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Fertilizer Treatment Effects on Performance of Cassava under Two Planting Patterns in a Cassava-based Cropping System in South West Nigeria

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Abstract: A study was carried out at the Teaching and Research Farm of the University of Ibadan in south-western Nigeria to assess the effects of two cassava planting patterns and fertilizer type on growth and yield of cassava in cassava/maize/melon system. The experiment was a randomized complete block design (RCBD) with 3 replications, in a split-plot arrangement. The main factor was cassava planting pattern at 2 levels: A regular rectangular planting pattern at a spacing of 1 m was compared with triangular planting, where cassava was planted in squares of 2 m x 2 m with one plant at each corner of the squares and one in the centre at 1m. Fertilizer types were: Inorganic fertilizer (400 kg ha^{-1} NPK 15-15-15); Organic fertilizer (5 t^{-1} ha^{-1} yr^{-1} poultry manure + decomposed urban wastes); Inorganic + organic fertilizer (2.5 t^{-1} $ha^{-1}yr^{-1}$ organic fertilizer + 200 kg ha^{-1} NPK 15-15-15) and control (no fertilizer application). Overall cassava yield was significantly higher under regular planting (10.97 t ha^{-1}) than with triangular planting (9.40 t ha^{-1}). Average number of tubers per plant was also significantly higher with regular planting (6.90) than with triangular planting that had an average of 5.30 tubers per plant. Cassava tuber girth was however significantly higher under triangular planting pattern (212 mm) than for regular planting pattern (143 mm). Average tuber weight was also significantly higher with triangular planting (795 g) than for regular planting (424 g). Cassava yields were statistically similar under inorganic and organic fertilizer treatments. Inorganic fertilizer gave an average yield of 11.8 t ha^{-1}which was comparable with 11.0 t ha^{-1} given by a mixture of inorganic and organic fertilizers. The lowest yield of 7.91 t ha^{-1} was from the unfertilized plot.

Key words: Cassava intercropping; Spatial arrangement; Fertilizer type.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) plays an important role in terms of food security, employment creation and income generation for farm families in parts of the humid tropics where hunger and starvation prevail[28]. It is the major staple starch of the people in most parts of the tropics. Farmers generally realize a higher income from cassava production than from the production of most other staples[29]. Cassava is however not usually planted sole under the traditional cropping system so as to maximize the farmer's income generation and also to produce diverse crops on the limited available land area[16]. Due to the limitation of available land, majority of the subsistence farmers practice intercropping for several years without fallow, with no definite planting pattern. Little or no fertilizers are applied[11].Both soil fertility and crop yields decline over time[7].

Cassava/maize mixed cropping system is popular and widespread among the West African farmers[15]. The popularity is attributed to the compatibility and complementarities of the crops[15]. The faster - growing maize explores the environment early while the slower - growing cassava explores later. Other crops like melon, which has a creeping habit, could also be planted in the mixture to control weeds and soil erosion. Although intercropping produces a stable and sustainable system of cropping in the tropics, there is the need for development of appropriate spatial arrangements for intercropping.

Cassava removes substantial amounts of nutrients with the harvested roots, the highest being K, followed by N, Ca, Mg and P[8,25]. CIAT in Palmer[8], showed that the variety: M Col 1684 removed a total of 294 kg N, 34.4 kg P and 302 kg K ha^{-1}. Without application of fertilizers, soil nutrients are depleted. Yield depressions have been reported in many cases

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under cassava-based cropping systems. (1; 15).Decline in soil fertility is especially serious in tropical regions where the soil lacks adequate plant nutrients and organic matter due to leaching and erosion of topsoil by intense rainfall[13]. Inorganic fertilizers are usually expensive and not available in required quantities to the subsistence farmers who produce the bulk of the food. Organic inputs which are often proposed as alternatives cannot meet crop nutrients demand for large scale production because of their relatively lower nutrient composition; high application rates; high labour requirements and limited availability[24].

