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Original Article

Agronomic Evaluation of New Varieties of Cassava (*Manihot esculenta* Crantz) under Different Rates and Modes of NPK (12-12-17-2) Fertilizer Application in Two Seasons

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Abstract

A study was carried out at the Teaching and Research Farm of the Department of Crop Science, University of Nigeria, Nsukka to evaluate the growth and yield of four improved cassava varieties, determine their optimum NPK fertilizer rate and the best modes of fertilizer application for increased productivity. The experiment was factorial laid out in a randomized complete block design with three replications. Four varieties of cassava, four fertilizer rates and three modes of fertilizer application were used for the study. The early planting had higher survival count, number of leaves, tuber and garri yield when compared with late planting. The variety TMS 98 05 05 gave significantly ($p < 0.05$) higher number of leaves, tuber and garri yields of 39.8 and 9.68 t/ha, respectively, at 12 months. At 6 months of crop growth, 200 kg/ha fertilizer application rate gave significantly higher tuber and garri yield of 24.69 t/ha and 5.15 t/ha, respectively. Furthermore, 400 kg/ha of NPK fertilizer rate gave higher tuber and garri yields of 39.4 and 10.12 t/ha, respectively at 12 months of crop growth. Split application of fertilizer gave significantly higher tuber and garri yield from single application, though it is statistically similar to split-split application. Therefore, early planting, 400 kg/ha fertilizer rate and split application should be adopted for cassava production. The variety TMS 98 05 05 with higher growth and yield should also be adopted by farmers for cassava production in Nsukka derived savannah agro-ecology.

Keywords: Cassava production; evaluation; fertilizer application; season; yield

Introduction

Cassava (*Manihot esculenta* Crantz.) is a perennial shrub of the family Euphorbiaceae. It is a root crop that is propagated vegetatively from stem cuttings for commercial purposes, but can also be propagated by seed. Due to its adaptability to marginal soils and erratic rainfall, high productivity per unit of land and labour, the possibility of supply throughout the year has been obtained (Nweke *et al*., 2002). The adaptation to different edapho-climatic conditions (Adeniji *et al*., 2011) makes cassava a favorite dry season crop grown in inland valleys in West and central Africa (Lahai and Ekanayake, 2009), noting it is highly susceptible to excessive water (Ande, 2011).

Cassava tubers contain about 92.2% carbohydrates and 3.2% protein in its dry matter, thus is said to have high energy content. It leaves and tender shoots are important source of vitamins, minerals and proteins (Balagopalan, 2002; Nweke *et al*., 2002). The tubers are mostly processed into Cassava flour, garri and fufu in Nigeria. It can also be cooked or eaten pounded and consumed in its raw form, most especially the sweet variety (Ogundari and Ojo, 2007). Cassava products are used in various forms for human consumption, livestock feed and manufacturing of industrial products (Ene, 1992). According to IITA (1990), cassava products are also important feed stuff for livestock formulation. For example, it has a capacity of substituting up to 44% maize in pig feed without any reduction in the performance (Okeke, 1998); it can also be observed that in compounding feed for pigs, broiler, pullets and layers, cassava meal plays a significant role.

To increase the yield potential of cassava, the crop has been reported to respond to good soil fertility and adequate fertilizer (Howeler, 1996). According to Howeler (1991) the major nutrients required by cassava for optimum top growth and tuber yields are nitrogen (N) and potassium (K). Soils that have low N (<0.10% total N) and K (<0.15

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meg/100 g) will require an additional fertilizer for optimum tuber yield (Kang and Okeke, 1991). Adequate K levels in the soil stimulate the response to N fertilizers, but excess amount of both nutrient leads to luxuriant growth at the expense of tuber formation (Onwueme and Charles 1994). Moreso, Kang and Okeke (1991) reported that cropping systems influence fertilizer requirements of cassava; for example, the continuous cropping of cassava leads to fast depletion of major nutrients, especially N and K and will require fertilizer supplement to give stable yield. Cassava removes about 55 kg/ha N, 132 kg/ha P and 112 kg/ha K (Howeler, 1991). Sittibusaya and Kurmarohita (1978) reported that after 15 years of continuous cassava production without fertilization in South East Thailand, yields dropped from an initial level of 30 t/ha to only 17 t/ha. When these were exhausted, soils were fertilized with 164 kg and 312 kg/ha, yield increased from 22 to 41 t/ha.

