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Effect of Green Manure Application on Cassava (M*anihot esculenta* Crantz) Growth, Yield Quantity and Quality in Degraded Alfisols

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ABSTRACT

The use of green manures as alternatives to minimize the usage of chemical fertilizers that are very expensive and also environmentally unfriendly is considered as a good agronomic practice. However, the effect of each green manure on soil properties and crop yield depends on its chemical composition. Hence field experiments were conducted in sandy soil during 2015/2016 and 2016/2017 to compare impacts of green manures (GM) and N15:P15:K15 fertilizer on soil properties, growth, root yield, mineral, starch and hydrocyanic acid (HCN) contents of cassava. The GM from leaves of: Neem (*Azadirachta indica* A. Juss.), Moringa (*Moringa oleifera* Lam.), Gliricidia (*Gliricidia sepium* (Jacq.) Kunth ex Walp.) and Leucaena (*Leucaena leucocephala* (Lam.) de Wit) were applied at 5 t ha^{-1}, and the NPK fertilizer was applied at 400 kg ha^{-1}. There was a no fertilizer (control). Application of GMs reduced soil bulk density and increased soil organic matter (OM), N, P, K, Ca, Mg, growth and fresh root yield of cassava compared with the control. The NPK fertilizer had no effect on soil bulk density and soil OM, but increased soil N, P, K, Ca, Mg, growth and fresh root yield of cassava compared with the control. Gliricidia increased growth and fresh root yield of cassava compared with other GMs and NPK fertilizer. In the first year (2015/2016) and compared with control; Gliricidia, Moringa, Leucaena, Neem and NPK fertilizer increased fresh root yield of cassava by 53, 33, 30, 29 and 28%, respectively. In the second year (2016/2017), these treatments increased fresh root yield of cassava by 85, 65, 61, 60 and 36%, respectively. The GMs and NPK fertilizer increased mineral and starch contents and reduced HCN content in the

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cassava tuber roots compared with the control. Use of GM has potential to improve soil properties, and growth, fresh root yield and nutritional contents of cassava than does NPK fertilizer. The Gliricidia treatment best improved soil properties and cassava productivity as indicated by the benefit:cost ratio. For those growing cassava for fresh root quantity Gliricidia is recommended as green manure. Moringa is recommended as green manure for those that desire fresh root quality.

Keywords: Azadirachta indica, cassava, *Gliricidia sepium*, growth, *Leucaena leucocephala, Moringa oleifera,* quality, yield

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is known for its inherent ability to produce reasonably good yields on eroded and degraded soils, and under adverse climatic and soil conditions, where other crops would fail (Agiriga & Iwe, 2016; Howeler, 2002, 2014), increasingly more marginal and fragile soils are being used for its production in Africa, Asia and Latin America (Cadavid, El-Sharkawy, Acosta, & Sanchez, 1998; El-Sharkawy, 1993; Howeler, 1994, 2014).

According to Howeler (1991b, 2012, 2014), cassava is often believed as a 'scavenger crop', that is, highly efficient in nutrient absorption from a low-nutrient soil, leaving that soil even poorer than before. Thus it is often concluded that cassava extracts more nutrients from soil than most other crops, resulting in nutrient depletion and a decline in soil fertility. For instance, for a target fresh root yield of 35.7 t ha^{-1}, cassava removes 55, 13.2 and 112 kg ha^{-1} of N, P and K, respectively from soils (Howeler, 1991b, 2014). This plainly shows the need to restore and maintain soil nutrient status during cultivation through the use of sound and appropriate nutrient management practices.

Additional nutrient in form of organic manure and inorganic fertilizer (especially NPK fertilizer) must be applied to restore soil fertility, and therefore sustain cassava productivity. However, use of chemical fertilizers is limited due to its high cost and scarcity during planting, and its prolong use leads to decline in soil organic matter content, acidification, nutrient imbalance and degradation of soil properties. Therefore, one way of restoring fertility, and increasing soil OM content of tropical soils, is with use of green manure (Ali, 1999; Adekiya, Agbede, Aboyeji, Dunsin, & Ugbe, 2017). Use of green manure as a source of soil fertility is not a common practice among cassava growers in the tropics. Green manure application can increase production of cassava under tropical conditions by reducing soil density, enhancing soil fertility and productivity. Green manure plants are non-polluting, less dangerous and biodegradable with no unsafe deposits in soil, water and air. They are environmentally friendly, edaphologically suitable, and by and large do not leave buildup in stored food product (Adekiya et al., 2017).

Neem (*Azadirachta indica* A. Juss.), Moringa (*Moringa oleifera* Lam.), Gliricidia (*Gliricidia sepium* (Jacq.) Kunth ex Walp.) and Leucaena (*Leucaena leucocephala* (Lam.) de Wit) can be used as green manure, but use of their leaves for cassava production has not been investigated. It was reported that application of fresh neem leaves at 5 t ha^{-1} or dry neem leaves at 1.25 t ha^{-1}, used in conjunction with urea, resulted in higher N recovery percent and N response ratio and gave increased grain yield compared to the yield obtained due to the application of urea alone (Santhi & Palaniappan, 1986). Moyin-Jesu (2014) also reported that mixture of water extracts of neem leaf and wood ash gave the best growth and yield parameters of plantain and this was due to its nutrients superiority compared to the other treatments. In contrast, Moringa is an underutilized tropical crops. Incorporation of Moringa shoots as green manure increased fertility level of agricultural soils (Ekene, Ezeaku, & Ndubaku, 2014; Fahey, 2005). Gliricidia has been used to improve quality and as a potential source of N (Makumba et al., 2006; Srinivasarao Rao et al., 2011). Incorporation of tender twigs of Leucaena has been found beneficial for meeting N requirement and improving productivity of maize; and there are significant residual effects on soil fertility and productivity of the following crops (Kebede, 2016; Mureithi, Tayler, & Thorpe, 1994).

