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Effect of Nitrogen Fertilizer Sources on the Quality and Mineral Nutrient Composition of Yam

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Abstract

Field experiments were carried out to evaluate the effects of nitrogen fertilizer sources on quality and mineral nutrient composition of white yam (*Dioscorea rotundata*).

Three rates of nitrogen, 0, 80 and 160 kg N/ha were applied in the forms of ammonium suphate (AS) calcium ammonium nitrate (CAN) and urea for two yam growing seasons. Soil acidity was increased with increasing application of AS followed by urea, whereas CAN application resulted in higher pH. The application of urea and CAN at 160 kg N/ha increased -N whereas AS decreased N,P and K in the leaves. A highly positive significant correlation was established between leaf -N and starch and glucose content of the yam tuber. In general, AS fertilization produced the highest fresh tuber yield, percent starch and glucose while CAN produced the lowest yield, percent starch and glucose.

Introduction

Yams are very important root crops in the tropical zone of the world. Coursey and Haynes (1970) reported that the production of root and tuber crops in the tropics is 140×10^6 tons per annum. About 50 percent of this is derived from cassava and around 12 percent from yams. These values, indicate that yams already make a sizeable contribution to the feeding of the tropical world.

Nutritionally, a good amount of crude protein and aminoacids has been obtained in yams (Martin, 1974). Litzenberzer (1974) working on the analysis of yam tuber observed values of 71% water, 3% protein, 23% carbohydrate and 1% ash, and concluded that the protein content on a dry weight basis of the tuber approached that of cereal grains. These findings contradict the popular belief that yams are inferior sources of dietary protein. It is therefore, probable that given proper agronomic management, the nutritional value of the yam crop can be greatly enhanced.

Like many other tropical root crops, yams are still cultivated largely by peasant farmers. Although some varieties of yam are capable of yielding up to 10 tons per hectare or more, under peasant farming conditions, yields are often low, averaging about one to three tons per hectare (Coursey, 1967).

Critical studies on the fertilization of yam are scanty. It is only of recent that information has become available concerning improved cultural practice and in particular the effects of fertilizer on yield. Farmers relied mostly on the inherent fertility of the soil (Coursey, 1967). Conflicting results about the benefits of fertilizers and manures have however been found in the literature (Coursey, 1967). This is to be expected due to lack of uniformity on a wide range of ecological conditions (especially soil types) under which yams are grown.

Since nitrogen is probably one of the major nutrients limiting crop production (Vine, 1953; Waitt, 1961, Sobulo, 1972) it can be inferred that the use of nitrogen fertilizer will increase drastically in the near future so as to enhance yam yield. This also suggests that consideration be given to the rate, time and method of application (Sobulo, 1972).

The yam crop undergoes various stages of growth before reaching maturity (Sobulo, 1972 a, b). Consequently, the distribution, advancement and accumulation of crude protein, starch, glucose and other mineral nutrient contents within the yam plant, varies in accordance with nutritional levels at various stages of growth.

This paper reports the results of a two-year field study of the yam crop (Dioscorea rotundata) aimed at assessing the yield, soil chemical composition, leaf and tuber mineral nutrient composition and percent starch and glucose contents of the white yam as influenced by the application of varying nitrogen fertilizer sources.

Materials and Methods

The experiment was sited at the University of Ife Research and Teaching Farm, Ile-Ife, Nigeria. The study site lies between longitude $4^{0}35$ 'E and latitude 8°N with an altitude of 800m above mean sea level (MSL).