Furthermore, in recent years the production of cassava has increased, but its current production rate per hectare (8-10 t/ha) is far lower than the potential (30-60 t/ha). However, causes of low productivity in cassava production are the high cost of farm inputs such as fertilizer and planting materials, deficiencies in the supply and delivery of farm inputs, soil fertility status of the farm land, cropping system adopted, the rainfall pattern during the growing season, sector dominance (90%) by small holder, resource-poor farmers etc. The indifference towards low productivity can also be attributed to the low and unstable prices of cassava tubers. Available record shows that both in absolute terms and on per hectare basis, Nigeria ranks among the lowest consumers of fertilizers in the world (Aderi *et al*., 2010). Its current fertilizer use is about one million tonnes per annum, while the projected demand estimate is 3.7 million tonnes (Aba, 2010). Average worldwide rates are 93 kg/ha of NPK, while the rate for Nigeria is about 13 kg/ha (Aderi *et al*., 2010).

Hence, it is important to determine NPK fertilizer requirements and the best mode of application for increased cassava productivity, in improved cassava varieties. Therefore, the objectives of the present study were to evaluate growth and yield of four improved cassava varieties, to determine the optimum NPK fertilizer rate and the best mode of fertilizer application for increased productivity.

Materials and Methods

The field trail was conducted at the Teaching and Research farm of the Department of Crop Science, University of Nigeria, Nsukka during 2014 planting season. Nsukka derived as savannah agro-ecology are and is located at latitude 06°54° N, longitude 07°24 E and altitude of 550 m above sea level. The rainfall is bimodal with the peaks in June and September, respectively. The soil is broadly characterized as sandy clay loam ultisol (oxic paleustult) and belongs to Nkpologu series (Mbagwu, 1992). The cassava varieties were planted at two seasons (e.g. early and late season). During the early season, cassava was planted between April to May at the stabilization of rainy season, while during the late season, it was planted between July to August at the mid - month of rainy season, which are the planting seasons of cassava in this agro-ecology. The experiment was 4x4x3 factorial laid out in randomized complete block design (RCBD) with 3 replications. The factors were four varieties of cassava (TMS 01 1368 (yellow root), TME 419, TMS 98 05 05 and TMS 05 10), four rates or levels of NPK fertilizer (0 kg/ha, 200 kg/ha, 400 kg/ha and 600 kg/ha) and three modes of fertilizer application (single at 4 weeks after planting, split at 4 and 8 weeks after planting and split-split at 4, 8 and 12 weeks after planting). The treatments comprised all possible combinations of cassava varieties, fertilizer rates and modes of fertilizer application. The experimental field measuring 2,461m^2 was cleared, ploughed, harrowed, ridged and marked out into three blocks. Each block was sub-divided into 48 plots, each with a dimension of 5 m × 2 m per plot. The cassava was planted at a spacing of 1 m × 1 m to obtain a plant population of 10,000 m^2 per hectare. Healthy cassava stem collected from National Root Crops Research Institute (NRCRI), Umudike, were cut between 4-6 nodes ,where two nodes were exposed above the soil surface when planted. The fertilizer used was NPK-Mg 12-12-17-2 and was applied by band placement method. Weeding was done three times manually during the period of the research.

Soil samples were randomly collected before planting from three representative locations by augering to the depth of 20 cm with a steel auger. The samples were bulked together and the composite samples were taken for laboratory analysis to determine the physical and chemical characteristics of the site. The organic matter was determined using the Walkey & Black method (Nelson and Sommers, 1996). Particle size analysis was done by pipette method (Gee and Bauders, 1986); soil pH in water was determined using soil: water ratio of 1:2 by a pH meter with a glass electrode. Exchangeable bases in the samples were extracted in 0.1 M NH_40AC at pH 7.0. Calcium (Ca) and Magnesium (Mg) in the extract, after which were read by Atomic Absorption Spectrophotometer. Total Nitrogen (N) in the soil was determined by Kjedahl digestion (Bremner, 1996). Sodium (Na) and Potassium (K) were analyzed by using flame photometry. Exchangeable acidity was determined by extracting with 1 M KCl and determined by NaOH titration (Sims, 1996). Available phosphorous was determined by Bray-1 extraction and determined colourimetrically by the molybdenum blue procedure (Bray and Kurtz, 1945).