An integrated nutrient management program, in which both organic manure and inorganic fertilizer are used, has been suggested as a rational strategy[24], The combined use will increase synchrony and reduce losses by converting inorganic N into organic forms[18]. It also reduces the environmental problems that may arise from the use of sole inorganic fertilizers and improves the microbial properties of the soil[4]. There are evidences from field research that high and sustainable yields are possible with integrated use of fertilizers and manure[3,26,27].

This study was conducted to determine the effects of cassava planting pattern on the growth and yield of cassava in cassava/maize/melon system in SW Nigeria. It also investigated the effects of fertilizer type on the growth and the yield of the cassava.

MATERIALS AND METHODS

Site Characteristics: The experiment was conducted between April, 1994 and March, 1996 at the Teaching and Research Farm of the University of Ibadan in south-west Nigeria ($7^0$30'N; $3^0$54'E). Total annual rainfalls during the period of investigation were 1,140, 1,673 and 1425 mm for 1994, 1995 and 1996, respectively. The soil of the experimental site was an Alfisol[30]. It had low humus content with a deep red-clay profile, with top sandy texture. It was slightly acidic.

Soil Sampling: Twenty core samples were taken from the top 15cm of the soil to have a composite sample which was air-dried, crushed and passed through a 2mm sieve before it was analyzed for the nutrient contents. Soil pH was determined in distilled water at 1:1 soil to water ratio. Organic carbon was determined by the Walkley-Black[31] method and the total N by the regular micro kjeldahl method. Percentage organic matter was derived by multiplying % organic carbon by Broadbent's[6] factor of 1.72. Available P was determined by Bray's P1 test using 0.03N NH_4F in 0.025N HCl as extractant[5]. Exchangeable bases were determined by extraction with neutral normal NH_4OAC at soil: solution ratio 1:10. Potassium and Sodium in the extract were read by flame photometry. Magnesium and Calcium were determined by atomic absorption spectrophotometry. Soil exchangeable acidity (H+) was determined by titration of normal KCI-extracted acidity against 0.05N sodium hydroxide[22]. Effective cation exchange capacity (ECEC) was obtained by a summation of the exchangeable cations (K,Na,Ca,Mg) and exchangeable acidity. The result of the analysis is shown in Table 1.

Table 1: Initial chemical and physical characteristics of the soil (0-15 cm) at the Experimental site.

Nutrient	Value
pH(H_2O)	5.70
Total N (%)	18.0
Organic C (%)	1.75
Available P (mg kg-1)	4.72
Exchangeable K (cmolkg^{-1})	0.36
Exchangeable Ca (cmolkg^{-1})	3.75
Exchangeable Mg (cmolkg^{-1})	2.44
Exchangeable Na (cmolkg^{-1})	0.57
Exchangeable Acidity (H^+) (cmolkg^{-1})	0.12
ECEC	7.24
Base Saturation (%)	98.34
Mn (mg kg^{-1})	35.40
Fe (mg kg^{-1})	8.80
Zn (mg kg^{-1})	1.10
Cu (mg kg^{-1})	4.45
Sand (%)	85.00
Silt (%)	7.40
Clay (%)	7.60

Table 2: Chemical composition of the organic fertilizer used.

Nutrient	Value
C %	34.5
N %	1.65
P %	0.52
K %	0.91
Ca %	0.26
Mg %	0.25
Mn (mg kg^{-1})	0.32
Fe (mg kg^{-1})	2.36
Zn (mg kg^{-1})	0.96
Cu (mg kg^{-1})	0.64

Experimental Design and Procedure: The field experiment was a randomized complete block design (RCBD) in a split-plot arrangement, with three replications. The main factor was cassava planting patterns at 2 levels: Regular planting pattern where cassava was planted at a spacing of 1m x 1m to give a plant population of 10,000 plant ha^{-1} and a triangular planting pattern where cassava was planted in quincunx (i.e. arranged in squares of 2 m x 2 m with one plant at each corner of the squares and one in the centre) to give a plant population of 5,000 plants ha^{-1} (Fig. 1).
The sub – factor was fertilizer application. It was in sub plots of 24m^2. There were 4 types:

