Use of Long Yam Bean (*Sphenostylis stenocarpa*) as Soil Amendment for the Growth, Leaf Chemical Composition and Yield of White Yam (*Dioscorea rotundata* L)

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Abstract: An experiment was carried out to investigate the use of long yam bean (*Sphenostilies sternocarpa*) as soil amendment for the growth and yield of white yam (*Dioscorea rotundata* L) between 1999 and 2003 at Akure in the rain forest zone of Nigeria. There were four treatment namely; NPK 15 – 15 – 15 fertilizer applied at 250kg/ha, poultry manure at 6 t/ha, long yam beans planted at two seeds per hole at a spacing of 1m x 0.5m between rows of yam plots (soil amendment) and a control (no fertilizer). The treatments were arranged in a randomized complete block design (RCB) and replicated five times. The soil analyses before planting and after harvesting were carried out. Each plot size is 4m x 4m ($16m^2$). The growth parameters measured for the yam were vine length (cm), leaf population and stem girth (cm). At harvest, yam tuber weight (kg), tuber length (cm) tuber girth; root length and seed yield of long yam bean plants were determined. The leaf and soil N, P, K, Ca, Mg, pH and organic matter contents were also analysed at end of the experiment. The results showed that there were significant ($p<0.05$) increases in the vine length, leaf population, stem girth, tuber weight, tuber length, tuber girth, soil and leaf N, P, K, Ca, Mg; pH and organic matter of white yam cultivated under the different fertilizer treatments compared to the control treatment. Long yam bean plants used as soil amendment increased the yam vine length, stem girth, leaf population, tuber weight, tuber length and tuber girth by 81% 88.4%, 69.5%, 88.97%, 76% and 94% compared to the control. The same treatment (long yam bean plants) also increased the leaf population, tuber weight, tuber length and tuber girth of yam by 11%, 31%, 30% and 55% respectively compared to NPK fertilizer treatment. Long yam plants also increased the soil pH, O.M, K, Ca and Mg by 29%, 92%, 97%, 86%, 96%, 97% and 89% respectively compared to the control treatment. It increased soil pH, organic matter, K Ca and Mg by 31%, 87%, 1.42, 98% and 98.5% compared to NPK fertilizer. Long yam plants gave seed yield of 2.3 t/ha and produced yam tuber yield of 4900kg/ha amounting to $6,050 compared to $3453.00 and $3,380.00 estimated on yam yields alone under poultry manure and NPK fertilizer treatments. Finally, the use of long yam bean plants as biological fertilizer source for yam production could substitute for 250kg/ha NPK fertilizer and 6t/ha poultry manure. [Journal of American Science. 2010;6(11):10-17]. (ISSN: 1545-1003).

Keywords: Long yam bean, soil amendment, white yam performance.

1. Introduction

One of the major problems facing tropical agriculture is the inherently low fertility status of the soils because of the presence of low activity clay minerals (1:1 Kaolinite). Soil organic matter status is identified as one of the major indicators of soil fertility Agboola and Obatolu, (1989) and it is now very important that agricultural practices and farming systems must be evolved to ensure stable soil organic matter levels. In-addition, agricultural production in low input systems in the tropics relies partly on nutrient recycling and the maintenance of soil fertility through biological processes.

Many researchers have advocated the use of green manuring and, the application of household and industrial wastes for crop production, even though the adoption of these practices has been very low because of the difficulty in transporting the bulk materials to the field, the labour intensive nature of the materials and absence of immediate income or source of food (Ojeniyi, 1998; Moyin-Jesu 2003; Cherr et al., 2006; Brennan et al., 2009; Alluvione et al., 2010).

Therefore, there is need to look inwards for alternative sources of biological fertilizers using the traditional leguminous shrub crops such as pigeon pea (cajanus cajan) and long yam bean (*Sphenostylis stenocarpa*) to enrich the fertility of the soil grown to arable crops, serve as source of income and food to the farmers and livestock.

Having reviewed literature extensively, there is scarcity of research information on the use of long yam bean as soil amendments to increase the soil fertility, growth and yield of white yam.