The following data were collected on the agronomic and processed parameters on each plot: survival count, number of branches, number of leaves, plant height, stem girth, canopy diameter, tuber and garri yields. After 3 weeks of planting, the surviving sprouted stems were counted to ascertain the plot population. Numbers of branches were visually counted on 2 and 4 months after planting (MAP) to note the architecture and branching types. Number of leaves was visually counted on 2 and MAP. Stem girth was measured at 6, 8, 10 and 12 MAP when the stem was of good size and was measured in millimetre (mm) using vernier calipers. Canopy diameter was taken at 8, 10 and 12 MAP to get the area covered by the leaves in centimetre (cm). Tuber yield measurement was taken in weight at three different sampling periods e.g. at 6 months, 9 months and 12 months after planting (MAP).

Statistical analysis

The data collected were analyzed according to the procedure outlined by Gomez and Gomez (1984) for a factorial experiment laid out in a randomized complete block design.

Results

Meteorological data of the experimental site

The meteorological data showed that bimodal peaks of rain in 2014 were in June (271.79 mm) and September (401.99 mm) (Table 1). The amount of rain in August and December of 2014 were low. There was no rain in January, 2015 and the subsequent months of February to April were low (34-56 mm in a month).

Physico-chemical properties of the soil of the experimental site

Physico-chemical properties of the experimental sites before planting showed that the textural class of the site of the early season planting was loamy sand, while the site of the late season planting was sandy loam (Table 2). The soil of the experimental sites was highly acidic with pH in H_20 and KCL of 4.7 and 3.8 for the early planting and 4.8 and 3.7 for the late season planting, respectively. The soils of both seasons were characterized to be low in organic matter, exchangeable bases and cation exchange capacity (CEC).

Agronomic and yield performance of the varieties at early season planting

However, under early establishment TME 419 variety gave significantly ($p<0.05$) higher percentage survival count of 91% although it was statistically similar to TMS 01 1368 (yellow root) with 90.8% (Table 3). The variety TMS 98 05 05 gave significantly ($p< 0.05$) higher number of leaves, while TME 419 variety had significantly ($p< 0.05$) lower number of leaves in the second and fourth month of planting. Fertilizer application rate of 200 kg/ha gave significantly higher number of leaves at the second month after planting, while 600 kg/ha gave significantly ($p<0.05$) higher number of leaves in the fourth month. However, the control (0 kg/ha) gave the lowest number of leaves in both months. Single application of fertilizer gave significantly ($p<0.05$) higher number of leaves at fourth month of crop growth. The variety TMS 98 05 05 gave the highest number of branches at two months after planting (MAP) and it was significantly ($p< 0.05$) higher than other varieties. The rate and mode of fertilizer application did not cause any significant differences in the number of branches of the cassava varieties over the four months after planting in the early season planting.

Furthermore, the variety TMS 98 05 05 gave significantly higher tuber and garri yields of 39.8 and 9.68 t/ha, respectively at twelfth months of crop growth, although it was statistically similar to TMS 01 05 (Table 5). The rate of 200 kg/ha of NPK gave significantly ($p < 0.05$) higher tuber and garri yields of 24.69 t/ha and 5.15 t/ha, respectively at 6 months of growth. However, the rate of 400 kg/ha of NPK gave significantly ($p < 0.05$) higher tuber and garri yields of 39.4 and 10.12 t/ha at 12 months of growth. Split-split application of NPK fertilizer gave the highest yield of tuber and garri at 12 months of growth. Significantly higher peel weight of 8.94 t/ha was obtained in TME 419 at 6 MAP, as well as non-significant higher peel weight of 6.25 t/ha at 9 MAP. At 12 MAP, TMS 98 05 05 gave significantly higher peel weight of 9.36 t/ha. More so, TMS 98 05 05 showed higher canopy diameter and stem girth throughout the months of growth (Table 4). TMS 01 1368 showed non – significant lower canopy diameter from 8 to 12 months after planting. The 400 kg/ha rate of NPK fertilizer gave higher canopy diameter and stem girth at 12 MAP.