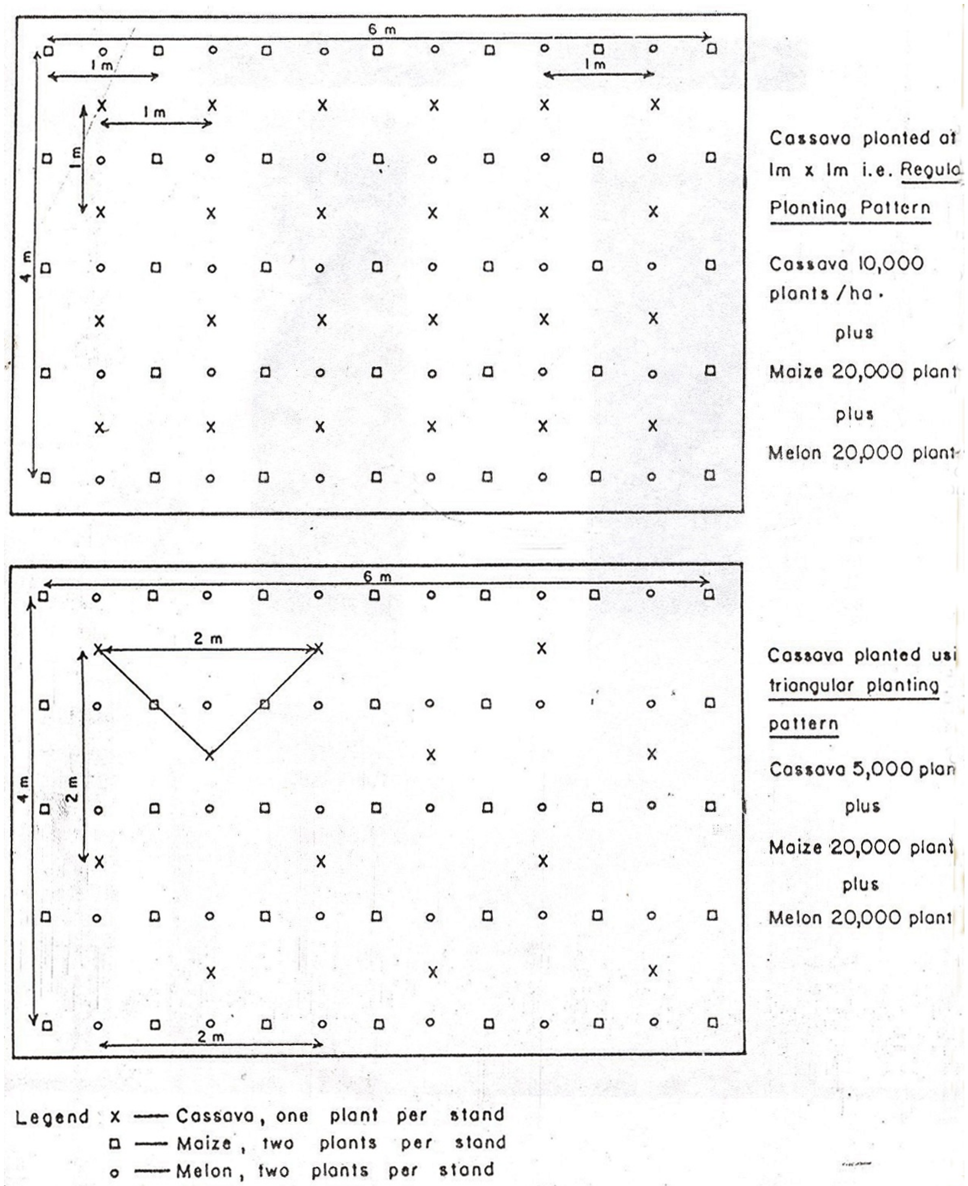

Fig. 1:

1. No fertilizer - Control
2. Inorganic fertilizer: - 400 kg ha^{-1} NPK 15-15-15. (i.e. 60kg N – 60kg P – 60kg K/ha based on recommendations for cassava/maize/melon mixture.
3. Organic fertilizer: Mixture of poultry manure and decomposed urban refuse (1:1) at the rate of 5 t^{-1} ha^{-1} $year^{-1}$[12].
   The chemical composition of the organic fertilizer used during the experiment is presented in Table 2.
4. Inorganic + Organic fertilizer: - 200 kg ha^{-1} NPK 15-15-15 and 2.5 t ha^{-1} organic fertilizer (i.e. half of inorganic and organic fertilizers rate combined).