No field study has been conducted in Nigeria to determine the effects of green manures and NPK fertilizer on soil properties, and cassava yield's quality and quantity. In Nigeria, cassava yields have declined in recent years, particularly in Alfisols that are very low in organic matter content and nutrients (Salami & Sangoyomi, 2013). Such soils are used intensively, receiving little or no fertilizer, and are rarely fallowed (Ayoola & Makinde, 2007; Salami & Sangoyomi, 2013). The working hypothesis in this study was that application of green manures would significantly improve soil properties, and cassava yield's quality and quantity in comparison with application of NPK fertilizer. Thus, the objectives of this study were to determine the effects of green manures and NPK fertilizer on soil properties, growth, yield, mineral, starch and hydrocyanic acid content of cassava.

MATERIALS AND METHODS

Site Description and Treatments

Field experiments were conducted at the Teaching and Research Farm, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria, in April 2015 and 2016. Rufus Giwa Polytechnic, Owo, lies between Lat 7°12'N and long 5°35'E and is located in the forest-savanna transition zone of Nigeria. The soil at Owo is in the Okemesi Series and is an Alfisol classified as Oxic Tropuldalf or Luvisol (Soil Survey Staff, 2014) derived from quartzite, gneiss and schist. Rainfall is bimodal, averaging about 1400 mm per year, with most of it occurring during March to July and mid-August to November. Mean annual temperature is about 32°C. The trial was established in a field left fallowed for a year after it had been cropped with yam, maize, cassava, melon, cocoyam and tomatoes, respectively, during the previous 6 years and had not received fertilizer application. The predominant weeds at the site were Siam weed (*Chromolaena odorata* L. King and Robinson), Haemorrhage plant (*Aspilia africana* Pers. Adams) and goat weed (*Ageratum conyzoides* L.).

The experiment consisted of green manure from leaves of: Leucaena, Neem, Moringa, Gliricidia, and N15: P15: K15 fertilizer and a control with no green manure or fertilizer. The treatments were arranged in a randomized complete block design with 4 replications. Each block comprised 6 plots, each of which measured 7 × 5 m^2. Blocks were 2 m apart, and plots were 1 m apart. The same site was used in both years.

Land Preparation and Crop Establishment

The site was manually cleared and weeds removed. Thereafter, the soil was plowed and disked to a 20 cm depth followed by ridging at a spacing of 1 m apart. The green manure plant leaves used for the experiments were harvested from nearby sites and comprised green tender stems and leaves of the plants. Plant leaves were chopped to 5 mm and incorporated at 5 t ha^{-1} to a depth of about 10 cm using hoes. The NPK and control treatments plots were prepared the same way as those of green manures plots, but without incorporation of green manure. Plots were left for 1 week before planting.

Healthy mature stems of cassava (TMS 30572) obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria were cut at 25 cm length, with 5 to 8 nodes. One stem cutting was planted per hill on the crest of ridges on 6 April 2015 and 10 April 2016 at a spacing of 1 m x 1 m, providing 35 plants per plot which is equivalent to a plant population of 10,000 plants per hectare. 400 kg ha^{-1} of NPK fertilizer (15 N, 15 P_2O_5, 15 K_2O) was applied manually by ring method in two split applications, the first at one month after planting (1 MAP) and the second at 3 months (3 MAP) after planting. Four manual weeding regimes were carried out at 3, 7, 12 and 17 weeks after planting (WAP) to control weeds.

Determination of Growth and Yield Parameters

Ten plants per plot were randomly selected from which growth and yield data were obtained. Growth parameters measured were plant height, number of leaves and leaf area index (LAI = LA/a, where LA = leaf area and a = land area) and these were determined at 6 months after planting (MAP). At harvest (12 months after planting), fresh storage root yields were determined.

Soil Sampling and Analysis

Prior to the start of the experiment in 2015, soil samples were collected from 0-15, 15-30 and 30-45 cm depths of a profile pit dug in 10 different points selected randomly from the experimental site. Undisturbed samples were collected from the centre of the depth intervals using steel coring tubes (4 cm diameter, 15 cm high) and were put in an oven set at 100^{o}C for 24 h for determination of bulk density (Campbell & Henshall, 1991). Particle-size analysis was done using the hydrometer method (Gee & Or, 2002). Textural class was determined using a textural triangle (Brady & Weil, 1999; Hunt & Gilkes, 1992). Before ridging, composite soil samples were collected from the three depths and analysed for chemical properties. Disturbed soil samples were also collected per plot at harvest of cassava from 0-15 cm depth in 2015/2016 (first year) and 2016/2017 (second year) and similarly analysed for chemical analysis. The soil samples collected were air dried, ground, and passed through a 2 mm sieve. The sieved soil samples were taken to the laboratory for chemical analysis as described by Carter and Gregorich (2007). Soil organic carbon was determined by the procedure of Walkley and Black using the dichromate wet oxidation method (Nelson & Sommers, 1996). Organic matter (OM) was deduced by multiplying carbon (C) by 1.724. Total N was determined by micro-Kjeldahl digestion (Bartels, 1996) and distillation techniques; available P was extracted using Bray-1 solution and determined by molybdenum blue colorimetry (Frank, Beegle, & Denning, 1998). Exchangeable bases (K, Ca and Mg) were extracted with 1 N NH_4OAC buffered at pH 7.0 (Van Reeuwijk, 2002). Thereafter, K was determined using a flame photometer, and Ca and Mg were determined by the EDTA titration method (Hendershot, Lalande, & Duquette, 2008). Soil pH was determined in 1:2 soil-water medium using glass electrode pH meter (Ibitoye, 2006).