Table 1. Meteorological data for the cropping seasons of 2014 and 2015

Month	Rainfall (mm)	Temperature (°C)		Relative Humidity (%)	
		Min	Max	10 am	4 pm
Year 2014					
April	105.16	22.30	31.30	69.93	70.53
May	241.14	21.06	28.29	72.26	72.26
June	271.79	20.87	29.13	72.00	72.00
July	195.81	20.90	27.74	72.19	72.19
August	92.36	20.71	27.29	73.00	73.00
September	401.99	20.33	27.90	73.00	73.00
October	211.08	20.84	28.90	73.00	72.77
November	77.22	21.00	30.07	73.80	71.97
December	4.83	19.03	30.65	70.58	70.06
Total	1601.38	187.04	261.27	649.70	647.78
Mean	177.93	20.78	29.03	72.20	71.98
Year 2015					
January	Nil	20.52	30.32	61.42	59.58
February	56.64	22.68	32.04	70.11	64.21
March	34.8	22.61	32.29	70.61	70.19
April	39.63	22.4	31.47	71.03	67.67
May	267.98	21.81	30.71	71.65	71.42
June	121.43	21.17	29.07	76	76
July	110.49	20.61	27.87	76	76.03
August	410.4	20.43	27.69	76	76.1
Total	630.97	151.8	213.77	496.82	485.1
Mean	90.14	21.69	30.54	70.97	69.3

Source: Meteorological Station, Department of Crop Science, University of Nigeria, Nsukka.

Table 2. Physical and chemical properties of the soil in the experiment area

Properties Particle size distribution (%)	Early season site	Late season site
Clay	10	14
Silt	5	7
Fine Sand	33	43
Coarse Sand	52	36
Textural Class	Loamy Sandy	Sandy Loam
Chemical Properties		
pH (H_2O)	4.7	4.8
pH (KCL))	3.8	3.7
Organic Carbon (%)	0.95	1.25
Organic Matter (%)	1.63	2.15
Total nitrogen (%)	0.084	0.098
Exchange bases (Meq/100 g soil)		
Sodium (Na+)	0.12	0.15
Potassium (K+)	0.15	0.19
Calcium (Ca+)	11.4	13.2
Magnesium (Mg+)	0.4	2.4
Cation Exchange Capability (Meq/100 g soil)	13	16.4
Base Saturation (%)	92.85	97.2
Phosphorus (ppm)	6.53	3.73
Exchangeable Acidity (Meq/100 g soil)		
Aluminium Oxide (AL+)	-	-
Hydrogen Oxide (H+)	2.4	2.4
- = Not detected		

Table 3. Survival count (%) and number of leaves and branches of the early season planted cassava varieties as influenced by rates and modes of fertilizer application at four months after planting (MAP)

Treatments	Survival count (%)	Number of leaves/Plant		Number of branches/Plant	
	Months after planting				
Varieties		2	4	2	4
		Early season			
TMS 0I 1368	90.8	10.55	71.80	1.84	3.54
TME 419	91.1	10.05	38.10	1.73	3.09
TMS 98 05 05	80.6	14.78	84.90	2.18	3.64
TMS 05 10	84.2	11.78	44.30	1.79	2.92
LSD(p<0.05)	4.5	0.85	6.01	0.26	NS
Rates					
0		10.27	54.20	1.77	3.33
200		12.54	56.90	1.98	2.87
400		12.17	61.70	1.91	3.61
600		10.47	65.30	1.87	3.38
LSD (p<0.05)		0.85	6.01	NS	NS
Modes					
Single		11.40	67.30	1.91	3.37
Split		11.85	54.60	1.90	3.10
Split-Split		12.12	57.40	1.84	3.42
LSD (p<0.05)		NS	5.21	NS	NS
		Late season			
TMS 0I 1368	62.8	8.55	61.80	1.44	3.24
TME 419	61.1	7.05	28.40	1.35	3.09
TMS 98 05 05	70.6	12.58	74.60	2.00	3.33
TMS 05 10	64.2	8.80	34.60	1.35	2.22
LSD (p<0.05)	1.5	0.85	5.01	0.26	NS
Rates					
0		8.25	45.20	1.12	3.00
200		10.52	48.90	1.00	2.11
400		10.14	52.70	1.00	3.21
600		9.45	55.30	1.31	3.08
LSD (p<0.05)		0.85	6.01	NS	NS
Modes					
Single		10.40	50.30	1.01	3.16
Split		9.85	49.30	0.98	3.10
Split-Split		9.12	47.40	1.04	3.02
LSD (p<0.05)		NS	NS	NS	NS