White yams (*Dioscorea rotundata*) C.V. Olonko were grown for two consecutive growing seasons from February to October on ridges. Yam setts involving mixtures of heads, middles and tails were used for planting. Although the yams were planted in February of each year, sprouting was observed only in April/May when adequate soil moisture was attained. The soil was derived from volcanic ash, generally of coarse grained granites and gneisses and poor in feromagnesium (Smyth and Montgomery, 1962). The soil type is of the Iwo series (Oxic Hapludalf) of Western Nigeria. The Iwo series is generally known to have dark brownish grey to greyish brown coloration. It is made up of gravelly sandy clay loam, well drained, friable and porous to a depth of at least 1.52 meters. This allows for free passage of air and water and ease of root development. Annual precipitation is about 1500 mm. Furthermore, the presence of relatively unweathered minerals at moderate depths as revealed by detailed profile study (Smyth and Montgomery 1962) suggests an ample reservoir of nutrients for both shallow and deep rooted crops. This soil is suited geneally to yam cultivation (Adepetu and Corey, 1977; Obigbesan 1977; Aduayi and Okpon, 1980). The pretreatment chemical composition of the experimental site is shown in Table 1. The layout of the experiment was that of a randomized complete block design. Each block had an area of 36 by 15 meters. Each block was further sub-divided into 9 plots each measuring 15 by 4 meters with each plot consisting of 60 stands of yams. The experiment was replicated four times.

There were three nitrogen treatments viz: O, 80 and 160 kg N/ha applied as ammonium sulphate, calcium ammonium nitrate and urea. Application was by banding. Basal fertilizer treatments consisting of 100 kg/ha each of P_20_5 (as single superphosphate) and K_20 (as sulphate of potash) and 50 kg/ha of Mg as $MgSO_4$ were applied before planning. The various nitrogen treatments were applied once in the first week of May when the plants were in the early stages of vegetative growth.

Leaf sampling was done one month after fertilizer application when the plants were at their maximum vegetative growth stage. Leaves that were nearly mature were taken from middle canopy of staked vines (Aduayi and Okpon, 1980; Okpon, 1983).

Tuber harvesting was done in November of each planting season.

Leaf and tuber samples were carefully washed in a plastic basin to remove sand and other deposits in order to prevent surface elemental contamination. The washed leaves and yam tubers were first dried in an oven at 65°C — 70°C and then ground in a stainless steel mill to pass through a 40-mesh sieve. The ground samples were later redried at 105°C in order to eliminate accumulated moisture prior to chemical analysis. Total — N was determined colormetrically on a Technicon Autoanalyser; P by the Vanado-molybdate method; K and Na by flame photometry while Ca and Mg were determined by atomic absorption spectrophotometry. Starch and glucose were determined by the Anthrone colorimetric method.

Results

Soil Chemical Composition

Table 1 shows the effects of fertilizer treatment on soil chemical composition. Soil pH as measured in $CaCl_2$ varied in accordance with fertilizer treatments.

TABLE 1: CHEMICAL COMPOSITION OF SOILS PRIOR TO AND AFTER TREATMENT, WITH AMMONIUM SULPHATE, CALCIUM AMMONIUM NITRATE AND UREA

Elements	Pre-treatment value	Control	AS	CAN	UREA
pH (O.OIM $CaCl_2$)	6.00	5.40	5.15	5.90	5.24
OM (%)	4.95	2.96	1.43	1.52	1.52
Total N (%)	0.24	0.16	0.11	0.12	0.10
P (Bray — 1 ppm)	13.6	12.0	9.0	10.0	10.0
K (me/100g)	0.46	0.30	0.20	0.21	0.24
Ca(" ")	0.95	0.86	0.86	0.96	0.95
Mg(" ")	0.48	0.41	0.44	0.46	0.40
Na(" ")	0.09	0.06	0.05	0.04	0.06
Mn(" ")	7.5	7.0	7.0	7.0	7.0
Total Acidity (Al + H)	0.45	0.49	0.62	0.58	0.60
CEC (me/100 g)	6.63	4.63	4.46	4.58	4.56

The application of ammonium sulphate and urea resulted in lower pH of about 5% and 3% respectively relative to the control. Calcium ammonium nitrate application increased soil pH by 9%. Soil OM was considerably decreased in soils receiving fertilizer treatments than in the control. Similar trend was observed for total -N. There was tendency towards reduced soil — P under cultivated and fertilized soil conditions. The exchangeable cations analysed were not affected by treatments. However soil total acidity was lower in the unfertilized plot than in plots receiving various

