.96
200	19.12	16.20	17.66	6.18	6.42	6.30
300	19.16	19.57	19.36	6.48	7.28	6.88
400	11.55	13.00	12.27	4.23	5.19	4.71
Mean	15.60	14.70	15.15	5.30	5.68	5.49
LSD (P<0.05)	3.472	2.700	1.531	1.760	1.502	1.446

Tab. 3 Effects of different levels of NPK 15:15:15 fertilizer on N, P and K content in leaves and tubers of *D. rotundata* at 16 WAP on dry matter basis

Nutrient applied	Nutrient content of leaves (g kg-1)			Nutrient content of tubers (g kg-1)		
(kg ha-1)	N	P	K	N	P	K
			2005 cropping			
0	4.51	0.25	2.34	2.00	0.19	1.13
100	4.57	0.26	2.40	2.08	0.22	1.15
200	4.66	0.27	2.45	2.10	0.24	1.20
300	4.74	0.26	2.50	2.20	0.23	1.22
400	4.81	0.25	2.59	2.29	0.23	1.26
Mean	4.66	0.26	2.46	2.13	0.22	1.19
LSD (P<0.05)	0.051	ns	0.122	ns	ns	0.05
			2006 cropping			
0	4.65	0.16	2.25	2.05	0.18	1.02
100	4.68	0.16	2.28	2.14	0.20	1.05
200	4.70	0.16	2.35	2.20	0.19	1.10
300	4.80	0.15	2.53	2.29	0.22	1.15
400	4.85	0.16	2.45	2.35	0.20	1.18
Mean	4.74	0.16	2.35	2.21	0.20	1.18
LSD (P<0.05)	0.104	ns	0.190	0.151	ns	0.044
			Combined			
0	4.58	0.21	2.29	2.03	0.19	1.08
100	4.63	0.21	2.34	2.10	0.21	1.10
200	4.68	0.22	2.40	2.15	0.22	1.15
300	4.77	0.21	2.46	2.25	0.23	1.19
400	4.83	0.20	2.53	2.32	0.22	1.22
Mean	4.70	0.21	2.40	2.17	0.21	1.15
LSD (P<0.05)	0.102	ns	0.138	0.212	ns	0.065
			ns-not significant			

ter accumulation) and fresh tuber yield. This could be as a result of their interference with the absorption and utilization of other elements that would have improved yield (Uguru, 1996). The plants without fertilizer treatment had the lowest yield which could have been partly due to deficiency of nutrients as revealed by low native fertility status of the soil. The significant correlation ($r = 0.62$, $p < 0.05$) of tuber yield with NPK fertilizer rate suggests that nutrient status can exert a significant influence on crop yield (Kayode, 1985). The difference in the optimum levels of NPK fertilizer rate in both years may be attributed to differences in the nutrient reserve in the soils. According to Yayock *et al*. (1988), Crop response to fertilizer application is affected by nutrient reserve in the soil and response trends to be more in soil with very low nutrient status than those with high reserve.

Dry matter accumulation followed the same pattern as fresh tuber yield (Tab. 2). There was significant correlation of dry matter accumulation with NPK fertilizer application levels ($r = 0.65$ at $P<0.05$).

Nutrient content (%) in leaf and tuber

Notable changes in nutrient composition were recorded during the growth stages. The content of N and K increased steadily from 16 WAP (Tab. 3) and attained a peak at 24 WAP (Tab. 4) and declined at final harvest (Tab. 5). The highest nutrient concentration and therefore the greatest intensity of nutrients removed occurred at 24 WAP (Tab. 4).

Means values of the mineral nutrient contents of tubers harvested in 2006 had higher P and K. In contrast to the results of leaf analysis, the concentration of P in yam tubers in relation to the P content at 16 and 24 WAP was the highest, indicating that relatively more P was translocated into tuber (Tab. 5). N was the most abundant mineral element in the tuber at final harvest followed by K (Tab. 5).

N and K are the main nutrients limiting yam yield as evident through nutrient content of the leaves and tubers. Many workers including Obigbesan and Agboola (1978) and Kayode (1985) have shown in earlier studies that these nutrients could be loss easily from the soil through leaching (N), evolution of gases (N and P) and possibly K

Tab. 4: Effects of different levels of NPK 15:15:15 fertilizer on N, P and K content in leaves and tubers of *D. rotundata* at 24 WAP on dry matter basis.

Nutrient applied	Nutrient content of leaves (g kg-1)			Nutrient content of tubers (g kg-1)		
(kg ha-1)	N	P	K	N	P	K
			2005 cropping			
0	4.65	0.24	2.45	2.13	0.03	2.30
100	4.72	0.25	2.51	2.20	0.06	2.42
200	4.70	0.28	2.70	2.22	0.08	2.50
300	4.89	0.27	2.77	2.25	0.05	2.57
400	4.96	0.26	2.78	2.31	0.04	2.63
Mean	4.78	0.26	2.64	2.22	0.05	2.48
LSD (P<0.05)	0.114	ns	0.154	0.119	0.017	0.133
			2006 cropping			
0	4.71	0.22	2.25	2.16	0.01	2.30
100	4.76	0.22	2.35	2.18	0.01	2.42
200	4.88	0.27	2.40	2.22	0.03	2.50
300	4.90	0.26	2.38	2.50	0.02	2.57
400	4.95	0.25	2.50	2.56	0.02	2.63
Mean	4.25	0.24	2.38	2.33	0.02	2.48
LSD (P<0.05)	0.150	0.022	0.088	0.139	ns	0.186
			Combined			
0	4.71	0.23	2.35	2.22	0.02	2.30
100	4.74	0.23	2.43	2.19	0.04	2.42
200	4.79	0.28	2.55	2.22	0.05	2.50
300	4.90	0.27	2.75	2.38	0.04	2.57
400	4.96	0.26	2.64	2.42	0.03	2.63
Mean	4.82	0.25	2.51	2.27	0.04	2.48
LSD (P<0.05)	0.118	0.028	0.115	0.113	0.014	0.155