Determination of Soil Physical Properties

Two months after incorporation of green manure leaves, determination of bulk density in all plots was started and repeated at 4, 6, 8, 10 and 12 months after green manure incorporation. Five soil samples were collected at 0-15 cm depth from the centre of each plot and 10 cm away from each cassava plant using steel coring tubes and were used to evaluate bulk density as described above (Campbell & Henshall, 1991).

Analysis of Green Manure Leaves and Fresh Storage Roots of Cassava

Prior to incorporation of green manure leaves to plots, leaf samples were collected randomly from each green manure, oven-dried for 24 h at 80°C and ground in a Willey mill. The samples were analyzed for leaf N, P, K, Ca and Mg as described by Tel and Hagarty (1984). Leaf N was determined by the micro-Kjeldahl digestion method. Ground samples were digested with nitric-perchloric-sulphuric acid mixture for determination of P, K, Ca and Mg. Phosphorus was determined colorimetrically using the vanadomolybdate method, K was determined using a flame photometer and Ca and Mg were determined by the EDTA titration method. The percentage of organic carbon (OC) in the green manure leaves was determined by the Walkley and Black procedure using the dichromate wet oxidation method.

At 12 months after planting, the 10 central plants from each plot were harvested. From all the roots harvested per plot, five of them were selected randomly. Selected roots were washed and peeled. From the proximal, central and distal sections of each root, a slice was taken. Samples from each root were mixed together and chopped into small pieces. Resulting chips were properly mixed to obtain a uniform sample of root tissue from the five original roots. A 100 g sample was then taken and oven-dried at 60^{o}C for 24 h. Dried samples were then ground in a mill with a stainless steel grinding tool and stored in air-tight containers prior to chemical analysis. Hydrocyanic acid (HCN) in the cassava root were determined, using the enzymatic assays developed by Cooke (1978) and O'Brien, Taylor and Poulter (1991). Mineral elements of cassava roots were determined according to methods recommended by the Association of Official Analytical Chemists (AOAC) (2012). The samples were digested using nitric-perchloric-sulphuric acid mixture. Phosphorus was determined by the molybdenum blue colorimetric technique. K, Ca, Fe and Zn contents were determined by the atomic absorption spectrophotometer. Peeled cassava tubers 100 g each were macerated and passed through 15 µm pore size sieve, using tap water. The extracted starch in water was allowed to stand for 6-12 h, after which excess water was decanted, and the starch was dried to a constant weight in an oven set at 80^{o}C.

Statistical Analysis

Data collected from each experiment were subjected to analysis of variance (ANOVA) using the Genstat statistical package (Genstat, 2005). If the treatment by year interaction was significant it was used to explain the results. If the interaction was not significant, treatments means were separated using Duncan's multiple range test.

A cost: benefit analysis was done to determine relative economic returns on treatments using 2016 and 2017 annual market prices. Total yield and cost benefit analyses were determined using the harvest from the central bed (1 m^2) of each plot. Costs of farm services were from Emure-Ile market in Owo Local Government Area of Ondo State, Nigeria.

RESULTS AND DISCUSSION

The physical characteristics and chemical properties of the experimental site before the commencement of the experiment in 2015 are shown in Table 1. The soil was sandy loamy in texture, slightly acidic and high in bulk density. The clay content increased progressively down the profiles, which was attributable to clay lessivation at the soil surface, whereas the sand and silt contents decreased with depth. Also, the value of soil organic matter (OM), total N, available P, exchangeable K, Ca and Mg decreased with depth. This was adduced to the fact that more decomposition occurs on the upper layers of soil profile because more organic matter was added through litter fall. All of the soil nutrients in the soil profile clearly showed that the nutrient status of the soil was low, and below the critical levels recommended for cassava cultivation (Howeler, 1998). Therefore, it was expected that the crops should response to fertilizer application. The poor soil fertility status could be adduced to nature and continuous cultivation over the years without addition of manure or fertilizer inputs.

The chemical analysis of the green manures indicated considerable amount of nutrients which were expected to benefit the soil and cassava crop (Table 2). The green manures have high amounts of nutrients and lower C-to-N ratios. Gliricidia had the highest K and N values, and Moringa had the highest Ca value. Neem was highest in P and Mg, while Leucaena had higher N value similar to that of Gliricidia (Table 2).

Table 1

Soil physical and chemical properties of the experimental site before experimentation in 2015

Soil property	0-15 cm depth	15-30 cm depth	30-45 cm depth
Sand (g kg^{-1})	757 ± 3.5	749 ± 2.5	735 ± 3.2
Silt (g kg^{-1})	125 ± 1.5	118 ± 1.8	112 ± 1.4
Clay (g kg^{-1})	118 ± 0.6	133 ± 0.5	153 ± 0.4
Textural class	Sandy loam	Sandy loam	Sandy loam
Bulk density (Mg m^{-3})	1.65 ± 0.02	1.68 ± 0.03	1.71 ± 0.04
pH (water)	5.8 ± 0.05	5.7 ± 0.06	5.8 ± 0.04
Organic matter (%)	1.75 ± 0.01	1.53 ± 0.02	1.24 ± 0.02
Total N (%)	0.14 ± 0.01	0.11 ± 0.01	0.09 ± 0.01
Available P (mg kg^{-1})	7.1 ± 0.4	6.8 ± 0.3	5.9 ± 0.2
Exchangeable K (cmol kg^{-1})	0.11 ± 0.01	0.09 ± 0.01	0.07 ± 0.01
Exchangeable Ca (cmol kg^{-1})	1.62 ± 0.02	1.42 ± 0.02	1.26 ± 0.03
Exchangeable Mg (cmol kg^{-1})	0.33 ± 0.01	0.27 ± 0.01	0.23 ± 0.01