Mulongoy and Kang, (1986) and Usman et al. (2006) reported that legumes have the potentials to improve soil fertility, thereby boosting subsequent crop yield. They stated further that other benefits of legumes include maintenance and improvement of soil physical properties, providing ground cover to reduce soil erosion, increasing soil organic matter, cation exchange capacity and reduction of soil temperature.

Kang (1992); Graham and Vance (2003) also reported that legumes could be integrated into existing cropping systems either as cover crops, live mulch, and food or fodder crops through planted fallows of multiple cropping systems. Therefore, the role of traditional legumes in soil fertility must be properly investigated.

Yam (Dioscorea spp) is a tuber crop belonging to the family Dioscoreaceae and it is a tropical crop with many species originating in South, east Asia. Among the species of yam is white yam (Dioscorea rotundata L) which produces edible tubers and it serves as sources of food to man and livestock and generates income to farmers (Adeyemi, 1999).

The objectives of this study are as follows:

(i) To determine the suitability of long yam bean with the convectional fertilizers (poultry manure and NPK fertilizers) as soil amendments on the growth and yield parameters of yam.
(ii) To determine their effectiveness on the yam leaf and soil chemical composition after harvesting
(iii) To determine the comparative advantage of long yam bean plants as soil amendment over the convectional fertilizers in term of cost/benefit ratio to farmers.

2. Materials and Methods

Collection, processing and analysis of the treatments used

The poultry manure was collected from over 10,000 poultry birds of Rhode Island breed in the livestock unit of Federal College of Agriculture, Akure. The long yam bean seed were obtained from four hectares farm in the institution while NPK fertilizer were purchased from Ondo State Agricultural Input and Supplies Company, Akure and it is of high grade.

The poultry manure was stacked or heaped to allow for proper mineralisation processes while the long yam bean seeds were soaked in a 100ml 0.01M dilute H_2S04 acid solutions for 30 minutes to weaken the hard seed coat for quick germination. The determination of the nutrients in the poultry manure was done using wet digestion method based on 25 – 5 – 5ml of H_2N0_3 – H_2S04 – $HCl0_4$ acids. The filtrate was collected for the amount of %P, K, Ca and Mg. The % P was evaluated using vanado-molybdate colorimetry and read on spectronic 20 while the % k and Ca were read on flame photometer. Mg was determined on atomic absorption spectrophotometry. The percentage N was determined by microkjedahl (Jackson, 1964) while the nutrients composition of NPK 15 – 15 – 15 fertilizer was obtained from the manufacturer's label' (240kg N, 240kgP and 240 kg K)

Soil Analysis Before Planting

The soil samples were collected from 0-15cm depth, air-dried, sieved with 2mm sieve and utilized for routine soil analysis. The particle size distribution was determined by the hydrometer method (Bouycous, 1951). The soil pH (1:1 soil/water and 1:2 soil/0.01M $Cacl_2$) was determined (Crockford and Nowell, 1956).

The organic matter (O.M) was determined by the Walkley and Black (1934) while the exchangeable bases (K, Ca, Mg and Na) were extracted with 1M NH_40A_C pH7 and the amount of K, Ca and Na were determined on the flame photometer using appropriate element filters. The Mg content in the extract was read on atomic absorption spectrophotometer (Jackson, 1958). The exchangeable acidity (H^+ and Al^{3+}) was measured from 0.01M KCl extracts by titrating with O.1M HC1 (McLean, 1965) while percent N was determined using microkjedahl method (Jackson, 1964). Available P was extracted using Bray P1 extractant and the extracts measured with Murphy-Riley blue method (Murphy and Riley, 1962) on spectronic 20 at 8821Um while the soil bulk density was determined using core method (Ojeniyi, 1985).

Field Experiments

The experiments were carried out at Akure in the rainforest zone of Nigeria and the soil is sandy clay loam, skeletal, kaolinitic, isohyperthemic oxic paleustalf (Alfisol) or Ferric Luvisol (FAO). The site had been continuously cropped to cereals and tuber crops for 10 years while the two experiments were conducted between October 1999 and March 2001 and January, 2003 on the same site.