Table 4. Influence of cassava varieties x rates x modes of fertilizer application on their canopy diameter and stem girth at twelve months after planting (MAP) of the early season planting

Treatments	Canopy diameter(cm)			Stem girth (mm)			
	Months after planting						
Varieties	8	10	12	6	8	10	12
Early season							
TMS 0I 1368	96.70	101.50	103.20	3.65	4.01	4.55	5.66
TME 419	113.60	114.70	116.00	4.01	4.48	4.56	6.07
TMS 98 05 05	112.70	115.40	121.70	4.35	4.97	5.06	5.78
TMS 05 10	100.00	101.0	105.70	4.12	4.37	4.39	6.00
LSD (p<0.05)	NS	11.39	15.06	0.43	0.53	NS	NS
Rates							
0	101.90	104.50	107.70	4.22	4.52	4.56	5.62
200	101.30	103.80	105.40	4.26	4.54	4.45	5.42
400	115.90	117.00	120.20	4.23	4.48	4.92	6.31
600	108.80	110.20	114.20	3.72	4.29	4.63	6.12
LSD (p<0.05)	NS	NS	NS	NS	NS	NS	NS
Modes							
Single	109.90	110.20	110.90	4.32	4.51	4.54	5.95
Split	105.60	105.80	107.50	4.25	4.59	5.06	6.06
Split-Split	104.50	105.20	111.30	4.01	4.27	4.33	5.62
LSD (p<0.05)	NS	NS	NS	NS	NS	NS	NS
Late season							
TMS 0I 1368	60.40	71.50	73.20	2.85	3.01	3.53	3.66
TME 419	73.60	72.70	76.00	3.01	3.48	3.56	3.67
TMS 98 05 05	73.70	75.40	78.70	3.35	3.67	3.76	3.78
TMS 05 10	60.00	71.20	75.70	3.12	3.27	3.39	3.40
LSD (p<0.05)	NS	NS	NS	NS	NS	NS	NS
Rates							
0	60.60	61.50	62.70	3.02	3.12	3.56	3.62
200	71.30	73.80	75.40	3.26	3.54	3.45	3.42
400	72.40	81.00	85.20	3.23	3.48	3.92	3.91
600	72.80	80.20	84.20	3.52	3.29	3.63	3.62
LSD (p<0.05)	NS	NS	NS	NS	NS	NS	NS
Modes							
Single	89.20	80.20	81.90	3.12	3.51	3.42	3.55
Split	75.60	75.80	85.50	3.25	3.49	3.60	3.26
Split-Split	74.50	75.20	86.30	3.01	3.27	3.33	3.62
LSD (p<0.05)	NS	NS	NS	NS	NS	NS	NS

Agronomic and yield performance of the varieties at late season planting

In the late season planting, variety TMS 98 05 05 gave significantly higher survival count of 70.6% (Table 4). The survival count in the later season was generally reduced when compared with the earlier planting. The variety TMS 98 05 05 also gave significantly higher number of leaves and branches at the late season planting. Fertilizer application rate of 200 kg/ha and 600 kg/ha gave significantly higher number of leaves at 2 and 4 MAP, respectively. The TMS 98 05 05 variety gave significantly ($p<0.05$) higher canopy diameter at the 10 and 12 MAP (Table 4). The variety also gave significantly higher stem girth at the 6 and 8 MAP. The fertilizer rate of 400 kg/ha gave non-significant higher canopy diameter at 8, 10 and 12 MAP. Single dose of fertilizer gave non-significant higher stem girth and canopy diameter at 6 and 8 MAP, respectively. There were non–significant effect of the rates and modes of fertilizer application on the canopy diameter and stem girth of the varieties over the months of the growth.