The rates used for the organic and inorganic fertilizer treatments were based on the recommendation of Fertilizer Procurement and Distribution Division for the zone[12]. The combined organic and inorganic fertilizer treatment was to investigate the effects of complementary application at a reduced rate.

Planting Materials: Maize (*Zea mays* L) variety DMR LSR-W, which is downy mildew (*Perenoschlerospora maydis*) and Streak resistant was planted with local variety of "egusi" melon (*Colocynthis vulgaris*) and cassava (*Manihot esculenta* Crantz) variety: TMS 30572 which is an improved, early - maturing and low-branching variety.

Experimental: The site for the study had been cultivated with maize followed by cowpea for three years before it was left to fallow for a year prior the commencement of the experiment. The site was covered by both annual and perennial weeds. It was slashed and cleared manually without burning.

It was thereafter mechanically ploughed and harrowed. Organic fertilizer was applied a week before planting. It was uniformly spread on the plots and lightly worked into the soil with a hoe. The actual quantity applied per plot of $72m^2$ was 36 kg whereas half of this (18 kg) was applied to plots treated with a mixture of inorganic and organic fertilizers. Inorganic fertilizer was applied in a ring round each plant at 3 weeks after planting. 2.88 kg was applied to each of the plots treated with sole inorganic fertilizer and 1.44 kg applied to plots treated with a mixture of inorganic and organic fertilizers.

Cassava, maize and melon were planted on the flat at the same time (Fig. 1) in each year of experimentation. Planting was done on 27th April, 1994 and on 22nd April 1995. Maize and melon were planted at a spacing of 1 m x 1 m at 2plants /stand to achieve a plant population of 20,000 plants ha^{-1} for each of the crops. Cassava was planted, based on the planting pattern. The plots were weeded manually whenever necessary, throughout the experimental period. Maize was harvested fresh at 12 weeks after planting (WAP) and it was sun - dried to 14 % moisture content to get the dry grain weight. Melon fruits were gathered when the vines had dried up. The fruits were broken with a club and left for 5 days to soften for easy extraction of the seeds. Seeds were also sun - dried to 14 % moisture content and weighed. Cassava was harvested at 12 months after planting (MAP).

Data Collection: Data were taken on cassava at 12 months after planting (MAP). Plant height was taken from ground level to the top most leaf. Stem girth was taken at 1 m above ground level and tuber girth taken at the mid region was estimated from measurement of the circumference with a flexible tape. Fresh stem weight and root yield were taken from plants within a net plot of $15m^2$. Number of tubers per plant was a visual count. Average fresh tuber weight was taken by weighing the tubers from the net plot..

Data Analysis: Analysis of Variance (ANOVA) procedure was carried out to determine the differences in parameters using planting pattern as main plot and fertilizer type as sub-plots. Mean values were compared using Duncan's Multiple Range Tests (DMRT) at 0.05 level of probability when the F-ratio was significant.