The annual rainfall of the study area is 1300mm and it is well distributed throughout the year while the annual temperature ranged between 22^{o}C and 28^{o}C. These climatic conditions are considered adequate for growth and yield of white yam. The land was cleared, ploughed, harrowed and ridged while the plots were laid out at 4m x 4m (16m^2) and yam setts prepared from white yam variety (*Dioscrea rotundata L*) were planted in early November each cropping year into the plots at a spacing of 1m x 1m. The plots were mulched immediately to prevent scorching and decay of the planted yam setts by heat.

There were four treatments namely poultry manure, long yam beans, NPK 15 – 15 – 15 fertilizer and a control (no fertilizer; no manure), replicated six times and arranged in a randomized complete block design. The poultry manure was applied at 6 t/ha,
NPK 15 – 15 – 15 fertilizer was applied at 250kg./ha, long yam beans were planted at two seeds per hole at a

spacing of 1m x 0.5m between the middle rows of yam plots and the control treatment (no fertilizer; nor manure nor long yam bean plants).

Manual weeding operation was first carried out in the third week after sprouting and it continued at every three weeks interval until the 16^{th} week sprouting. Individual staking of the yam vines was done in the second week after sprouting in early March 2001 and 2002 and the mulching materials were removed in each cropping year when the rain was steady. The young yam vines were trailed on the stakes to prevent vines from creeping on the soil and proper drainage channels were made to prevent the applied treatments from being washed away by rain water. The yam vine length (cm), leaf population and stem girth (cm) were measured at weekly interval beginning from two weeks after application of treatments till 12 weeks after sprouting.

Harvesting of the yam tubers was done at 32 weeks after sprouting and the yield parameters such as tuber girth, tuber length(cm) and tuber weight (kg) were measured. The harvesting of the long yam bean pods started in November 2000 to February 2001 for the first experiment and between November 2002 and February 2003 for the second experiment. The weight of the shelled grains were measured and recorded for each experiment. At end of the harvesting of the long yam bean pods in the first experiments, all the plants were allowed to dry in-situ and ploughed into the soil at the commencement of the second experiment.

Leaf analysis of the yam plants

At 18 weeks after sprouting, leaf samples were taken from the top, middle and lower parts of the yam crop in each treatment using secateurs, properly cleaned, milled into smaller pieces and dry ashed in a muffle furnace for 6 hours at $450^{o}C$. The ash produced, was made into solution, filtered and filtrates analyzed for N, P, K Ca and Mg.

The percentage N was determined using micro-kjedahl method (Jackson, 1964) while the P content was determined using Vanado-molybdate colorimetry and read on Spectronic 20 at 4421Um. The K and Ca contents were determined on flame photometer using appropriate filters while the Mg content was read on atomic absorption spectro photometer.

Soil analysis after the experiment

At the end of each experiment, soil samples were taken from 0-15cm depth from each treatment plot, air-dried, sieved and analyzed for soil pH, N, P, K, Ca, Mg and SOM, and soil bulk density as described earlier.

Statistical analysis

The data obtained from the means of the two experiments for the growth, yield parameters, leaf and soil chemical composition were analyzed using ANOVA F-test and the overall treatment effects were compared using Duncan Multiple Range Test at 5% level.

3. Results

Soil fertility status before planting of yam

Table 1 presents the soil physical and chemical properties before planting of yam.

Table 1: Pre-planting soil analysis

SOIL PROPERTIES	
pH (H2O)	5.80
(CaCl2)	5.30
Organic Matter (%)	0.50
Total Nitrogen (%)	0.06
Available Phosphorus (ppm)	5.08
Sodium (cmol/kg)	0.14
Potassium (cmol/kg)	0.06
Calcium (cmol/kg)	0.11
Magnesium (cmol/kg)	0.14
Bulk Density	1.60

The soil is acidic and very low in organic matter. The low organic matter content of the soil also reflected in the low values of soil N, P, K, Ca, Mg and Na, which were below 10mg/kg P, 0.20cmol/kg K, Ca, Mg and Na (Agboola and Corey, 1973) and 0.15% N (Sobulo and Osiname, 1981) considered as soil critical levels for optimum crop production in South western Nigeria. The soil bulk density was $1.60g/cm^3$.

