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COMPARISON OF YIELD PERFORMANCE AND PROFITABILITY OF *Dioscorea rotundata* UNDER DIFFERENT NPK FERTILIZER REGIME IN HUMID FOREST ULTISOLS

[COMPARACIÓN DE LA PRODUCTIVIDAD Y RENTABILIDAD DE *Dioscorea rotundata* BAJO DIFENTES ESQUEMAS DE FERTILIZACIÓN NPK EN ULTISOLES DE SELVA HÚMEDA]

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SUMMARY

Studies were conducted to determine the appropriate level of NPK 15:15:15 fertilizer application that will produce the most profitable yield in a humid forest ultisol. This study involved the use of *Dioscorea rotundata* Poir fertilized with NPK (15:15:15) at rates of 0 (0 kg N + 0 kg P + 0 kg K), 100 (15 kg + 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 kg ha^{-1} (60 kg N + 27.16 kg P + 49.80kg K) using a randomized complete block design. Results from the trial showed that leaf area index values ranged from 1.24 to 2.88 at 16 weeks after planting (WAP) and 2.20 to 3.10 at 24 WAP respectively for the unfertilized and 400 kg NPK ha^{-1}. The corresponding values for dry matter accumulation were 1.29 to 3.70 t ha^{-1} and 2.97 to 5.67 t ha^{-1} at 16 and 24 WAP respectively. These parameters were responsible for higher tuber yield and relative yields for plants fertilized. The greatest yield (19.16 tonnes hectare) was produced from plots treated with 300kg ha^{-1} fertilizer. The production cost increased from ₦ 390440.00 – ₦ 417920.00, revenue from ₦ 1036000 – ₦ 1155000.00, gross margin from ₦ 680000.00 – ₦ 773200.00, net income from ₦ 645560.00 – ₦ 732080.00 and benefit-cost ratio from 1.65 – 3.73 as fertilizer application rate increased from zero to 400 t/ha. The optimum fertilizer application rate was 200kg ha^{-1} based on the fact that it had the greatest gross margin (₦ 1547600.00), net income (₦ 1507720.00) and benefit-cost ratio (3.73).

Key words: Benefit-cost ratio; *Dioscorea rotundata;* economic analysis; crop performance; leaf area index.

RESUMEN

Se condujeron estudios para determinar el nivel apropiado de fertilización con NPK y que resulte en la mejor rentabilidad en un ultisol de selva húmeda. Se empleo *Dioscorea rotundata* Poir fertilizada con NPK (15:15:15) a tasas de 0 (0 kg N + 0 kg P + 0 kg K), 100 (15 kg + 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) y 400 kg ha^{-1} (60 kg N + 27.16 kg P + 49.80kg K) empleando un diseño de bloques al azar. Los resultados mostraron que el índice de area foliar varió de 1.24 - 2.88 en la semana 16 (WAP) a 2.2 – 3.1 en la semana 24 para los tratamientos 0 y 400 kg NPK respectivamente. Los valores correspondientes de acumulación de materia seca fueron 1.29-3.70 t ha^{-1} y 2.97 – 5.67 t ha^{-1} en las semanas 16 y 24 respectivamente. Estos parametros se relacionaron con la mayor producción de tuberculos y rendimientos relativos de las plantas fertilizadas. La mayor productividad (19.16 t ha^{-1}) se obtuvo en las parcelas con 300kg ha^{-1} fertilizante. Los costos de producción se incrementaron de ₦ 390440.00 a ₦ 417920.00, la rentabilidad de ₦ 1036000 – ₦ 1155000.00, margén bruto de ₦ 680000.00 a ₦ 773200.00, ingreso neto de ₦ 645560.00 a ₦ 732080.00 y la razón costo beneficio de 1.65 a 3.73 al incrementar la fertilización de 0 a 400 t ha^{1}. La tasa optima de fertilización fue 200kg ha^{-1} tomando como criterio el mayor margen bruto (₦ 1547600.00), ingreso neto (₦ 1507720.00) y razón costo beneficioand benefit-cost ratio (3.73).