TABLE 2: NUTRIENT COMPOSITION OF YAM LEAVES

Treatments (kg N/ha)	N	P	K %	Ca	Mg
0 (0)	3.45	0.46	1.06	1.46	0.89
AS_1(80)	3.36	0.52	1.26	1.34	0.85
AS_2(160)	3.28	0.48	1.21	1.34	0.92
CAN_1(80)	3.47	0.44	1.03	1.60	0.89
CAN_2(160)	3.72	0.45	1.18	1.30	0.82
$UREA_1$(80)	3.53	0.45	1.06	1.47	0.76
$UREA_2$(160)	3.83	0.40	1.04	1.28	0.91
C.V. (%)	6.81	19.32	21.82	4.57	21.51
LSD 5%	0.36	0.14	0.26	0.30	0.28

forms of N fertilizers. Soil CEC decreased slightly with fertilization and cultivation.

Leaf and Yam tuber Nutrient Composition

As shown in Table 2, leaf N, P and K varied in accordance with N — fertilizer applications. Leaf — N was significantly increased at the 160 kg N/ha rate of urea. There were slight but non-significant increases in leaf — N at the 160 kg N/ha as CAN whereas, decreases were observed for leaf — N at increasing rates of ammonium sulphate. Phosphorus concentration in the leaves was not markedly affected by N application. However, there was a tendency of higher levels of ammonium sulphate depressing P uptake. CAN had no effect on leaf — P whereas higher levels of urea tended to increase it. Ammonium sulphate application markedly increased leaf — K whereas other forms of N

TABLE 3: NUTRIENT COMPOSITION OF YAM FLOUR ANALYSED 2 WEEKS AFTER HARVEST

Treatments (Kg N/ha)	N	P	K % in dry matter	Ca	Mg
0. (0)	0,92	0.14	2.00	0.15	0.07
AS_1(80)	1.27	0.19	1.64	0.26	0.07
AS_2(160)	1.35	0.16	1.90	0.14	0.08
CAN_1(80	1.03	0.14	1.78	0.18	0.05
CAN_2(160)	0.62	0.14	1.78	0.20	0.06
$UREA_1$(80)	0.86	0.14	1.85	0.16	0.07
$UREA_2$(160)	1.32	0.15	0.65	0.21	0.06
C.V. (%)	0.65	4.18	0.35	2.07	7.96
L.S.D. @ 5%	0.02	0.02	0.02	0.01	0.01

had no appreciable effect. Nitrogen treatments did not seem to affect leaf — Ca and Mg.

Results of chemical analyses of yam flour are shown in Table 3. Ammonium suphate and urea at increasing rates significantly increased N — content of the yam whereas calcium ammonium nitrate at the highest rate significantly depressed N. Yam tuber — P and Mg were not significantly affected by N treatments, however, K was generally reduced when compared to the control. Ammonium suphate application at 80 kg N/ha significantly increased yam Ca followed by a marked decreased at the 160 kg N/ha application. Increasing levels of CAN and Urea application resulted in marked increases in yam Ca.

Yield, Starch and Glucose Content of Yam

Figure 1 shows the average yield of white yam *(Dioscorea rotundata)* for the two year period. Yam tuber yield range from 15.3 to 21.2 tons/ha. Ammonium suphate applied at 80 kg N/ha resulted in the highest tuber yield of 21.2 tons/ha. representing 39% increase over the control. Calcium ammonium nitrate (CAN) at all levels produced the lowest yield.