The variety TMS 98 05 05 gave significantly ($p<0.05$) higher tuber and garri yields at the sixth month of test period of the late planting season (Table 5). The variety also had higher non-significant yield at the twelfth months of harvest. The TME 419 variety gave higher garri yield at the ninth month. Fertilizer application of 400 kg/ha gave higher tuber and garri yields at ninth and twelfth month of harvest. Application of 200 kg/ha of NPK fertilizer gave significantly higher tuber and garri yields at the sixth month of harvest. Split method of fertilizer application gave significantly higher tuber yield but non-significant higher garri yield at the sixth month of harvest. Split – split fertilizer application gave non-significant higher tuber and garri yields at 12 MAP. There was reduction in tuber and garri yields in the late planting when compared to the early planting.

Interaction effects

The interaction of variety, rate and mode of fertilizer application showed that TMS 98 05 05 gave significantly ($p<0.05$) higher number of leaves at 2 and 4 months after planting when the fertilizer was applied split - split (Table 6). The result was statistically similar to TMS 01 1368 at single and split dose of fertilizer application. The variety also had non-significant higher number of branches, stem girth and canopy diameter at 4, 8 and 12 MAP, respectively. The variety TMS 98 05 05 that received 600 kg/ha rate of fertilizer application gave significantly ($p<0.05$) higher tuber yield of 27.89 t/ha and 50.1 t/ha at the sixth and twelfth months of harvest, respectively (Table 7). It was statistically similar to TMS 05 10 that gave 45.6 t/ha at 600 kg/ha of NPK at the twelfth month after planting. The variety TMS 05 10 gave significantly higher tuber yield of 36.67 t/ha at 200 kg/ha of NPK that was applied singly at 6 MAP (Table 8). At 9 and 12 MAP, TMS 98 05 05 gave higher tuber yield of 37 t/ha and 60t/ha at 600 kg rate that was applied by split and split - split application, respectively.

Table 5. Harvest index and garri yield of the early season planted cassava varieties as influenced by rates and mode of NPK fertilizer application

Treatments	Tuber yield (t)/ha			Peel wt(t)/ha			Garri yield (t)/ha		
	Months after planting								
Varieties	6	9	12	6	9	12	6	9	12
Early season									
TMS 01 1368	19.83	18.74	30.20	7.94	5.68	8.08	3.79	4.24	6.62
TME 419	19.17	20.58	26.70	8.94	6.25	6.81	3.79	5.44	7.31
TMS 98 05 05	24.06	22.43	39.80	8.86	5.42	9.36	4.72	4.94	9.68
TMS 05 10	21.28	22.50	31.70	6.97	5.79	7.12	4.29	5.83	8.33
LSD (p<0.05)	3.17	NS	5.62	1.37	NS	1.44	0.66	1.78	1.40
Rates									
0	16.25	14.10	19.30	5.83	4.18	4.19	2.90	3.46	4.35
200	24.69	21.43	31.00	9.44	5.79	8.71	5.15	5.36	7.76
400	21.69	25.62	39.40	8.78	6.97	9.24	4.40	5.97	10.13
600	21.69	23.10	38.70	8.67	6.19	9.24	4.14	5.67	9.71
LSD (p<0.05)	3.17	3.30	5.62	1.37	1.06	1.44	0.66	1.03	1.40
Modes									
Single	21.94	20.05	30.00	8.46	5.69	7.66	4.03	4.66	7.14
Split	22.67	21.34	32.10	8.71	5.82	8.05	4.77	5.38	8.29
Split-Split	18.65	21.79	34.20	7.38	5.84	7.82	3.65	5.31	8.48
LSD (p<0.05)	2.74	NS	NS	NS	NS	NS	0.57	NS	NS
Late season									
TMS 01 1368	10.73	11.54	20.20	3.94	4.28	5.08	1.29	2.32	3.48
TME 419	10.17	10.58	16.70	4.14	4.23	5.31	1.53	3.04	3.41
TMS 98 05 05	15.06	16.43	29.80	4.46	4.42	6.36	2.62	2.64	4.38
TMS 05 10	12.20	13.50	21.70	3.37	4.12	5.12	2.09	2.93	3.53
LSD (p<0.05)	2.27	NS	3.72	1.37	NS	1.44	0.66	NS	NS
Rates									
0	6.25	5.10	11.30	1.83	2.13	2.12	1.30	1.46	2.33
200	14.29	13.13	25.00	4.44	3.79	5.71	2.45	3.32	4.76
400	11.69	17.32	31.20	3.58	4.37	6.24	2.40	3.93	5.43
600	10.39	15.10	30.30	4.17	4.16	6.24	2.14	3.62	5.31
LSD (p<0.05)	2.27	3.30	NS	NS	NS	1.44	0.66	NS	NS
Modes									
Single	11.34	14.05	20.10	3.46	3.89	5.66	2.03	2.66	3.34
Split	12.62	15.34	22.13	3.71	4.22	6.05	2.57	3.48	3.29
Split-Split	8.25	15.09	24.20	2.18	3.84	6.82	2.45	3.31	3.45
LSD (p<0.05)	2.26	NS	NS	NS	NS	NS	NS	NS	NS

