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Fertilizer Treatment Effects on Yam (*Dioscorea* species) Tuber Yield in Two Soil Types of Nigeria

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Abstract: Fertilization is crucial to crop productivity sustenance under continuous land-use, but crop response could vary widely in different agro-ecologies. Effectiveness of sole and combined organic fertilizer- O.F, 0.6% N; crystallizer- 8.83% P; muriate of potash- MOP- 49.8% K; triple superphosphate- TSP- 19.22% P and urea- 45% N (replicated thrice in randomized complete block design) for yam (*Dioscorea rotundata* i.e., TDr-99-6 and *Dioscorea alata* i.e., TDa-98/01176) performance were evaluated on *Typic paleudalf* (at Ibadan, Rainforest) and *Arsenic haplustalf* (at Abuja, Guinea Savanna) in Nigeria. Short-term and residual-effect differences in TDr-99-6 tuber yields were insignificant ($p<0.05$) while highest TDa-98/01176 yield (40.21 t ha^{-1}) was obtained with urea at Ibadan. Residual effects of O.F+TSP enabled TDa-98/01176 to produce the highest yield (27.97 t ha^{-1}) at Abuja. TDa-98/01176 out-yielded TDr-99-6 but with dry-matter contents being more dependent on fertilizer treatment. The hypothesis that O.F effects could improve with increased application rates needs to be tested.

Key words: Fertilizer treatment, *D. rotundata*, *D. alata*, dry matter content, tuber yield

INTRODUCTION

Fertile soils and well-distributed rainfall are crucial for high crop performance; hence the wide variations in crop productivity in different agro-ecological zones of the world. Traditionally, farmers produce yams (*Dioscorea species*) on fertile soils after long periods of fallows because of the crop's high nutrient demand. However, increased pressure on land (caused by natural catastrophes, the ever increasing human population and the use of agricultural lands for housing, roads, industry and other human activities) has drastically reduced the fallow period, resulting in the decline of fertility of soils and the loss of their ability to support the required biodiversity (Ojating, 1997). Farmers in most of the developing countries continue to crop such infertile lands that do not guarantee sustainable production without external inputs, particularly the use of external sources of nutrient elements to improve crop yield.

Obigbesan (1983) and IITA/NCNRI (1999) summarized several field experiments on the nutritional requirements of yam in different agro-ecological zones of Nigeria. In most of the reviewed research efforts, recommendations have been based on inorganic fertilization. Kayode (1985) reported that nitrogen (N) at 35 kg ha^{-1} was optimum for successful production of white yam in a forest Alfisol that had been cultivated for two years. However, Amon and Adetunji (1970) recommended N rates of 25 to 56 kg ha^{-1} (with or without 56 kg ha^{-1} of K) for the Alfisols of southwestern Nigeria. The contribution of residual fertilizer-N to the N assimilation of subsequent cotton crops is of no agronomic importance because much of the original fertilizer ^{15}N was stabilized into more recalcitrant soil N fractions (Fritschi *et al*., 2005). Gutser *et al*. (2005) reported that N from organic fertilizers often shows little effect on crop growth in the year of application. The agronomic effectiveness of residual P from both rock phosphate and super-phosphate fertilizers could also show a similar decline as a result of cultivation (Bolland and Gilkes, 1990). In most developing countries, inorganic fertilizer materials are not readily available when needed by the grower. Rising costs (arising from removal of subsidy by the various governments) particularly made them unaffordable by resource poor, small-scale farmers. These problems demand that research should be targeted at sourcing alternative fertilizer materials that are cheap and that could readily be made available.

The research being reported here was aimed at investigating the short-term and long-term (residual) effects of various fertilizer treatments, including an Organic Fertilizer (OF) made from market waste and a Rock Phosphate (RP) based fertilizer (crystallizer = Sokoto RP + talc) on the performance of two species of yam (*D. alata* and *D. rotundata*) in two locations within Nigeria.

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MATERIALS AND METHODS

The first field experiments were established in Ibadan (Rainforest zone) and Abuja (Guinea Savannah zone) at the onset of the 2003 rainy season (April and June, respectively). The Ibadan location soil is *Typic paleudalf* while Abuja location soil is *Arsenic haplustalf* (Soil Survey Staff, 2003). Yam setts were planted on ridges and soil samples were randomly taken at the experimental sites for the determination of their physico-chemical properties (Table 1).

The experiments involved a split plot arrangement in randomized complete block design (RCBD) with two species of yam (*Dioscorea rotundata*, var. TDr 99-6 and *Dioscorea alata*, var. TDa 98/01176) as main plot and thirteen fertilizer treatment combinations (T1, T2, T3, … T13) as sub plots. The treatments were replicated three times. The plot size was 6 m by 6 m (36 m^2) while plant spacing was 1 m by 1 m.