RESULTS AND DISCUSSIONS

Cassava planting pattern did not have significant effects on maize grain yields in both years of planting. Makinde and Alabi[20] also found that maize grain yield was not significantly affected by spatial arrangement and intercropping with melon. Yield of melon under triangular planting pattern was significantly higher than that obtained under regular planting pattern. This could be attributed to competition for soil resources (nutrients and moisture). Competition for these resources would be higher under regular planting pattern where cassava was planted at 10,000 plants/ha in comparison with 5,000 plants/ha under triangular planting pattern. Maize yield average was 2.31 t ha^{-1} with inorganic + organic fertilizer application , 2.04 t ha^{-1} for inorganic fertilizer , 1.63 t ha^{-1} for organic fertilizer and 1.13 t ha^{-1} for the control treatment that had no fertilizers. It has been reported by Makinde *et al.*[21] that maize yields from sole inorganic fertilizer and from a mixture of organic and inorganic fertilizer applications were similar and were significantly higher than from organic fertilizer application. They also found that organic fertilizer application did not benefit the yield of maize significantly. Melon yields were statistically similar with the different fertilizer types. The lowest yield (0.20 t ha^{-1}) was obtained from the unfertilized plot while the highest of 0.32 t $ha^{-1}$was got from organic fertilizer application (Table 3).

There were significant differences in cassava height at harvest under the two planting patterns with regular planting pattern producing taller plants (1.69 m) than triangular planting pattern (1.47 m) over the two years (Table 4). Cock *et al*., (10) reported that cassava responded to increased competition by diverting more dry matter to stem. Jalloh[17] also found that the stem of cassava planted with rice elongated due to competition with the component crop.

Inorganic fertilizer application gave plants not significantly shorter (1.65 m) than that recorded under inorganic + organic fertilizer (1.69 m) but were both significantly taller than recorded from organic and no fertilizer treatments. Cassava had a thicker stem girth under triangular planting (84 mm) than regular planting pattern that had plants 68 mm thick. (Table 4). In 1994, stem girth under inorganic fertilizer (74 mm) and inorganic + organic fertilizer (79 mm) were similar and were higher than from organic fertilization and from the unfertilized plots. In 1995 however, cassava stem girth values were

Table 3: The effects of planting pattern and fertilizer type on yield of early season maize and melon in intercrop with cassava.

Treatment		Maize yield (t ha^{-1})			Melon yield (t ha^{-1})		
		1994	1995	Average	1994	1995	Average
Planting pattern							
	Regular	1.73a	1.75a	1.74	0.10b	0.15b	0.13
	Triangular	1.79a	1.80a	1.80	0.19a	0.24b	0.22
Fertilizer							
	No fertilizer	1.26c	1.00c	1.13	0.16b	0.24b	0.20
	Inorganic	2.03a	2.05a	2.04	0.26a	0.33a	0.30
	Organic	1.63b	1.63b	1.63	0.28a	0.35a	0.32
	Inorg. + org.	2.20a	2.42	2.31	0.26a	0.34a	0.30

Values followed by the same letter in the same column under each treatment are not significantly different at P = 0.05 (DMRT)

Table 4: The effect of planting pattern and fertilizer type on plant height, stem girth and stem weight of cassava planted in intercrop with maize and melon.

Treatment	Average Cassava plant height (m)			Stem Girth (mm)			Stem Weight (kg)		
	1994	1995	Average	1994	1995	Average	1994	1995	Average
Planting pattern									
Regular	1.64a	1.74a	1.69	63.00b	73.00b	68.00	6.4a	8.3b	7.35
Triangular	1.42b	1.51a	1.47	78.00a	91.00a	84.50	6.9a	11.4a	9.15
Fertilizer									
No fertilizer	1.36c	1.46b	1.41	62.00b	69.00b	65.50	6.2b	7.1c	6.65
Inorganic	1.58ab	1.72a	1.65	74.00a	85.00a	79.50	7.1a	11.4a	9.25
Organic	1.52b	1.61a	1.57	66.00b	87.00a	76.50	6.2b	10.1b	8.15
Inorg. + org.	1.65a	1.72a	1.69	79.00a	87.00a	83.00	7.0a	10.8ab	8,90

Values followed by the same letter in the same column under each treatment are not significantly different at P = 0.05 (DMRT)

statistically similar under all the fertilizer treatments.

Cassava fresh stem weight was significantly higher under triangular planting pattern in 1995 alone (11 40 t ha^{-1}). Anil-Kumar and Sasidhar[2] reported reduced competition when cassava was planted at lower density because more light and nutrients were available.