Palabras clave: razón costo beneficio; análisis económico; productividad de cultivos; índice de área foliar; *Dioscorea rotundata.*

INTRODUCTION

Nigeria is the world leading producer of edible yam both in terms of surface (1.5 million hectares) and production (18.3 million tons) (FAO, 2007). According to the same report, yam production in Nigeria has more than tripled over the past 45 years, from 6.7 million tons in 1961 to 39.5 million tons in

2006. This increase in output is more attributed to large area planted than to productivity increment.
Average yield per hectare has been drastically dropped from 14.9% in 1980 – 1990 to 2.5% in 1996 – 99 (Amegbeto *et al.* 2002). The decline in productivity is due to low native soil fertility resulted from the practice of slash and burn farming system associated with bush fallow and with excessive leaching of the soil. The system is presently unsustainable due to high population pressure and other human activities which have resulted in reduced fallow period (Steiner, 1991).

The problem of low productivity associated with intensive cropping practices has forced farmers and researchers to the use of soil inorganic nutrients (Okwuowulu, 1995). Inorganic fertilizers exert strong influence on plant growth, development and yield (Stefano *et al.* 2001). The availability of sufficient growth nutrients from inorganic fertilizers leads to improved cell activities, enhanced cell multiplication and enlargement (Fashina *et al.* 2002). Excess vegetative growth associated with fertilizer application results in increased leaf area index (LAI) which can lead to larger dry matter production (Obi *et al.* 2005) and better bulking ability owing to better utilization of solar radiation and more nutrients (Okwuowulu, 1995).

Profitable crop production depends on adequate but not excessive supply of essential nutrients (Al-Bakeir, 2003). Nutrient supply above the optimum rate has resulted in more vegetative growth at the expense of tuberization (Law-Ogbomo and Remison, 2007). Adediran and Banjoko (2003) observed that there was substantial depletion of nutrients with the least yield when no NPK fertilizer was applied and that nitrates and available phosphorus were substantially reduced with cropping in humid zones of Southern Nigeria.

Contradictory results about the positive and negative effects of fertilizer have been found in literatures. Ayoola and Adeniyan (2006) reported that fertilizers were not been helpful under intensive agriculture because it is often associated with reduced yield, soil acidity and nutrient imbalance. This could be likely due to differences in pre-cropping nutrient status

For the mentioned inconsistencies in the fertilizer usage and the increasing cost of production associated with such fertilizers, field trials were conducted to determine the appropriate NPK 15:15:15 fertilizer level for optimum tuber yield in the humid forest ultisols.

MATERIAL AND METHODS

This study was conducted in 2004 and 2005 at Evboneka located in Edo State, Nigeria. Located at 5^o 04′ longitude and 5^o45′ latitude. The area is a typical humid rain forest environment with loam sand with low nutrient reserve and derived from coastal plain sand classified as ultisols. The experimental soil had been cultivated in previous years; with no record of fertilizer application. One composite soil sample (0-30cm depth) was taken from the site and analysed for routine soil physical and chemical properties using standard laboratory procedures (Mylavapus and Kennelley, 2002). Weather data during the trial period were obtained from the Nigerian Institute for Oil Palm Research (NIFOR), Benin City. Rainfall was 1262 mm, sunshine 1494 hours and solar radiation 4354 annually for the two cropping seasons. Daily averages were relative humidity 82.3 %, minimum and maximum temperature of 21.8 °C and 32.3 °C respectively.

A randomized complete block design with three blocks was utilized at each year of the trial. Each block comprised five plots, each of which measured 7 x 6 m. The treatment consisted of five fertilizer levels viz. 0 (0 kg N + 0 kg P + 0 kg K), 100 (15 kg + 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 + 49.80kg K) kg\ha of NPK 15:15:15 compound fertilizer.