NS = non - significant

Table 6. Interaction of varieties x mode of NPK fertilizer on the number of leaves, branches, canopy diameter and stem girth at different months after planting (MAP)

		2	4	2	4	8	10	12	2	4	6	8
Varieties	Modes	Number of leaves		Number of branches		Canopy diameter (cm)			Stem girth (cm)			
TMS 01 1368	Single	12.23	70.90	2.00	3.62	105.50	104.4	104.80	7.21	3.90	4.53	5.72
	Split	10.09	75.00	1.77	3.51	100.20	93.10	105.20	8.19	4.38	5.22	5.80
	Split – Split	9.32	68.80	1.75	3.49	98.70	92.70	99.70	8.00	3.78	3.88	5.45
TME 419	Single	9.48	38.30	1.61	2.75	114.20	115.10	119.30	8.77	4.43	4.49	6.09
	Split	9.69	36.90	1.69	3.08	108.00	110.20	105.80	8.41	4.55	4.68	6.16
	Split – Split	10.98	39.20	1.88	3.46	113.00	115.50	116.80	8.37	4.46	4.50	5.97
TMS 98 05 05	Single	13.69	72.90	2.21	3.70	117.50	114.50	121.40	4.29	5.05	4.64	5.95
	Split	14.06	64.10	2.17	2.95	111.80	117.70	119.00	4.39	5.25	6.07	5.17
	Split – Split	16.58	78.40	2.15	4.26	113.90	117.90	124.60	3.77	4.61	4.48	6.23
TMS 05 10	Single	10.17	47.00	1.83	3.42	104.79	105.60	98.00	3.68	4.65	4.47	6.04
	Split	13.57	42.40	1.57	2.88	103.20	101.30	100.20	3.68	4.19	4.25	6.07
	Split – Split	11.59	43.50	1.96	2.46	94.90	96.10	103.90	3.55	4.26	4.45	5.88
LSD (p<0.05)		1.47	10.41	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = non - significant

Table 7. Interaction of varieties x rate of NPK fertilizer application on cassava tuber yield at 6, 9 and 12 MAP

Varieties	Rates	Months after planting (MAP)		
		6	9	12
TMS 01 1368	0	18.56	10.94	27.40
	200	20.56	19.44	24.60
	400	19.33	25.89	40.30
	600	19.56	18.67	28.70
TME 419	0	12.11	13.00	11.90
	200	23.44	18.89	26.40
	400	22.11	26.56	37.80
	600	19.00	23.89	30.60
TMS 98 05 05	0	19.44	18.06	19.20
	200	27.33	25.39	42.20
	400	21.56	24.39	47.80
	600	27.89	21.89	50.10
TMS 05 10	0	12.56	14.39	18.70
	200	27.44	22.00	30.90
	400	23.78	25.67	31.60
	600	21.33	27.94	35.60
LSD (p<0.05)		6.33	NS	5.67

NS = non - significant

Table 8. Interaction of variety, rate and mode of NPK fertilizer on cassava tuber yield