Table 2

Chemical composition of various green manures

Green manure	OC (%)	N (%)	C:N	P (%)	K (%)	Ca (%)	Mg (%)
Neem leaves	40a	1.30c	30.8a	0.83a	1.67c	0.77d	0.75a
Leucaena leaves	39a	3.23a	12.1c	0.23c	1.68c	1.24b	0.35c
Moringa leaves	36b	2.56b	14.1b	0.43b	2.04b	2.62a	0.56b
Gliricidia leaves	41a	3.26a	12.6c	0.41b	2.76a	1.08c	0.36c

Values followed by similar letters under the same column are not significantly different at p = 0.05 according to Duncan's multiple range test.

Incorporation of green manures and NPK fertilizer influenced soil bulk density and chemical properties in both years (2015/2016 and 2016/2017) (Table 3). When studied as individual factors, year (Y) was not significant for bulk density, but fertilizer (F) was significant for bulk density (Table 3). The Y × F interaction was not significant for bulk density. The second year (2016/2017) reduced bulk density compared with the first year (2015/2016) (Table 3). In both years, incorporation of green manure leaves significantly reduced soil bulk density compared to NPK fertilizer and the control (Table 3). This could be attributed to increased soil OM from decomposed green manures. Presence of green manures should have increased activities of beneficial soil fauna in organic matter decomposition which could lead to enhanced soil porosity and reduced soil bulk density (Salahin, Alam, Islam, Naher, & Majid, 2013). In both years, all treatments had similar trend for bulk density. In both years, there were no significant differences in bulk density between Moringa, Leucaena, Gliricidia and Neem leaves used as green manure (Table 3). Application of NPK fertilizer did not reduce soil bulk density compared with green manures. Averaged over cropping seasons, the green manures (Moringa, Leucaena, Gliricidia and Neem) reduced soil bulk density by 23% compared with NPK fertilizer and the control.

When studied as individual factors, year (Y) was significant for soil pH and N, but not significant for OM, P, K, Ca and Mg; fertilizer (F) was significant for soil pH, OM, N, P, K, Ca and Mg (Table 3). The interaction of Y × F were not significant for soil pH, OM, N, P, K, Ca and Mg. In both first year (2015/2016) and second year (2016/2017), incorporation of green manures increased soil OM, N, P, K, Ca and Mg compared to the control (Table 3). In both years, the treatments had similar trend for soil chemical properties. The second year (2016/2017) had higher concentrations of soil chemical properties compared to the first year (2015/2016). The high concentrations of OM, N, P, K, Ca and Mg in the second cropping season than the first cropping season could be attributed to improved soil organic matter status of the organic materials, since soil organic matter is a natural source of nutrients and cation exchange capacity. It also implies that the values of organic materials as fertilizers are cumulative and extend considerably beyond the year of application. This might be due to the slow release patterns of their nutrients. Adeleye and Ayeni, (2010) reported that the cumulative agronomic values of some organic wastes applied to agricultural soils could be more than five times greater in the post application period than the values realized during the year of application. There was no significant difference in pH between the first year (2015/2016) and the second year (2016/2017). In both years, among fertilizers, incorporation of green manures increased soil OM, N, P, K, Ca and Mg compared with the control. This indicates that nutrients in the plant tissues are released into the soil. NPK fertilizer increased soil N, P, K, Ca and Mg compared with the control. The OM of NPK fertilizer treated soil was similar to the control. NPK fertilizer did not increase soil OM because it did not contain organic matter. All the various green manures had similar pH, but pH of NPK fertilizer was significantly lower compared with other treatments. The significant decrease in pH of the plots treated with NPK fertilizer compared with organic manures and the control could be due to its acidic nature. In both years, Gliricidia leaves incorporated as green manure had the highest soil N, K and Mg compared with other green manures (Table 3). NPK fertilizer and the control decreased soil nutrient status over time, whereas incorporation of leaves of green manures increased soil nutrient status over time.

When studied as individual factors, year (Y) affected fresh root yield of cassava, but not plant height, number of leaves and leaf area index of cassava; fertilizer (F) did affect number of leaves, plant height, leaf area index and fresh root yield of cassava (Table 4). The interaction of Y × F did affect fresh root yield of cassava, but not plant height, number of leaves and leaf area index of cassava. In both years, incorporation of green manures and NPK fertilizer influenced growth and fresh root yield of cassava (Table 4). Year 2016/2017 (second crop) significantly increased number of leaves, leaf area index and fresh root yield of cassava compared with year 2015/2016 (first crop). The improved growth performance of cassava crops in the second year compared with the first year could be attributed in part to the increased plant nutrients availability due to residual concentration from the first cropping season and the subsequent application of the organic manure in the second year. Plant height in both years did not differ from each other. In both years, plant height, number of leaves, leaf area index and fresh root yield of cassava in green manured plots and NPK fertilizer treated plots were significantly greater than the control plots (Table 4). In the second year (2016/2017) of cropping, Gliricidia and other green manures significantly increased growth, and cassava fresh root yield (Figure 1) compared with NPK fertilizer. Across similar individual treatment over the 2 years, growth and cassava fresh root yield of control plots and NPK fertilizer plots decreased gradually over the years, whereas growth and cassava fresh root yield of green manured treated plots increased gradually over the years. In both years, and in all cases of growth (Table 4) and fresh root yield (Figure 1, Table 4) decreasing order was: Gliricidia > Moringa = Leucaena = Neem > NPK fertilizer > control. In the first year (2015/2016) and compared with control; Gliricidia, Moringa, Leucaena, Neem and NPK fertilizer increased fresh root yield of cassava by 53, 33, 30, 29 and 28%, respectively. In the second year (2016/2017), these treatments increased fresh root yield of cassava by 85, 65, 61, 60 and 36%, respectively. In the first year and compared with NPK fertilizer; Gliricidia, Moringa, Leucaena and Neem increased fresh root yield of cassava by 19, 4, 1 and 0.7%, respectively, whereas in the second year, the same treatments increased fresh root yield of cassava by 36, 22, 19 and 18%, respectively. Averaged across similar individual treatment, second year (2016/2017) Moringa, Leucaena and Neem increased cassava fresh root yield by 13, 13, 10 and 13%, respectively, compared to the first year (2015/2016).