The land was cleared of existing vegetation and ridges constructed using hoes after the site has been deep ploughed with a tractor drawn disc plough. *D. rotundata* cv "Obiaoturugo" (average of 250 g sett) were planted each year at a spacing of 100 cm within row to give a population of 10000 plants per hectare. Planting was done on 24^{th} of April in each of the two years. The plots were weeded when necessary. Basal application of fertilizer was done at six weeks after planting (WAP).

Measured variables include number of leaves, leaf area and total dry matter at 16 and 24 (WAP). Leaf discs were punched out with a cock borer and relationship between area and dry weight of the disc was used to determine leaf area (Agboola, 1997). Total dry weight was determined at 16 and 24 WAP using ISTA (1993) procedures. The growth attributes computed from leaf area and total dry weight were leaf area index and harvest index. All growth parameters were computed using Remison (1997) procedures.

The yams were harvested at 33 WAP when all the leaves and vines had withered and there was no more vegetative growth. Twelve yam stands in each plot were harvested and data collected on number of tubers per stand, tuber yield per stand, tuber yield per hectare (ha^{-1}) and relative yield.
Year-wise data were analysed using analysis of variance, followed by combined analysis over the two year in GENSTAT version 8.1 (GENSTAT, 2005). Means were compared using Tukey's test (0.05). Linear correlation linking variables were also computed in GENSTAT.

The profitability of tuber yield produced from the different fertilizer rate was estimated as outlined by Erhabor (2005).

RESULTS AND DISCUSSION

Physiochemical Properties of Soil

The soil routine showed the next characteristics pH (in H_2O) 5.20; organic carbon (g kg^{-1}) 1.62; total nitrogen (%) 0.18; available phosphorus (mg kg^{-1}) 7.30; exchangeable Mg (cmol kg^{-1}) 0.60; exchangeable K (cmol kg^{-1}) 0.40; exchangeable Ca (cmol kg^{-1}) 7.80; clay (%) 11.00; silt (%) 11.00 and sand (%) 78.00. The soil is texturally loamy sand and acidic. It has low native soil fertility since it contain less than the critical levels of nutrients (Ibude *et al*. 1988).

Growth Parameters

Plants fertilized with 400 kg NPK\ha had the highest number of leaves in both sampling periods in both years which were 74% and 103% increase over the unfertilized plants at 16 and 24 WAP, respectively (Table 1). These findings agree with the view of Stefano *et al* (2001) who reported that fertilizer application resulted in excessive leaves.

There was significant difference among treatment in LAI at the two sampling periods (Table 1). Plants fertilized with 400 kg NPK ha^{-1} had the greatest LAI at samplings. The unfertilized plants had lower LAI due to less number of leaves resulting from premature leaf fall and early vine senescence (Okwuowulu, 1995). The higher LAI associated with the fertilized plants was probably due to higher number of leaves, leaf area and leaf area duration. It signifies greater leaf production rates, leaf area expression and leaf area duration (Law-Ogbomo and Remison, 2007).

The total dry weight (TDW) increased the fertilizer rate increased with correlation coefficient of 0.60 at 16 WAP in both years. Plants fertilizer with 200kg ha^{-1} at 16 WAP had the greatest TDW which was 70 % higher than the unfertilized plants. This pattern of distribution was maintained at 24 WAP. However, plants fertilized with 300 kg NPK ha^{-1} had the greatest TDW at 24 WAP (Table 1) which value is 101% greater than the unfertilized plants. These findings are in accordance with previous reports of Obi *et al* (2005) who reported increase in dry matter production with increasing NPK fertilizer rates. Increased number of leaves lead to a greater dry matter accumulation per unit of land area, because of better utilization of solar radiation and more nutrient utilization (Okwuowulu, 1995).