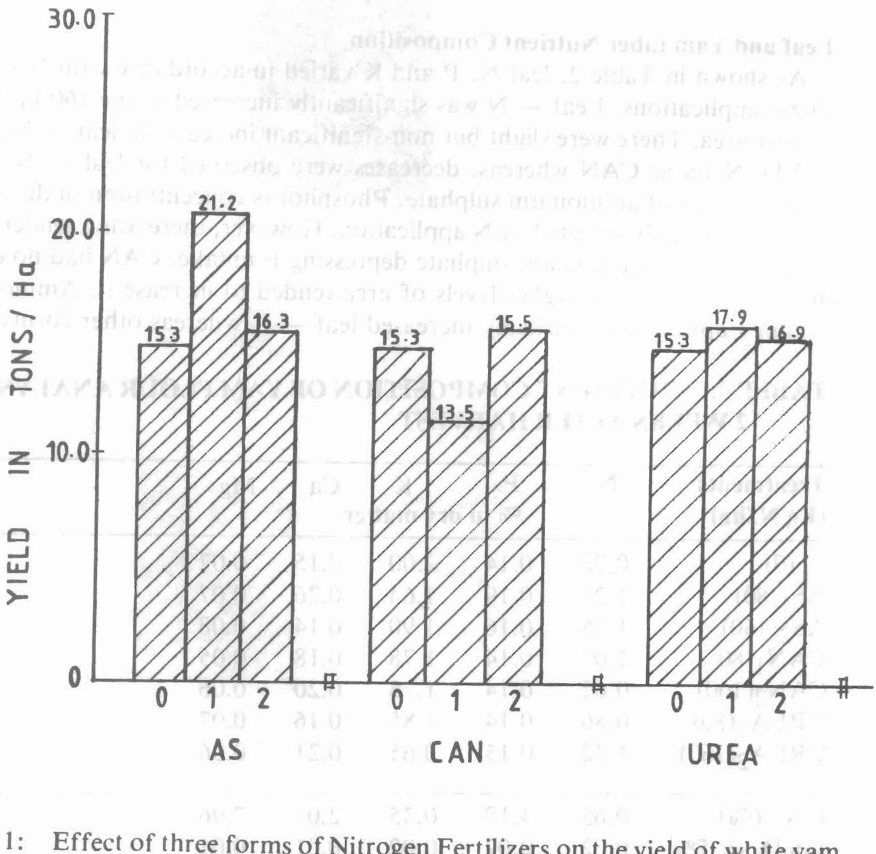

Fig. 1: Effect of three forms of Nitrogen Fertilizers on the yield of white yam *(Dioscorea rotundata)*

Figure 2 shows the starch and glucose contents of the yam as influenced by N fertilization. The highest starch content of 31.5% was produced at the 80 kg N/ha as ammonium sulphate. Calcium ammonium nitrate at 160kg N/ha produced the least starch content when compared to the control. Urea at 160 kg N/ha was superior to CAN in starch production in white yam. The effects of the three sources of N — fertilizer on the glucose content of the yam are similar to the observation obtained for starch.

As shown in Table 4, yam yield showed a highly significant positive correlation with starch and glucose. Tuber yield was also positively correlated with leaf — P and K while Ca and Mg were negatively correlated though Mg was not significant.

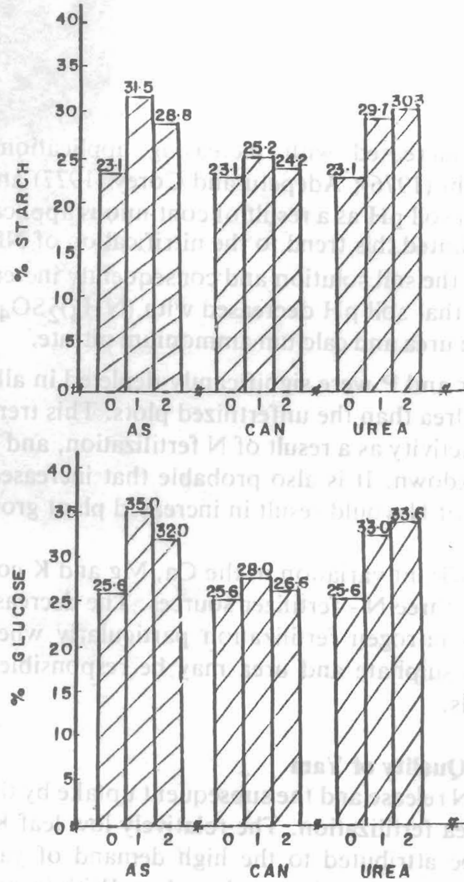

Fig. 2: Effect of three forms of Nitrogen fertilizers on Starch and Glucose contents of Yam *(D. rotundata)*.