Average cassava fresh stem weight value obtained over the two years under inorganic fertilizer was the highest (9.25 t ha^{-1}). It was slightly higher than 8.90 t ha^{-1} recorded under inorganic + organic fertilizer. Over the two years, the lowest fresh stem weight of 6.65 t ha^{-1} was obtained from the unfertilized plots (Table 4).

Cassava root yield was significantly higher under regular planting pattern (10.97 t ha^{-1}) than for triangular planting pattern (9.40 t ha^{-1}) for the two years due to higher cassava population (Table 5). Inorganic fertilizer application gave an average yield of 11.77 t ha^{-1} while inorganic + organic fertilizer gave 10.97 t ha^{-1} .The control treatment, with no fertilizers gave 7.97 t ha^{-1} Yields obtained under inorganic fertilizer and inorganic + organic fertilizer application were similar but were higher than from organic fertilizer application (Table 5).

Table 5: The effects of planting pattern and fertilizer type on yield of cassava.

Treatment		Cassava root yield (t ha^{-1})		
		1994	1995	Average
Planting pattern				
	Regular	9.40a	12.53a	10.97
	Triangular	7.61b	11.19a	9.40
Fertilizer				
	No fertilizer	7.04c	8.78d	7.91
	Inorganic	9.55a	13.98a	11.77
	Organic	8.23b	11.97c	10.10
	Inorg. + org.	9.21a	12.72b	10.97

Values followed by the same letter in the same column are not significantly different at P = 0.05 (DMRT)

Average number of tubers per plant was lower with triangular planting (5.30) than the regular planting that had average of 6.90 tubers per plant. There were no significant differences in average number of tubers per plant under the various fertilizer treatments (Table 6). Cassava tuber girth was significantly higher under triangular planting pattern (212 mm) than for regular planting pattern (143 mm). Fertilizers also had effects on tuber girth over the two years. Inorganic fertilizer application gave tubers 197 mm big while inorganic + organic fertilizer gave tubers 184 mm big. The smallest tubers of 155 mm

Table 6: The effects of planting pattern and fertilizer type on yield components of cassava planted intercrop with maize and melon.

Treatment		Average No. of Tubers plant^{-1}		Tuber girth(cm)		Average Tuber Weight (g)	
		1994	1995	1994	1995	1994	1995
Planting pattern							
	Regular	6.7a	7.1a	136.00b	150.00b	368.0b	480.9b
	Triangular	5.0b	5.5b	202.00a	222.00a	618.8a	971.5a
Fertilizer							
	No fertilizer	5.4b	6.9a	139.00c	172.00b	325.0b	537.2c
	Inorganic	6.3a	6.2ab	194..00a	199.00a	586.1a	828.8a
	Organic	6.2ab	6.6a	170.00b	184.00b	515.5a	628.8b
	Inorg. + org.	5.7b	5.6b	177.00ab	190.00ab	546.9a	909.9a

Values followed by the same letter in the same column under each treatment are not significantly different at P = 0.05 (DMRT)

big were got from the no – fertilizer treatment (Table 6). Howeler *et al.*[14] reported that higher tuber girth resulted from lesser number of roots for storing the synthesized assimilates. Magoon *et al.*[19] also found that the storage root size was inversely related to the number of tuber.

Cock *et al.*[9] found that a disadvantage of growing cassava at high plant population is the decrease in root size which may lead to a decrease in the yield of commercially acceptable roots. Odurukwe[23] reported that increased yields resulting from higher population density are achieved at the expense of size of tuber. He however pointed out that this is only important where tuber size determines marketability.

In 1994, tuber weights from inorganic, organic and a mixture of inorganic and organic fertilizers were statistically the same. However, average tuber weight from the unfertilized plot was significantly lower than from all the fertilized plots. Average tuber weight was higher with triangular planting (795 g) than for regular planting. (424 g). Inorganic + organic fertilizer gave the biggest tubers of 728 g which was statistically the same with values obtained with inorganic fertilizer application (707 g). The smallest tubers were from the unfertilized plots (Table 6).