The fertilizer materials tested were: Organic fertilizer, OF (0.6% N, 0.1% P and 1.13% K); Crystallizer (8.83% P and 0.08% K); muriate of potash, MOP (49.8%K); triple super phosphate, TSP (19.22%P) and urea (45% N). They were applied at the rate of 2 tonnes, 21.85 kg P, 41.5 kg K, 21.85 kg P and 70 kg N per hectare, respectively. The application rates have been based on the recommendations of the Fertilizer Procurement and Distribution Division, FPDD of the Federal Ministry of Agriculture, Water Resources and Rural Development, Lagos, Nigeria (1999) for different soil fertility classes and yam productions in Nigeria.

The fertilizer treatment combinations were: T1 = control, T2 = O.F, T3 = TSP, T4 = Crystallizer, T5 = MOP, T6 = urea, T7 = O.F + TSP, T8 = O.F + crystallizer, T9 = O.F + MOP, T10 =O.F + TSP + MOP, T11 = O.F + crystallizer + MOP, T12 = urea + TSP + MOP and T13 = urea + crystallizer + MOP. They were applied six Weeks After Planting (WAP) by side band application method, ensuring even distribution along the groove and placed 15 cm away from the base of the vine and about 3 cm deep. The grooves were covered immediately after application.

Tubers were harvested in December of the planting season and yields were estimated per plot and subsequently per hectare. The dry matter contents of the tubers were determined after oven drying at 100°C for 24 h.

The second cropping at each of the two locations was carried out in 2004 to study the residual effects of the fertilizer combinations on the yield of yam. Yam setts were again planted in May and June in Ibadan and Abuja, respectively. The field layout and planting ensured that the main plot (*Dioscorea sp*) and sub-plots (fertilizer combinations) were maintained as they were in the first cropping. Agronomic practices were also conducted as described in the first cropping.

Data were subjected to analysis of variance (ANOVA) and in separating the means multiple comparisons were performed across treatments using Duncan's Multiple Range Tests (DMRT).

RESULTS AND DISCUSSION

Pre-cropping soil fertility status: Table 1 shows the chemical properties of O.F as well as the physical and chemical properties of the soils in the two experimental locations. Potassium (K) was sufficient for yam growth and development in the two locations. In Ibadan location soil (slightly acidic, pH 6.5) the inherent organic carbon content (15.2 g kg^{-1}) was sufficient while total N and available P contents were marginal in the soil. In Abuja location soil (with medium acidity, pH 5.2) total N, available P and organic C contents were low.

First cropping: The immediate or short-term effect of the fertilizer treatments was not significant ($p<0.05$) on tuber yield of *D. rotundata* at the two locations and *D. alata* at Abuja (Table 2). However, significant differences in the yields were obtained in respect of *D. alata* in Ibadan location where TSP treatment resulted in lowest yield of 22.30 t ha^{-1} and urea gave the highest (40.21 t ha^{-1}). These values are quite high when compared with the mean yield of 23.11 t ha^{-1} for *D. rotundata* with combined application of urea, TSP and MOP at Ibadan. The highest tuber yields of the two yam species were recorded at Abuja with the application of P based fertilizer treatment combinations. This is most likely due to the deficiency of the element in the Abuja experimental soil. It is also an indication that P may limit the yield of the crop in the southern guinea savannah agro-ecological zone of the country. The insignificance of the differences in the yields obtained from the different fertilizer treatment

Table 1: The physical and chemical properties of the soils used and the chemical compositions of the Organic Fertilizer (OF)

Parameter	Experimental location: Ibadan	Experimental location: Abuja	Organic fertilizer
pH (in H_2O)	6.5	5.2	-
Organic C (g kg^{-1})	15.2	6.3	-
Nitrogen (g k^{-1})	0.17	0.8	5.97
Phosphorus (mg kg^{-1})	15.7	13.88	973.8
Potassium (cmol kg^{-1})	0.49	0.29	0.49
Calcium (cmol kg^{-1})	12.77	2.08	13.74
Magnesium (cmol kg^{-1})	3.57	0.41	3.26
Sand (g kg^{-1})	745.0	780.0	-
Clay (g kg^{-1})	150.0	120.0	-
Silt (g kg^{-1})	150.0	120.0	-

Table 2: Effects of fertilizer treatments on tuber yields of *D. rotundata* and *D. alata* grown in Ibadan (Rainforest agro-ecological zone) and Abuja (Guinea Savanna agro-ecological zone)