Table 3

Effect of various green manures and NPK fertilizer on soil bulk density, and soil chemical properties

Year/ season	Fertilizer	Bulk density ($Mg\ m^{-3}$)	pH (water)	OM (%)	N (%)	P (mg kg^{-1})	K (cmol kg^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})
2015/2016	Control	1.56a	5.75a	1.48c	0.12e	6.4d	0.10e	1.37d	0.28d
	Moringa leaves	1.28b	5.65ab	2.84b	0.17c	11.4b	0.27b	2.73a	0.47b
	Leucaena leaves	1.29b	5.54bc	3.17a	0.20b	9.2c	0.24c	2.37b	0.48b
	Gliricidia leaves	1.28b	5.54bc	3.12a	0.22a	11.2b	0.32a	2.71a	0.61a
	Neem leaves	1.30b	5.55bc	2.83b	0.17c	12.7a	0.23c	2.34b	0.50b
	NPK 15-15-15 fertilizer	1.54a	5.34d	1.51c	0.16d	10.3c	0.22d	1.86c	0.39c
2016/2017	Control	1.51a	5.73a	1.42c	0.10e	6.0d	0.08e	1.31d	0.26d
	Moringa leaves	1.17b	5.63ab	3.24b	0.19c	13.6b	0.33b	3.13a	0.57b
	Leucaena leaves	1.19b	5.52bc	3.57a	0.22b	11.4c	0.30c	2.77b	0.54b
	Gliricidia leaves	1.18b	5.52bc	3.52a	0.24a	13.4b	0.38a	3.11a	0.67a
	Neem leaves	1.20b	5.53bc	3.23b	0.19c	14.9a	0.29c	2.74b	0.56b
	NPK 15-15-15 fertilizer	1.51a	5.32d	1.45c	0.14d	9.9c	0.20d	1.80c	0.37c
P									
Year (Y)		0.120	0.002	0.388	0.010	0.461	0.224	0.369	0.630
Fertilizer (F)		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y x F		1.000	0.999	0.998	0.735	0.995	0.895	0.995	0.993

p – Probability of F statistic from ANOVA; means in column for each effect followed by similar letter are not significantly different at p = 0.05 according to Duncan's multiple range test.

Table 4

Effect of various green manures and NPK fertilizer on growth and fresh root yield of cassava

Year/ season	Fertilizer	Fresh root yield ($t\ ha^{-1}$)	Plant height (m)	Number of leaves per plant	Leaf area Index (LAI)
2015/2016	Control	21.5c	1.05d	70c	1.57d
	Moringa leaves	28.6b	1.33bc	91b	2.32b
	Leucaena leaves	27.9b	1.46a	89b	2.24b
	Gliricidia leaves	32.8a	1.40ab	97a	2.61a
	Neem leaves	27.7b	1.31bc	86b	2.23b
	NPK 15-15-15 fertilizer	27.5b	1.35bc	87b	2.07c
2016/2017	Control	19.6d	0.99d	62e	1.43d
	Moringa leaves	32.4b	1.35bc	99bc	2.72b
	Leucaena leaves	31.6b	1.48a	105b	2.64b
	Gliricidia leaves	36.3a	1.42ab	113a	3.01a
	Neem leaves	31.3b	1.33bc	102b	2.63b
	NPK 15-15-15 fertilizer	26.6c	1.29c	79d	1.95c
P					
Year (Y)		0.005	0.840	0.690	0.494
Fertilizer (F)		0.000	0.000	0.000	0.000
Y x F		0.024	0.845	0.975	0.992

p – probability of F statistic from ANOVA; means in column for each effect followed by similar letter are not significantly different at p = 0.05 according to Duncan's multiple range test-