Table 2 presents the chemical analysis of the poultry manure and long yam bean used for the cultivation of yam. The poultry manure had high values of %N, P, K, Ca, Mg, and Na.

Table 2: Chemical composition of the organic fertilizers used for the experiment

Organic Material	N	P	K	Na	Ca	Mg
Poultry manure	3.90	0.75	0.48	0.10	0.54	0.35
Long yam bean	226 kg/ha (symbiotic N fixed)	3.70	3.00	0.30	0.80	1.00

Source: Boonche and Anecksamphant (1993)

Growth and yield parameters of yam under different treatments.

Table 3: The growth and yield parameters of yam under different fertilizer treatments

Treatments	Vine length (cm)	Stem girth (cm)	Leaf population	Tuber weight (kg/ha)	Tuber length (cm)	Tuber girth (cm)
Control (No fertilizer application)	40.20	0.40	12.00	540.20	9.00	1.00
NPK 15-15-15	210.00	3.41	44.00	3380.40	26.00	7.00
Poultry manure	189.70	2.10	32.00	3453.20	30.00	9.00
Long yam bean	210.40	3.30	39.00	4900.00	37.00	15.70
LSD	**4.30**	**0.63**	**2.10**	**12.20**	**3.50**	**2.00**

Table 3 presents the values of leaf area, vine length, leaf population and stem girth, tuber weight, tuber length and tuber girth of white yam under the different fertilizer treatments. There were significant increases ($P<0.05$) in these parameters for yam compared to the control treatment. The long yam bean treatment increased the yam vine length, stem girth, leaf population, tuber weight, tuber length and tuber girth by 81%, 88.4%, 69.5%, 89%, 76% and 94% compared to the control treatment. The same treatment (long yam bean plants) also increased these parameters by 10%, 37%, 18%, 29%, 19.4% and 40% respectively compared to the poultry manure treatment.

Long yam bean plants increased the leaf population, tuber weight, tuber length and tuber girth of yam by 11%, 32%, 30% and 55% respectively. Except in stem girth and vine length where NPK fertilizer treatment increased these parameters by 3.8% and 0.2% respectively compared to the long yam plants treatment.

Leaf Chemical composition of Yam under different Fertilizer treatments

Table 4: Leaf composition of yam under different fertilizer treatments

Treatments	N	P	K	Ca	Mg
Control (No fertilizer application)	1.50	0.30	0.20	0.15	0.15
NPK 15-15-15	2.50	1.80	1.73	0.10	0.12
Poultry manure	2.70	1.98	1.20	0.32	0.36
Long yam bean	2.80	1.93	1.50	0.42	0.45
LSD	**0.10**	**0.12**	**0.20**	**0.10**	**0.09**

Table 4 gives Leaf Chemical composition of Yam under different Fertilizer treatments.

There were significant ($p<0.05$) increases in the leaf N, P, K, Ca and Mg under the fertilizer treatments compared to the control treatment (Table 4). The long yam bean plants increased the yam leaf N, P, K, Ca and Mg 99.14%, 99.45%, 97.3%, 90.3% and 88.6% respectively compared to the control treatment. It also increased the same parameters N, K, Ca and Mg by 2.13%, 20%, 31.3% and 26% respectively compared to the poultry manure treatment except in leaf P where poultry manure increased the value by 2.52% compared to the long yam beans. Long yam bean plants increased the yam leaf N, P, Ca and Mg by 10.63%, 6.7%, 96.7% and 97.14% respectively compared to the NPK fertilizer treatment.

Soil Chemical Composition of yam plot after harvesting.

Table 5: Soil chemical composition of yam plots after harvesting under different fertilizer treatments

Treatments	Bulk Density	pH	Organic Matter	N	P	K	Ca	Mg
Control (No fertilizer application)	1.63	5.1	0.21	0.04	3.40	0.05	0.03	0.07
NPK 15-15-15	1.66	5.0	0.34	1.40	29.30	1.38	0.02	0.01
Poultry manure	1.36	6.7	2.38	1.34	25.20	0.93	0.75	0.56
Long yam bean	1.20	7.2	2.70	1.37	27.30	1.40	0.91	0.65
LSD	**0.15**	**0.3**	**0.31**	**0.03**	**1.50**	**0.32**	**0.01**	**0.09**

There were significant increases ($p<0.05$) in the soil pH, O.M, N, P, K, Ca and Mg, compared to the control treatment (Table 5).