	Tuber yield (t ha^{-1})			
	D. rotundata		*D. alata*	
Treatments	Ibadan	Abuja	Ibadan	Abuja
Control	21.68	18.32	34.53ab	23.65
OF	20.78	17.05	37.03a	22.06
TSP	22.24	17.21	22.3b	24.75
Crystalizer	17.41	20.57	34.51ab	23.58
MOP	19.14	20.97	29.00ab	20.27
Urea	18.90	19.87	40.21a	22.97
OF+TSP	20.20	22.55	33.26ab	24.71
OF+crystalizer	15.42	18.48	33.56ab	26.17
OF+MOP	18.49	17.65	33.56ab	26.52
OF+TSP+MOP	16.55	17.65	35.86ab	26.67
OF+crystalizer+MOP	19.82	21.09	31.39ab	21.47
Urea+TSP+MOP	23.11	19.54	35.96ab	30.27
Urea+crystalizer+MOP	21.06	20.41	30.52ab	25.93
	NS	NS		NS

Means followed by the same letter(s) within a column are not significantly different at p = 0.05 by the Duncan Multiple Range Test (DMRT), NS = Not Significant OF = Organic Fertilizer; TSP = Triple Super Phosphate, MOP = Muriate Of Potash

Table 3: Residual effects of fertilizer combinations on the yield of *D. rotundata* and *D. alata* grown in Ibadan and Abuja

	Tuber yield (t ha^{-1})			
	D. rotundata		*D. alata*	
Treatments	Ibadan	Abuja	Ibadan	Abuja
Control	7.05	8.47	9.96	19.01ab
OF	8.69	15.04	9.17	20.63ab
TSP	10.02	17.65	12.33	22.77ab
Crystalizer	7.32	11.00	12.49	23.38ab
MOP	8.29	11.72	10.47	21.73ab
Urea	6.39	11.26	8.32	18.22b
OF+TSP	6.59	12.59	14.74	27.97a
OF+crystalizer	9.44	11.71	14.52	22.27ab
OF+MOP	7.65	14.78	15.09	27.83a
OF+TSP+MOP	8.65	10.28	14.01	21.30ab
OF+crystalizer+MOP	7.26	10.63	14.19	25.42ab
Urea+TSP+MOP	8.82	12.62	14.74	22.44ab
Urea+crystalizer+MOP	8.79	10.68	14.31	23.47ab
	NS	NS	NS	

Means followed by the same letter(s) within a column are not significantly different at p = 0.05 Duncan Multiple Range Test (DMRT), OF = Organic Fertilizer, TSP = Triple Super Phosphate, MOP = Muriate Of Potash NS = Not Significant

combinations could be associated with the fact that N and K were at sufficiency levels in Ibadan location soil and K was also adequate in Abuja location soil. Obigbesan *et al.* (1977) noted that N and K are the most critical nutrient elements for maximum production of yams.

Second cropping: The residual effects of the fertilizer treatment combinations on the performance of the crop in the two experimental locations (Ibadan and Abuja) were expressed in the second cropping (Table 3). For both species, tuber yields were quite low compared with those obtained in the preceding cropping.

Table 4: Effects of fertilizer combinations on tuber dry matter contents of *D. rotundata* and *D. alata* grown in Ibadan and Abuja

	Tuber dry matter content (%)			
	D. rotundata		*D. alata*	
Treatments	Ibadan	Abuja	Ibadan	Abuja
Control	41.47	44.55	29.97bc	28.08ab
OF	43.80	44.29	29.16c	37.12a
TSP	44.56	43.57	33.38ab	37.08a
Crystalizer	43.64	45.54	31.29abc	37.34a
MOP	41.99	44.59	30.83bc	36.55a
Urea	43.84	47.34	31.26a-c	38.84a
OF+TSP	43.03	45.01	29.69bc	33.55ab
OF+crystalizer	44.86	44.37	27.47c	36.34a
OF+MOP	43.77	42.93	34.57a	26.97ab
OF+TSP+MOP	42.30	46.52	29.95c	33.74ab
OF+crystalizer+MOP	42.94	44.50	29.50c	21.59b
Urea+TSP+MOP	40.00	44.02	31.18a-c	36.71a
Urea+crystalizer+MOP	42.43	38.97	30.73bc	29.44ab
	NS	NS		

Means followed by the same letter(s) within a column are not significantly different at P = 0.05 Duncan Multiple Range Test (DMRT), NS = Not Significant, OF = Pace setter Organic Fertilizer, TSP = Triple Super Phosphate, MOP = Muriate Of Potash

Somé *et al.* (1995) observed similar trend in response to fertilizer application in Burkina Faso in spite of better rainfall in the second year. In Ibadan, the lowest yields (means of 6.39 t ha^{-1} for *D. rotundata* and *D. alata* respectively) were obtained from urea treatment plots suggesting that the N contained in the fertilizer had been exhausted in the first cropping. This is not surprising considering the nature of the inorganic fertilizer. It is a known fact that soil and fertilizer N in excess of crop removal suffer leaching or erosion losses in the humid tropics.