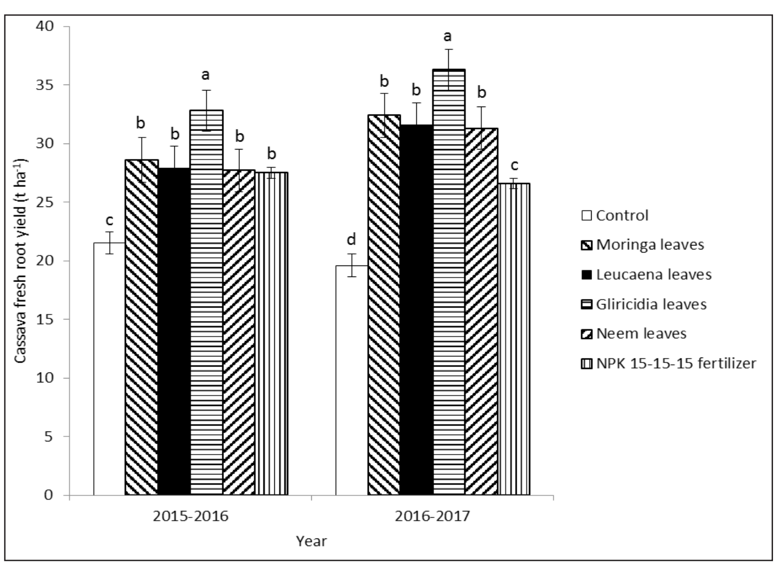

Figure 1. Effect of various green manures and NPK 15-15-15 fertilizer on fresh root yield of cassava in 2015-2016 and 2016-2017

In both years, incorporation of green manures and NPK fertilizer increased growth and fresh root yield of cassava compared with the control. The increase in the performance of cassava as a result of green manure could be due to reduced soil bulk density and increased availability of soil OM, N, P, K, Ca and Mg concentrations from the manures. The increase in the performance of cassava as a result of green manure compared with the NPK fertilizer could be due to reduced soil bulk density and increased availability of soil OM, N, P, K, Ca and Mg concentrations from the manures. Lampurlanes and Cantero-Martinez (2003) found that reduced soil bulk density enhances root growth and water and nutrient uptake and yield. The better performance of cassava under NPK fertilizer plots compared with the control might be due to availability of essential nutrient elements especially (K and N) from the inorganic fertilizer which were absorbed by the cassava plants. In both years, incorporation of Gliricidia increased performance of cassava compared with NPK fertilizer and other green manures due to availability of soil N and especially soil K (Table 3).

According to Howeler (2011) and Uwah, Effa, Ekpenyong and Akpan (2013), the two major elements that are particularly critical in production of cassava are K and N. Nitrogen plays a dominant role in promoting vegetative growth, including leaf development, and K being important in tuber initiation and bulking. Potassium is required in large amount which has a special role in carbohydrate synthesis and translocation. Abundant K supply favours the primary processes of photosynthesis. It also regulates the balance between assimilation and respiration in a way that improves net assimilation. This is a prerequisite for vigorous growth and the formation of reserve assimilates (Imas & John, 2013; Jansson, 1980). Potassium application not only enhances tuber yield, but also improves tuber quality (Imas & John, 2013; Nair & Aiyer, 1986). Soil K was greatly increased by green manure incorporation after the second year, irrespective of green manure treatments. The soil K increased by 13% in the second year of cropping due to incorporation of green manure, indicating that the incorporation of plant residues rich in K was advantageous. Cassava is known to accumulate more than 60% of the absorbed K in its storage roots (Howeler, 1991a; Pellet & El-Sharkawy, 1997), pointing to the need to replenish soil K in poor soils under continuous cassava cultivation. The results suggested that K was an important limiting factor (the main limiting nutrient) for storage root yield of cassava. Soil K level of 0.09 cmol kg^{-1} recorded under the control treatment was much below the critical level recommended for cassava (Cadavid et al., 1998; Howeler, 2002), hence poor growth and yield.

In both years, soil Ca and Mg were also greatly enhanced by incorporation of green manure leaves compared with NPK fertilizer and the control. For example, these two elements under the control plots depleted rapidly by continuous cassava cultivation. These findings indicate that incorporation of green manure leaves into poor sandy soils are advantageous in supplying adequate levels of Ca and Mg. The lower performance of cassava under NPK fertilizer compared with Gliricidia, Moringa, Leucaena and Neem leaves might partly be due to its quick release of nutrients within a short time that may not benefit long gestation crops like cassava, and also losses due to leaching and erosion.

When studied as individual factors, year (Y) was not significant for P, K, Ca, Fe, Zn, starch and HCN contents; fertilizer (F) did significant for P, K, Ca, Fe, Zn, starch and HCN contents (Table 5). The interaction of Y × F were not significant for P, K, Ca, Fe, Zn, starch and HCN contents. The second year (2016/2017) significantly increased P,

Table 5

Effect of various green manures and NPK fertilizer on mineral composition, starch and HCN contents of cassava roots

Year/ Season	Fertilizer	P	K	Ca (mg 100^{-1} g)	Fe	Zn	Starch (%[1])	HCN (mg kg^{-1})
2015/2016	Control	20.5d	189.4d	10.7d	0.12e	0.23d	19.7c	64.2a
	Moringa leaves	56.6a	348.8a	21.4a	0.27a	0.48a	29.3a	44.5d
	Leucaena leaves	28.4c	220.5c	13.7c	0.20c	0.44b	28.1a	49.9c
	Gliricidia leaves	43.1b	311.1b	14.0c	0.19cd	0.33c	28.6a	51.0c
	Neem leaves	44.7b	306.3b	17.4b	0.22b	0.44b	28.2a	50.6c
	NPK 15-15-15 fertilizer	43.0b	223.3c	13.5c	0.22b	0.32c	24.9b	56.0b
2016/2017	Control	18.1d	179.8d	8.9d	0.11e	0.21d	17.9c	63.4a
	Moringa leaves	65.8a	381.2a	23.6a	0.29a	0.52a	33.9a	38.9d
	Leucaena leaves	35.2c	252.9c	15.9c	0.22c	0.48b	32.7b	44.3c
	Gliricidia leaves	49.9b	343.5b	16.2c	0.21cd	0.37c	33.2b	45.4c
	Neem leaves	51.5b	338.5b	19.8b	0.24b	0.48b	32.8b	45.0c
	NPK 15-15-15 fertilizer	49.8b	253.7c	15.7c	0.24b	0.36c	29.5c	50.4b
P								
Year (Y)		0.283	0.383	0.423	0.449	0.798	0.994	0.206
Fertilizer (F)		0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y x F		1.000	0.995	0.996	0.996	0.871	0.358	1.000

p – probability of F statistic from ANOVA; means in column for each effect followed by similar letter are not significantly different at p = 0.05 according to Duncan's multiple range test