Conclusion: Cassava yield is more favoured with the regular planting but the development of big-sized tubers is more favoured with the triangular planting. The trend of cassava growth and yield was generally most favoured with inorganic fertilizer, followed by application of a mixture of organic and inorganic fertilizers. This indicates that cassava was still able to utilize nutrients from both inorganic and organic sources in the presence of early season crops.

This study has shown that higher cassava yield produced at high plant population is compensated for by tubers with big size obtained at low plant population. Cassava was also able to utilize nutrients to produce bigger tubers with better quality in the fertilized plots than from the unfertilized ones after the early season maize and melon had been harvested.

REFERENCES

1. Ambe, T.J., S.N. Lyonga, A.A. Agboola and S.K. Hahn, 1988. The performance of Cassava with other staples in intercrops in Cameroon. *In proc.* of 1st Annual meeting of Cassava-based cropping system research group, IITA, Ibadan, Nigeria, pp. 91-97.
2. Anil Kumar, A.S. and V.K. Sasidhjar, 1985. Productivity of cassava as influenced by planting patterns, intercrops and spatial arrangement. In: T. Ramanujam, P.G. Rajendran, M. Thankappan, C. Balagopal and R.B. Nair (ed.) *Tropical Tuber Crops Production and Utilization*. Proc. of National Symp. On Production and Utilization of Tropical Tuber Crops Nov. 27-29, CTCRI, Trivandium India Pg. 105-107.
3. Bayu, W., N.F.G. Rethman, P.S. Hammes and G. Alemu, 2006. Effects of Farmyard Manure and Inorganic Fertilizers on Sorghum Growth, Yield and Nitrogen use in a Semi-arid area of Ethiopia. J. Plant Nutrition, 29(2): 391-407
4. Belay, A., A.S. Classens, F.C. Wehner and J.M. De Beer, 2001. Influence of residual manure on selected nutrient elements and microbial composition of soil under long term crop rotation. South Africa J. Plant and Soil, 18: 1-6
5. Bray, R.H., L.T. Kurtz, 1945. Determination of Total, Organic and Available Forms of Phosphorus in Soil. Soil Sci., 59: 39-45.
6. Broadbent, F.E., 1953. The Soil Organic Fraction. Adv. Agron., 5: 153-183.