ns-not significant

fixation which is not lost from the soil but unavailable to the plants. The relatively high leaf K compared to P could be attributed to the high demand of yam crop for K to enhance translocation of assimilates to the tuber (Obigbesan, 1987). The low relative P content of leaves compared to N and K (Tables 3 and 4) was due to low P mobility in the plants and its eventual accumulation in the tuber at final harvest with the possible formation of complexes between P and tuber protein (Oyenuga, 1968). It might also be that yams depend on an effective mycorrhizal association to meet their phosphorus requirement (Vanderzaag *et al.*, 1980). Sanders and Tinker (1973) observed that in most Nigerian soils, *D. rotundata* roots are heavily infested with mycorrhizal; hence utilize P efficiency at low levels

Tab. 6. Effects of different levels of NPK 15:15:15 fertilizer on the crude protein content of dried tuber of *D. rotundata* at final harvest

Nutrient applied	Crude protein content (%)		
(kg ha-1)	2005	2006	Combined
0	3.44	4.13	3.78
100	4.06	4.56	4.31
200	4.56	4.94	4.75
300	5.17	5.63	5.40
400	5.19	5.58	5.36
Mean	4.49	5.03	4.76
LSD (P<0.05)	0.375	1.156	0.794

Tab. 5. Effects of different levels of NPK 15:15:15 fertilizer on N, P and K content and nutrient removal of yam tubers of *D. rotundata* at 16 WAP at final harvest

Nutrient applied	Nutrient content of tubers (g kg^{-1})			Nutrient removal (kg ha-1 dry matter basis)		
(kg ha-1)	N	P	K	N	P	K
2005 cropping						
0	0.55	0.02	0.55	20.50	2.70	20.89
100	0.65	0.03	0.67	37.80	2.56	39.34
200	0.73	0.03	0.73	44.80	1.77	45.21
300	0.80	0.05	0.80	51.70	3.08	52.03
400	0.83	0.04	0.84	35.40	1.83	35.26
Mean	0.71	0.03	0.72	38.00	2.37	38.50
LSD (P<0.05)	0.035	ns	0.078	12.100	ns	11.240
2006 cropping						
0	0.66	0.02	0.42	22.80	0.65	14.56
100	0.73	0.02	0.46	44.00	1.19	27.87
200	0.79	0.02	0.55	51.00	1.31	35.44
300	0.90	0.03	0.60	66.40	2.25	43.44
400	0.94	0.02	0.63	48.80	1.08	32.64
Mean	0.80	0.02	0.53	46.60	1.30	30.80
LSD (P<0.05)	0.185	ns	0.081	18.97	1.227	8.71
Combined						
0	0.61	0.02	0.49	21.60	1.68	17.70
100	0.69	0.03	0.57	40.90	1.88	33.60
200	0.76	0.03	0.64	47.90	1.54	40.30
300	0.85	0.04	0.70	59.10	2.67	47.70
400	0.89	0.03	0.74	42.10	1.46	33.90
Mean	0.76	0.03	0.63	43.30	1.84	34.70
LSD (P<0.05)	0.123	0.018	0.074	14.21	ns	10.540

ns-not significant

of P because of this mycorrhizal association. The general increased tuber N assisted with high NPK application rate had promoted crude protein of yams which had resulted in improved nutritional quality.

Total nutrient uptake

The nutrient uptake increased significantly with increasing level of NPK. The combined analysis showed that, the NPK application level of 300 kg ha^{-1} had the highest uptake of 59.10 kg ha^{-1} N, 2.67 kg ha^{-1} P and 47.7 kg ha^{-1}, while 0 kg NPK ha^{-1} had the lowest nutrient uptake of 21.60 kg N, 1.68 kg P and 17.70 kg ha^{-1} (Tab. 5).

Nutrient uptake by yam could be used as a guide for determining nutrient needs of the crop and giving meaningful interpretation of field trials and soil analysis. Nutrient removal from the soil was found to be depending on soil nutrient status with or without fertilizer application and yield (dry matter accumulation) level. The significant correlation of nutrient content of leaves and tubers at the two sampling periods with the applied NPK rates is an indication that the soil nutrient status exerts significant effect on it as expected. At higher dry matter accumulation level, more nutrients were removed from the soil than at lower dry matter accumulation levels.

Crude protein content (%)

The crude protein content of tubers was significantly increased by NPK fertilizer application (Tab. 6). The crude protein contents showed a ranged of 3.78 and 5.53% on combined analysis. The lowest crude protein content was with 0 kg ha^{-1} (3.78%) and the highest was 400 kg ha^{-1-} (5.53%).

Conclusions

The results showed that yams respond positively to NPK fertilizer application. Application of 300 kg NPK ha-1 was found to be optimum rate for yam production since it produce the highest yield, nutrient content, nutrient uptake and crude protein.

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