The relatively high *D. rotundata* yields (10.02 and 17.65 t ha^{-1} at Ibadan and Abuja, respectively) on sole TSP treatment plots could be attributed to the availability of P not utilized in the first year. Singaram and Kothandaraman (1992) observed that super phosphate fertilizer had superior residual effect on crop yield relative to rock phosphate in the second cropping. However, the highest yield (15.09 t ha^{-1}) was obtained for *D. alata* with the residual fertilizer treatment effect of OF + MOP in Ibadan while the yield of 27.97 t ha^{-1} was obtained with the combination of OF +TSP at Abuja (Table 4). The yam species are most likely to respond differently to the same fertilizer amendments in a similar environment.

In the first cropping, the dry matter content of the tuber did not differ significantly regardless of fertilizer treatments in *D. rotundata* at the two locations (Table 4). The lack of response could be attributed to the sufficient inherent N and K in the two experimental sites. This agrees with the findings of Ricardo and Heber (1994) that fertilizer treatments did not affect tuber dry matter because the soil nutrient status was adequate to support optimum

Table 5: Residual effects of fertilizer combinations on dry matter content of *D. rotundata* and *D. alata* grown in Ibadan and Abuja

	Tuber dry matter content (%)			
	D. rotundata		*D. alata*	
Treatments	Ibadan	Abuja	Ibadan	Abuja
Control	37.58a	37.72b	29.94ab	30.08
OF	37.20a	37.29b	28.87ab	32.45
TSP	37.40a	38.21b	28.63ab	29.48
Crystallizer	36.27a	37.11b	30.35ab	29.57
MOP	35.26ab	37.27b	27.01ab	31.93
Urea	36.75a	39.31ab	29.48ab	33.27
OF+TSP	35.66ab	42.18a	29.80ab	31.00
OF+crystallizer	36.56a	36.31b	26.97ab	33.43
OF+MOP	35.27ab	39.10ab	28.78ab	34.25
OF+TSP+MOP	35.85ab	36.45b	28.95ab	31.91
OF+crystalizer+MOP	37.00a	36.29b	29.66ab	32.90
Urea+TSP+MOP	36.25a	40.69ab	32.03a	31.01
Urea+crystallizer+MOP	31.54	40.24ab	25.61b	32.76 NS

Means followed by the same letter(s) within a column are not significantly different at p = 0.05 Duncan Multiple Range Test (DMRT), POF = Pace setter Organic Fertilizer, TSP = Triple Super Phosphate, MOP = Muriate Of Potash, NS = Not Significant

yield of yam. However, in *D. alata*, there were significant variations with the highest mean dry matter accumulation of 34.57 and 38.84% in Ibadan and Abuja respectively. In the second cropping, the tuber dry matter was not significantly different in Ibadan location but varied significantly in Abuja where the dry matter content of the tubers produced with the combination of urea + crystallizer + MOP was significantly lower than those produced with the other fertilizer treatments. In *D. alata*, significant variations were recorded in the two locations with the highest values of 42.18% with the combination of O.F + TSP in Ibadan and the highest dry matter of 32.03 percent when urea + TSP + MOP were previously applied (Table 5). The response of *D. alata* to residual fertilizer could be associated with the genetic ability of the species to effectively utilize the nutrients in the soil because of the mass root developed for nutrient uptake. This was contrary to the findings of Héber *et al.* (1995) where dry matter was not significantly affected by fertilizer treatments regardless of the cropping season.

CONCLUSIONS

In most cases (particularly as regards *D. rotundata*), there was no clear or significant difference in the tuber yields and dry matter contents that could be attributed to the fertilizer treatments. However, the highest mean yields differ with respect to location, confirming that the critical nutrient requirement for the crop is location specific. The response of yam to P fertilizer particularly suggests that the nutrient element could limit the yield of yams when deficient in the soil to disqualify the previous report (Obigbesan, 1983) that P is not critical for yam production. Future studies could also target the determination of the crop's optimum nutrient requirement (using locally sourced materials) in the various agro-ecological zones where yams are popularly produced.

The organic fertilizer nutrient amounts (12 kg N, 2 kg P and 3.8 kg K ha^{-1}) supplied through the application of 2 t ha^{-1} were quite low, representing just 17, 9 and 7.6% of the various amounts supplied by the inorganic N, P and K fertilizers. Future works should, therefore, test the hypothesis that organic and organo-mineral fertilizer influences on the performance of yams could improve with organic fertilizer application rates that are higher than the conservative 2 t ha^{-1} recommended by FPDD (1999). It would also be worthy to evaluate how the various fertilizer treatments could affect the economics of production of the crop. This is to ascertain if the insignificant yield increases could translate into significant benefit: cost ratio.

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