7. Cadavid, L.F., El- Sharkawy, M.A. Acosta A. and T. Sanchez, 1998. Long term effects of mulch, fertilization and tillage on cassava grown in sandy soil in northern Colombia. Field Crops Research, 57: 45-56.
8. C.I.A.T., 1982. Centro International Agricultural Tropicale (CIAT). Report of Cassava Programme: Annual Report for 1981; CIAT: Cali, Columbia, C1-50.
9. Cock, J.H., H.D. Wholey and O. Guitierrez de las Casa, 1977. Effects of spacing on cassava (*Manihot esculenta* Crantz). Experimental Agriculture, 13: 289-299.
10. Cock, J.H., D. Franklin G. Sandoval and O. Juri, 1979. The ideal cassava plant for Maximum Yield. Crop Science, 19: 271-279.
11. El-Sharkawy and L.F. Cadavid, 2000. Genetic variation within cassava germplasm in response to potassium. Experimental Agriculture, 36: 323-334.
12. Fertilizer Procurement and Distribution Division (FPDD), 1980. Fertilizer use and Management practices for crops in Nigeria. Federal Ministry of Agriculture and Rural Development Abuja, Nigeria, 163 pp.
13. Gutteridge, R.C. and H.M. Shelton, 1994. The role of forage tree legumes in cropping and grazing systems. In: Gutteridge R.C. and Shelton HM (eds.) Forage Tree Legumes in Tropical Agriculture. CAB International, United Kingdom
14. Howeler, R.H., L.F. Cadavid and E. Burckhardt, 1982. Response of cassava to V.A.mycorrhizal inoculation and phosphorus application in greenhouse and field experiments. Plant and Soil 69: 327-339.
15. Ikeorgu, J.E.G., 1984. Some micro-environmental changes under cassava (*Manihot esculenta Crantz*) – maize (*Zea mays* L) intercrops grown with okra (*Abelmoschus esculentus* L.) and 'egusi' melon (*Colocynthis vulgaris* L.) Ph.D. Thesis, University of Ibadan, Nigeria. 259pp.
16. Iloka, A. and J.E.G. Ikeorgu, 1989. On-farm evaluation of the productivity and farmer's acceptability of four improved cassava cultivars intercropped with yam and maize in Nsukka and Awka ADP zones of Anambra state. Nigeria Cassava-based cropping systems research 2, IITA Ibadan, 256pp.
17. Jalloh, A., 1995, Production of rice (*Oryza sativa* L.) cassava (Manihot esculenta Crantz*)* Intercrop on the Upland in Sierra Leone. Ph.D. Thesis. University of Sierra Leone. 243 pp.
18. Kramer, A.W., T.A. Doane, W.R. Horwath and C.V. Kessel, 2002. Combining fertilizer and organic inputs to synchronize N supply in alternative cropping systems in California. Agriculture, Ecosystem and Environment, 91: 233-243
19. Magoon, M.L., R. Krishnan and K.R. Lakshmi, 1972. Association of plant and tuber characters with yield of cassava Trop. Root and Tuber Crops Newsletter, 5: 29-30.
20. Makinde, E.A. and B.S. Alabi, 2002. Influence of spatial arrangement on the growth and yield of maize-melon intercrop. Moor Journal of Agricultural Research, 3(1): 59-63.
21. Makinde, E.A., A.A. Agboola and F.I. Oluwatoyinbo, 2001. The effects of organic and inorganic fertilizers on the growth and yield of maize in a maize/melon intercrop. Moor Journal of Agricultural Research, 2: 15-20
22. McClean, E.O. 1982. Soil pH and Lime Requirement. In: Methods of Soil Analysis. Part 2; Page, A.L. Baker, D.E., Ellis, R., Jr., Keeney, D.R., Miller, R. H., Ohoades, J. D., Eds.; Soil Sci. Soc. Am. Am. Soc. Of Agron.; Madison, WI, Agron. No. 9.
23. Odurukwe, S.O., 1986. Yam-maize intercropping investigation in Nigeria, Tropical Agriculture, 63: 17-21.
24. Palm, C.A., R.J.K. Myers S.M. Nandwa 1997. Combined use of organic and inorganic nutrient sources for soil fertility maintenance and replenishment In: Buresh R.J., Sanchez,, D.A., Calhoun F (eds.) Replenishing Soil Fertility in Africa. Soil Science Society of America Madison, Wis., pp: 193-217.
25. Pellet, D. and M.A. El Sharkawy, 1993. Cassava varietal response to phosphorus fertilization. I. Yield biomass and gas exchange. Field Crops Research, 35: 1-11
26. Raman, K.R., M.P. Singh, R.O. Singh and U.S.P. Singh, 1996. Long-term effects of inorganic and organic-inorganic nutrient supply systems on yield trends of Rice-Wheat cropping system. J. Appl. Biol., 6(1-2): 56-58.
27. Singh, N.P., R.S. Sanchan, P.C. Pandey and R.S. Bishi, 1999 Effects of decade long fertilizer and manure application on soil fertility and productivity of Rice-Wheat system in a Mollisol. J. Indian Soc. Soil Sci., 47(1): 72-80.
28. Ugwu, B.O. and U.J. Ukpabi, 2002. Potential of soy-cassava flour processing to sustain increasing cssava prouctin in Nigeria. Outlook on Agriculture. 31(2): 129-133.

29. Ugwu, B.O., 1996. Increasing cassava production trend in Nigeria and prospects for sustaining the trend. Outlook on Agriculture, 25(3): 179-185.
30. United States Department of Agriculture (USDA), 1975. Agriculture handbook No. 436 SCA/VSA Washington DC. U.S.A. 200 pp.
31. Walkley, A., T.A. Black, 1934. An Examination of the Degtjaref Method for Determining Soil Organic Matter and a Proposed Modification of the Chronic Acid Titration. Soil Sci., 37: 29-38.