TABLE 4: RELATIONSHIP BETWEEN YIELD AND OTHER GROWTH PARAMETERS OF YAM

Sources of comparison	Correlation Coeff (r)
Yield vs Protein	0.360*
" " Starch	0.773***
" " Glucose	0.772***
" " Leaf-N	-0.286
" " " —P	0.803***
" " " —K	0.540**
" " " —Ca	-0.425*
" " " —Mg	-0.0332

* Significant @ 5%
* Significant @ 1%
*** Significant @ 0.1%

Discussion

Soil acidity was increased with increasing application of ammonium sulphate fertilizer. Obi (1976); Adepetu and Corey (1977) and Aduavi (1984) reported a decrease in soil pH as a result of continuous application of Nitrogen fertilizers. They attributed this trend to the nitrification of NH_4+ resulting in the release of H^+ to the soil solution and consequently increasing soil acidity. Obi (1976) observed that soil pH decreased with $(NH_4)_2SO_4$ fertilization and to a lesser extent with urea and calcium ammonium nitrate.

Soil organic matter and P were significantly depleted in all the soils treated with AS, CAN and Urea than the unfertilized plots. This trend may be due to increased microbial activity as a result of N fertilization, and hence increase in organic matter breakdown. It is also probable that increased fertilization of the plots and release of N would result in increased plant growth and root uptake of P and N.

There was no significant variation in the Ca, Mg and K composition of the soils treated with the three N - fertilizer sources. The decrease in soil pH as a result of continuous nitrogen fertilization particularly when applied in the form of ammonium sulphate and urea may be responsible for the reduced CEC value of the soils.

Glucose, Starch and Quality of Yam

The efficiency of N release and the subsequent uptake by the plant was more pronounced with urea fertilization. The relatively low leaf K as a result of N fertilization could be attributed to the high demand of yam crop for K to enhance carbohydrate translocation to the tuber. With increase in N application leaf — P was also gradually decreased. This observation may be due to the low P mobility in the plant and the eventual accumulation in the tuber with the possible formation of complexes between P and tuber protein (Oyenuga, 1968). It is also probable that the growth promoting effect of N could induce the plant to higher demands for P and hence dilute its effect (Okpon, 1983). The generally increased tuber-N could promote the crude protein content of the yam which would result in improved nutritional quality.

The highly positive correlation observed between tuber yield and leaf P (0.802***) and K (0.540**) at the vegetative stage of growth (Table 4) indicates that these parameters could be positive indicators of yam nutrition and growth.

Enyi (1972) found that nitrogen supply increased the proportions of dry matter and starch content of the yam. Singh *et al* (1973 a) observed that maximum starch and total carbohydrate content were obtained with the application of 40 kg N/ha and 120 kg K_2O/ha to *Dioscorea esculenta*. Thus with judicious use of N — fertilizers, percentage starch and glucose content of the yam tubers can be increased considerably. The relative increase in starch and glucose contents of yam would increase the degree of mealiness, a characteristic which would replace the undesirable texture characteristics of waxiness, gumminess and jelliness found in most *Dioscorea rotundata* clones (Oyenuga, 1968). From the results of this study, it is inferred that the yield and quality, in terms of starch and glucose contents of white yam can be appreciably increased in the humid soils of south western Nigeria with the application of between 80 and 160 kg N/ha of either ammonium sulphate or urea.

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