K, Ca, Fe, Zn and starch composition and reduced hydrocyanic acid (HCN) content compared with the first year (2015/2016) (Table 5). In the first year (2015/2016) and second year (2016/2017), the various green manures and the NPK fertilizer increased P, K, Ca, Fe, Zn and starch composition and reduced HCN content in cassava root tubers significantly compared with the control (Table 5). This could be adduced to nutrient availability in soil because of the mineralization of the manures/fertilizer leading to take-up by cassava plants. In both years, Moringa had the highest P, K, Ca, Fe and Zn composition and lowest HCN content compared with other treatments. In the first year (2015/2016) and second year (2016/2017), there were no differences in starch content between Moringa, Leucaena, Gliricidia and Neem. In both years, Moringa, Leucaena, Gliricidia, and Neem had higher starch content and lower content of HCN than NPK fertilizer. This could be attributed to their higher soil K levels and their subsequent absorption by cassava roots compared with NPK fertilizer. Organic manure reduced nutrient leaching due to its binding nature in building large and stable aggregates in most soils compared to chemical fertilizers which are susceptible to leaching of nutrients. Howeler (1985) found that application of fertilizer, especially K fertilizer, influenced the quality of tuberous roots resulting in an increase in dry matter and starch content and a decrease in cyanogenic potential. A marked decrease in total cyanogens (HCN) in fresh cassava roots was noted following the application of K fertilizer and this was attributed to increases in starch content and dry matter of the tuberous roots rather than a decrease in synthesis of cyanogens (Bokanga, Ekanayake, Dixon, & Porto, 1994; El-Sharkawy & Cadavid, 2000). Cadavid et al. (1998) found that application of NPK fertilizer resulted in a decrease in the concentration of total cyanogens in cassava roots, along with an increase in root biomass. Results of a long term fertilizer experiment carried out in India revealed that cassava plants supplied with ash and crop residues, which are known to have a high content of potassium, had low root cyanide content (Susan John, Ravindran, & George, 2005).

The correlation coefficient between soil properties and mineral composition, starch and HCN contents and growth and yield of cassava showed that in 2015/2016, cassava yield was more dependent on soil chemical properties (Table 6), whereas in 2016/2017 cassava yield, growth and mineral composition, starch and HCN contents were dependent on both soil chemical properties and soil bulk density (Table 7). The significant correlation of bulk density and growth, yield and mineral composition, starch and HCN contents in 2016/2017 could be related to the residual effects of the manure in the

Table 6

Correlation between soil properties and mineral composition, starch and HCN contents and growth and yield of cassava in 2015/2016

	P	K	Ca	Fe	Zn	Starch	HCN	Yield	Plant height	Number of leaves	LAI
Bulk density	-0.493 (0.321)	-0.729 (0.100)	-0.608 (0.200)	-0.578 (0.228)	-0.785 (0.065)	-0.927 (0.008)	0.877 (0.022)	-0.759 (0.008)	-0.741 (0.094)	-0.741 (0.092)	-0.860 (0.028)
pH	-0.297 (0.567)	0.042 (0.937)	0.072 (0.891)	-0.344 (0.504)	-0.078 (0.883)	-0.315 (0.543)	0.135 (0.799)	-0.482 (0.332)	-0.607 (0.192)	-0.518 (0.292)	-0.397 (0.436)
OM	0.362 (0.480)	0.635 (0.175)	0.502 (0.310)	0.471 (0.346)	0.726 (0.103)	0.874 (0.023)	-0.815 (0.048)	0.717 (0.109)	0.725 (0.103)	0.685 (0.133)	0.820 (0.046)
N	0.431 (0.393)	0.513 (0.298)	0.249 (0.634)	0.408 (0.421)	0.418 (0.410)	0.823 (0.044)	-0.655 (0.158)	0.954 (0.003)	0.866 (0.026)	0.929 (0.007)	0.950 (0.004)
P	0.847 (0.033)	0.821 (0.045)	0.730 (0.099)	0.791 (0.061)	0.704 (0.118)	0.841 (0.036)	-0.760 (0.080)	0.744 (0.090)	0.606 (0.202)	0.751 (0.085)	0.779 (0.068)
K	0.702 (0.12)	0.743 (0.090)	0.549 (0.259)	0.667 (0.148)	0.625 (0.185)	0.944 (0.005)	-0.833 (0.040)	0.976 (0.001)	0.856 (0.030)	0.984 (0.000)	0.994 (0.000)
Ca	0.734 (0.097)	0.849 (0.033)	0.716 (0.110)	0.733 (0.098)	0.768 (0.075)	0.975 (0.001)	-0.934 (0.006)	0.887 (0.018)	0.776 (0.070)	0.906 (0.013)	0.949 (0.004)
Mg	0.546 (0.263)	0.728 (0.101)	0.429 (0.396)	0.459 (0.360)	0.523 (0.287)	0.884 (0.019)	-0.728 (0.101)	0.948 (0.004)	0.746 (0.088)	0.892 (0.017)	0.973 (0.001)

Table 7

Correlation between soil properties and mineral composition, starch and HCN contents and growth and yield of cassava in 2016/2017