HI values varied from 0.14 to 0.60 at 16 WAP and 0.58 to 0.81 at 24 WAP (Table 1). The unfertilized plant had the least and the highest were plants fertilized with 200 kg NPK ha^{-1} at 16 WAP. The 200 kg NPK ha^{-1} fertilized plants had 429% HI higher than that of the unfertilized plants. At 24 WAP, the 300 kg NPK fertilized plants had the highest HI, which was 40% higher than the unfertilized plants. HI was significantly correlated with fertilizer rate at 16 and 24 WAP with correlation coefficient of 0.63 and 0.50, respectively. The positive correlation of HI with fertilizer rate at both sampling periods is an indication of enhanced efficiency of translocation of assimilates to tuber leading in higher HI as a result of increasing fertilizer rate. This is also indicated the intensification of the bulking ability of the plant as NPK fertilizer application increased up to 300 kg ha^{-1} (Okwuowulu, 1995).

Table 1: Growth attributes of *D. rotundata* as affected by different levels of NPK 15:15:15 fertilizer at humid forest ultisols.

NPK	16 WAP				24 WAP			
(kg ha^{-1})	No. of leaves	LAI	TDW (t ha^{-1})	HI	No. of leaves	LAI	TDW (t ha^{-1})	HI
0	315^{d}	1.74^{c}	2.20^{c}	0.14^{c}	226^{c}	2.48^{c}	2.97^{c}	0.58^{b}
100	362^{cd}	2.15^{bc}	2.72^{b}	0.15^{c}	288^{bc}	2.78^{bc}	4.27^{b}	0.70^{ab}
200	432^{bc}	2.30^{b}	3.75^{a}	0.60^{a}	339^{b}	3.00^{ab}	5.89^{a}	0.78^{a}
300	488^{b}	2.45^{ab}	3.10^{a}	0.51^{a}	358^{ab}	3.36^{a}	5.97^{a}	0.81^{a}
400	548^{a}	2.88^{a}	3.01^{a}	0.42^{b}	458^{a}	3.41^{a}	5.67^{a}	0.70
Mean	429	2.30	2.94	0.32	329	3.01	4.89	0.71

Means with the same superscript do not differ significant at 5% level of probability.

Keys LAI- leaf area index, TDW- total dry weight, HI- harvest index, WAP - Weeks after planting

Tuber Yield

Tuber yield increased as the fertilizer rate increased up to 300 kg and then declined (Table 2). The 300kg NPK/ha fertilized plants had the highest tuber yield and outweighed the unfertilized plants by 85%. The significant increase in tuber yield of yam plants treated with fertilizer reflects the effect of fertilizer nutrients, N, P and K. The untreated plants had lower yield as they have to rely on the native soil fertility which, from the results of chemical analysis was deficient in these nutrients. In this study, the average yield varied from 10.36 to 19.16 t/ha between 0 and 300 kg/ha (Table 2). These findings are in lined with the report of Adediran and Banjoko (2003) and are contrary to the views of Ayoola and Adeniyan (2006) who reported that the use of inorganic fertilizer is associated with reduced crop yield. Based on pooled analysis between the two years, there was no significant difference on the yield. This may be attributed to favourable agro-climatic conditions particularly temperature, solar radiation and relative humidity which coincide with even rainfall distribution which prevailed in both cropping seasons.

Table 2: Yield attributes of *D. rotundata* as affected different levels of NPK 15:15:15 fertilizer at humid forest ultisols.

NPK ($kg\ ha^{-1}$)	Tuber yield		
	$kg\ plant^{-1}$	$t\ ha^{-1}$	Relative yield
0	1.04^{c}	10.36^{d}	1.00^{b}
100	1.77^{b}	17.72^{b}	1.71^{a}
200	1.91^{ab}	19.12^{a}	1.85^{a}
300	2.18^{a}	19.16^{a}	1.85^{a}
400	1.16^{c}	11.55^{cd}	1.11^{b}
Mean	1.61	18.37	1.50

Means with the same superscript do not differ significant at 5% level of probability.