The long yam bean increased the soil pH, organic matter, N, P, K, Ca and Mg by 29%, 92%, 97%, 86%, 96%, 97% and 89% compared to the control treatment. Long yam bean increased soil pH, organic matter treatment. Long yam bean increased soil pH, organic matter, K, Ca and Mg by 31%, 87%, 1.42%, 98% and 98.5% respectively. The long yam bean decreased the soil bulk density by 25% and 27% compared to control and NPK fertilizer treatments respectively.

Comparative advantage of long yam bean plants as soil amendment.

Table 6: Comparative advantages of pigeon long yam bean bio-fertilizer over the conventional organic and inorganic fertilizers in term of utility parameters

Treatments	Yield of yam (kg/ha)	Yield of Long yam bean seeds (kg/ha)	Total Cost of Production (US Dollars)	Total Revenue (US Dollars)	Discounted Factor at 15%	Cost-Benefit Ratio
Control (No fertilizer application)	540.2	Nil	500.00	540.2	0.87	1.08
NPK 15-15-15	3,380.4	Nil	567.00	3,380.4	0.87	5.96
Poultry manure	3,453.2	Nil	583.00	3,453.2	0.87	5.92
Long yam bean	4,900.2	2,300.0	517.00	6,550.0	0.87	12.67

Table 6 presents the data on the comparative advantage of long yam bean plants as bio-fertilizer plants over the convectional organic and inorganic fertilizers (poultry manure and NPK fertilizer) used in the fertilization of yam. The long yam bean plants produced 2.3t/ha (2300 Kg) of long yam bean seeds, in-addition, to the 4,900 kg/ha of yam tuber weight recorded compared to the 3,453.20 kg/ha and 3,380.40kg/ha of yam tuber weight recorded for poultry manure and NPK 15 – 15 –15 fertilizer treatments respectively

4. Discussion

For the control treatment, the least values of growth and yield parameters such as vine length, leaf population, stem girth, tuber weight, tuber length and tuber weight of white yam compared to that of NPK 15 – 15 – 15 fertilizer, poultry manure and long yam bean plants might be due to the initial low nutrient status of the soil before application of the fertilizer treatments. This observation was in line with the work of Agboola (1982), which reported poor growth and yield responses in soils that did not receive fertilizer application.

The low soil nutrient status also accounted for the least values of yam leaf N, P, K, Ca and Mg; soil pH, N, P, k, Ca, Mg and organic matter. The low organic matter status of the soil is consistent with low N and P status (Agboola and Corey, 1973). The low organic matter status also increased the initial bulk density values to 1.63 and 1.66 Mgm-3 in control and

NPK fertilizer treatments respectively as a result of continuous cultivation.

The significant increases in the growth and yield of white yam due to application of poultry manure, use of long yam bean plants and NPK fertilizer were adduced to increased availability of nutrients in the soil. The application of poultry manure and the use of long yam bean plants as soil amendment increased soil organic matter, N, P, K, Ca and Mg status and reduced the soil acidity. Soil acidity (low pH) is known to affect the yields of crops adversely through inhibition of nitrogen fixation processes. (Aduayi, 1980).

The highest nutrient contents (SOM, N, P, K, Ca and Mg) supplied by the long yam bean plants into the soil were responsible for the shoot, and yield development. K had been reported to encourage photosynthesis and tuber formation in yam (Adu Daaph et al, 1994). This could explain why the long yam bean plant produced the best values of yam tuber weight (kg/ha), tuber length and tuber girth compared to NPK, poultry manure and control treatments. Long yam bean plant is a legume which fixes N into the soil and increases the level of soil organic matter. For-instance, Boonche and Anecksamphant (1993) reported that long yam bean plant fixed into the soil 220kg/ha symbiotic N, 4.3% P, 3.00% K and 0.70% Ca.