	P	K	Ca	Fe	Zn	Starch	HCN	Yield	Plant height	Number of leaves	LAI
Bulk density	-0.825 (0.028)	-0.717 (0.041)	-0.778 (0.013)	-0.868 (0.024)	-0.876 (0.040)	-0.883 (0.035)	0.818 (0.042)	-0.882 (0.020)	-0.852 (0.035)	-0.926 (0.008)	-0.939 (0.006)
pH	-0.361 (0.482)	-0.511 (0.301)	-0.179 (0.735)	-0.435 (0.388)	-0.216 (0.681)	-0.467 (0.351)	0.292 (0.574)	-0.285 (0.587)	-0.501 (0.311)	-0.234 (0.655)	-0.176 (0.739)
OM	0.462 (0.357)	0.364 (0.478)	0.615 (0.193)	0.535 (0.274)	0.765 (0.077)	0.785 (0.034)	-0.800 (0.026)	0.886 (0.019)	0.798 (0.037)	0.946 (0.004)	0.938 (0.006)
N	0.563 (0.245)	0.536 (0.273)	0.576 (0.231)	0.572 (0.235)	0.676 (0.140)	0.868 (0.025)	-0.822 (0.043)	0.979 (0.001)	0.906 (0.013)	0.978 (0.001)	0.973 (0.001)
P	0.813 (0.049)	0.772 (0.072)	0.866 (0.026)	0.805 (0.053)	0.822 (0.045)	0.917 (0.010)	-0.898 (0.015)	0.896 (0.016)	0.757 (0.031)	0.884 (0.020)	0.911 (0.012)
K	0.670 (0.146)	0.627 (0.183)	0.688 (0.130)	0.658 (0.155)	0.735 (0.096)	0.903 (0.014)	-0.882 (0.020)	0.993 (0.000)	0.886 (0.019)	0.974 (0.001)	0.993 (0.000)
Ca	0.771 (0.113)	0.628 (0.182)	0.790 (0.062)	0.715 (0.110)	0.819 (0.046)	0.894 (0.016)	-0.920 (0.009)	0.957 (0.003)	0.829 (0.041)	0.946 (0.004)	0.983 (0.000)
Mg	0.667 (0.148)	0.623 (0.187)	0.693 (0.127)	0.624 (0.186)	0.704 (0.118)	0.873 (0.023)	-0.853 (0.031)	0.986 (0.000)	0.822 (0.042)	0.972 (0.001)	0.994 (0.000)

second year of application which would have increased soil OM decomposition which led to enhancement of soil porosity and reduction in bulk density. Reduction in soil bulk density is known to increase root penetration and therefore water and nutrient uptake (Adekiya et al., 2017; Lampurlanes & Cantero-Martinez, 2003) which will consequently increase growth and yield.

Cost of purchasing of NPK fertilizer was higher than the cost of cutting and transporting each green manure treatment (Table 8). Use of Gliricidia produced the highest gross return (₦532,840 ha^{-1}) and net return (₦200,600 ha^{-1}) followed by Moringa treatment with a gross return of ₦469,700 ha^{-1} and net return of ₦137,460 ha^{-1}; the gross return and net return produced by Moringa was not significantly greater than that of Leucaena and Neem treatments. The lowest gross return (₦317,240 ha^{-1}) was produced by the control. All green manures, and the NPK fertilizer, produced higher net profit than the control. The economic returns and net benefits from all green manures were higher than for the NPK fertilizer treatment. The Gliricidia treatment was more cost effective and profitable in production of cassava than all other treatments, as indicated by its high return rate, or value/cost ratio of 13.37.

Table 8

Economics of producing cassava under green manures and NPK fertilizer tested in the first year (2015/2016) and second year (2016/2017)

Treatment	Monetary gain (₦ ha^{-1})	Production increase value (₦ ha^{-1})	Production increase (%)	Cost of cutting and transporting of green manures/ cost of NPK fertilizer (₦ ha^{-1})	Net return over each fertilization (₦ ha^{-1})	Return rate or value/cost ratio of each fertilization
Control	317,240	-		-	-	-
Moringa leaves	469,700	152,460	48.06	15,000	137,460	9.16
Leucaena leaves	458,920	141,680	44.66	15,000	126,680	8.45
Gliricidia leaves	532,840	215,600	67.96	15,000	200,600	13.37
Neem leaves	454,300	137,060	43.20	15,000	122,060	8.14
NPK 15-15-15 fertilizer	417,340	100,100	31.55	80,000	20,100	0.25

Notes: In the first year of 2015/2016, the price of fresh root yield of cassava was ₦15,400 per hectare; NPK 15-15-15 fertilizer was ₦9,800 per 50 kg bag. In the second year of 2016/2017, the price of fresh root yield of cassava was ₦15,400 per hectare; NPK 15-15-15 fertilizer was ₦9,800 per 50 kg bag.

This present study indicated that Gliricidia, Moringa, Leucaena and Neem could be used as green manure on degraded soils for sustainable soil and cassava productivity. The results of this investigation confirmed that these locally available plant species can be utilized as green manure to enhance soil and crop quality, and can serve as an alternative replacement for scarce and expensive chemical fertilizer.

CONCLUSIONS

Green manure serves as an important resource not only to supply nutrients for crops but also to replenish the soil organic matter content of most cultivated soils. For those that desire increased yield Gliricidia is recommended as green manure**.** For those desiring to grow cassava for root quality Moringa is recommended as green manure. Green manures can serve as an alternative replacement for inorganic fertilizers for optimum cassava yield and quality.

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