The relative tuber yield (LER) ranged from 1.00 to 1.85. There were significant differences among treatment means. It followed similar trend as that of tuber yield. This revealed the fact that there is positive relationship between tuber yield improvement and economic variability in yam production (Okwuowulu, 1995). This position was later confirmed by Law-Ogbomo (2007) who reported that excessive supply of essential nutrient to plants lead to excessive vegetative growth at the expense of tuberization

Economic Analysis

The gross margin, net return and benefit: cost ratio was highly influenced by fertilizer application. In generally, total cost of production increased as the rate increased up to 400kg ha^{-1} (Table 3).The total cost of production varied from 390440.00 to 417920.00 Naira (₦), which is an indication of 7% difference between unfertilized plants and plants fertilized with 400kg NPK ha^{-1} (Table 3).

The accrued revenue ranged from ₦103600.00 to ₦1916000.00 which is an indication of 85% difference between unfertilized plants and plants fertilized with 300 kg NPK ha^{-1} (Table 3). In general, revenue increased as fertilizer application increased up to 300 kg ha^{-1}, but declined thereafter (e.g. 400 kg ha^{-1}). The gross margin and net return had the same trend as the revenue. The gross margin and net return increased up to 200kg NPK ha^{-1} and decline at 300 and 400kg NPK ha^{-1}. The highest gross margin and net income were obtained from 200 kg NPK treated plants which had ₦1547600.00 and ₦1507720.00, respectively.

Benefit-cost ratio is an indication of the returns per $ invested and was greater than 1.0 at all fertilizer rates. The optimum yield was produced with the application of 200kg ha^{-1} was greater than the untreated plants' benefit-cost ratio with 126%. These findings is in conformity with the views of Al-Bakeir (2003) who reported that profitable crop production depends on adequate but not excessive supply of essential nutrients.

This economic analysis has showed that despite high production cost associated with the application of NPK fertilizer in producing yams, yam production is reported to be profitable from this study. Significant increases in yield as a result of NPK 15:15:15 fertilizer application is likely to persuade resource-poor farmers to buy and use fertilizer on their yam farms as indicated by the high returns per $ invested. Farmers' complain about the deleterious effects of chemical fertilizer; these undesirable effects include burning the plants, rendering the tuber susceptible to rot during storage and unpalatability of the tubers produced with fertilizer application as well as high cost of fertilizer in Nigeria. These effects may be due to the fact that they conduct blanket application without the benefit of soil testing and regard for laid down recommendations.

CONCLUSION

The results showed that NPK fertilizer rates have profound effect on the overall performance of yam. The application of NPK fertilizer at different levels had significant effect on the growth and yield of white Guinea yam. Fertilizer application rate of 200 kg ha^{-1} (i.e 30 kg N + 13.58 kg P + 24.90 kg K ha^{-1}) is the most effective for the production of white Guinea yam in humid forest ultisols.

Table 3: Economic analysis of the effect of NPK 15:15:15 fertilizer application on the performance of *D. rotundata*.

Items	Fertilizer application rate (kg ha^{-1})				
	0	100	200	300	400
Output (t ha^{-1})	10.36	17.72	19.12	19.16	11.55
Revenue (N 100 kg^{-1})	103600.00	1772000.00	1912000.00	1916000.00	1155000.00
Total variable cost (N)	352000.00	358200.00	364400.00	370600.00	376800.00
Total fixed cost (N)	38440.00	39260.00	39880.00	40500.00	41120.00
Total cost (N)	390440.00	397460.00	404280.00	411100.00	417920.00
Gross margin (N)	684000.00	1414000.00	1547600.00	1545400.00	773200.00
Net return (N)	645560.00	1374740.00	1507720.00	1494900.00	732080.00
Benefit-cost ratio	1.65	3.46	3.72	3.64	1.75

Assumption for economic analysis: Exchange rate, N 118 = US $1 at the time of experiment

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