The reduction in the soil bulk density by the use of long yam bean plants might have positively influenced other soil physical properties such as porosity, water-infiltration, permeability and aeration. Hence, the improvement of soil physical condition is consistent with the work of Woomer and Muchena (1993) which reported that continuous productivity of tropical soils is associated with maintenance and improvement of soil physical characteristics.

The increase in vegetative growth of white yam such as vine length, stem girth and leaf population under long yam bean plants compared to that produced by poultry manure and NPK 15 – 15 – 15 fertilizer might be attributed to the ability of the long yam bean plants to for nitrogen into the soil. This finding agreed with the work of Boonche and Anecksamphant (1993) who reported that roots of nitrogen fixing crops such as legumes have nodules where nitrogen fixation takes place. Thus, the 220kg N/ha/yr fixed into the soil by long yam bean plants would enhance its use for soil fertility maintenance.

The reduction in the SOM of plots fertilized with NPK fertilizer also affected the Ca and Mg contents of the soils and this is because of high nutrient interactions between P and K contents in the soil fertilized with NPK and Ca or Mg contents (P/Mg, K/ca and K/mg ratio) which reduced their uptake and this view was supported by Bear (1950).

The comparative advantage of long yam bean plants as soil amendment compared to the poultry manure and NPK fertilizer in terms of providing additional food and income for farmers could be the major ways of improving farmers' standard of living and ensured food security. Ali (1996) also reported that in semi-arid tropics of Asia, pigeon pea, and soya bean-based systems can replace other systems because of higher monetary returns, thus, long yam bean plants can also help in improving farmers income in tropical Africa and Asian countries.

Agboola (1982) reported that the main reasons why farmers in the tropics could not adopt the use of green manure such as *Calopogonium mucunoides* for soil fertility maintenance was that it was labour intensive and farmers did not usually get food or income in return for their cultivation.

Therefore, the adoption of long yam bean plants by farmers would fertilize the soil, provides food and income for the farmers. For-instance, the 2.3 t/ha of long yam bean seeds and yam tuber yield under long yam bean seeds and yam tuber yield under long yam bean plants treatment provided ($6,550.00) compared to $3,453.20 and $3,380.40 estimated on yam yields alone under poultry manure and NPK fertilizer treatments (Table 6). The higher Benefit/Cost ratio of 12.67 under long yam bean treatment was as a result of the sales of the additional 2,300kg/ha of long yam bean seeds.

However, the cultivation of traditional legumes such as long yam bean plants, pigeon pea, lima beans and forth by farmers had gone down drastically such that these crops were nearly going into extinction. There is need for a strong extension package on the cultivation and use of traditional legumes such as long yam bean, lima beans and pigeon pea as soil amendments for food crops. This will help in bringing them into commercial production by farmers, instead of the convectional legumes produced from research centers which encouraged heavy use of agrochemicals because they were susceptible to pests and diseases attack.

The use of long yam bean plants as soil amendment for yam production as reflected in the best values of yam tuber weight, tuber length and girth proved that it was compatible with food crops as an intercrop. This observation agreed with the work of Adeyemi (1999) which reported yield advantages in cocoyam/cowpea/maize/cassava intercrop.

5. Conclusion

The research work has identified that the use of fast growing legume such as long yam bean as soil amendment increased yam vine length, stem girth, leaf population, tuber weight, tuber length and girth;

leaf and soil N, P, K, Ca and Mg; soil pH and SOM. Therefore, the use of long yam bean plants as biological fertilizer source for yam production could substitute for 250kg/ha NPK fertilizer and 6t/ha poultry manure.

This recommendation agrees with the fact that long yam bean plant is environmentally compatible with the farming system in the tropics, provides additional source of food and income for the poor resource farmers. In-addition, the high cost of purchase, scarcity of inorganic fertilizers and the labour intensive nature of gathering high quantities of manure for crop production did not help farmers in achieving sustainable food production.

The utility of long yam bean as protein source and income will benefit the farmers but the successful adoption of long yam bean plants and other legumes based technologies may depend on dissemination of information on their production and utilization through extension approaches to stakeholders.

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