Varieties	Rates	Modes	Months after planting (MAP)		
			6	9	12
TMS 01 1368	0	Single	13.33	14.50	28.70
		Split	30.33	11.00	22.00
		Split –Split	19.00	7.33	31.70
	200	Single	22.67	14.67	30.70
		Split	16.33	23.00	35.30
		Split –Split	22.67	20.67	31.70
	400	Single	18.67	19.00	31.00
		Split	21.33	30.33	46.70
		Split –Split	18.00	22.33	43.30
	600	Single	27.67	18.67	31.30
		Split	18.00	21.33	37.70
		Split –Split	10.00	16.00	17.00
TME 419	0	Single	12.33	12.67	12.00
		Split	12.00	9.67	9.70
		Split –Split	12.00	16.67	14.00
	200	Single	22.00	17.33	22.30
		Split	32.33	17.00	23.70
		Split –Split	16.00	22.33	33.20
	400	Single	18.33	20.00	31.00
		Split	30.00	30.33	38.30
		Split –Split	18.00	29.33	37.20
	600	Single	20.33	20.00	33.00
		Split	19.00	30.33	28.30
		Split –Split	17.67	21.33	30.30
TMS 98 05 05	0	Single	24.33	18.17	20.30
		Split	17.00	20.00	18.30
		Split –Split	17.00	16.00	19.00
	200	Single	32.67	21.00	28.30
		Split	25.67	21.00	54.30
		Split –Split	23.67	34.17	44.00
	400	Single	21.00	19.00	37.30
		Split	25.00	27.17	53.00
		Split –Split	18.67	27.00	53.00
	600	Single	18.00	34.33	54.70
		Split	31.33	37.00	40.00
		Split –Split	34.33	34.33	60.00
TMS 05 10	0	Single	15.00	15.83	14.00
		Split	14.00	12.67	17.00
		Split –Split	8.67	14.67	25.00
	200	Single	36.67	22.33	34.70
		Split	25.67	16.00	28.70
		Split –Split	20.00	27.67	29.30
	400	Single	27.00	25.33	30.70
		Split	19.67	20.33	28.00
		Split –Split	24.67	31.33	36.20
	600	Single	21.00	28.00	25.00
		Split	25.00	28.33	52.70
LSD(p<0.05)		Split –Split	18.00	27.50	49.00
			10.97	NS	19.48

NS = non - significant

Discussion

The early season planted cassava took place in May and there were high rainfall in June and July, which supported its rapid early growth and canopy cover. The late season crop which was established in July had low rainfall at the beginning of the crop, but a heavy rainfall in September which was at extreme (stress) and may suggest the basis for low growth and slow canopy cover. Early growth indices in cassava have been reported to support high tuber yield in cassava (Akoroda *et al.*, 2001*)*. El-shakarwy *et al.* (1998) had also reported that early and mid-season stress significantly reduce top and root biomass than late and terminal stress which occurred during tuber maturity in cassava.

The interpreted physico-chemical properties of soil as contained in Table 1 revealed that the soil of the early season has loamy sand texture and was highly acidic, while the late season site had sandy loam texture and was highly acidic. The soil textural classes of both sites suggest very good support for optimum growth and yield of cassava. Sandy loam of late seasons site has been described as the best for cassava growth. The late season site identified to posse's moderate and high levels of organic carbon and organic matter when compared to the early season site had a reduced or lower yield. This was as a result of reduced effective growth period before dry season started, which was unfavourable for the plant. Early drought observed at late season planting resulted in reduction in tuber yield.

Early season planting that showed higher survival count in all the varieties suggested better growth conditions at early season when compared to the later season with lower survival counts after three weeks of planting. The variety, TMS 98 05 05 that was consistently higher than 70% in both seasons indicate higher survival rate from rottening and termite attack that predominates in lowering survivors in the late and early seasons respectively. Such a result implies that this genotype could be selected for late season planting

Higher number of leaves and branches at four MAP observed at the early season indicated that the plant growth rate had a favourable environmental condition at the earlier season when compared to late season. El-sharkawy *et al.* (1998) reported the severe stress effects of dry season on vegetative growth of late season cassava. This suggested that stress at vegetative stage caused reduction in yield of cassava for vegetative growth and eventual tuber yield. Rate of leaf formation in the varieties was related to branch number and rate of leaf retention. The variety TMS 98 05 05 had consistently higher number of branches and leaves in both seasons suggested that the rate of leaf formation in the varieties was related to the number of branches. The report agreed with Irikura *et al.* (1979) that early branching increase leaf formation rate. Also, Okogbenin (1999) noted that cultivars with high branching characteristics produce more leaves than non-branching. According to Okogun *et al.* (1999) an increase in number of branches per plant is important to expose the cassava leaves to sunlight for photosynthesis and increased translocation for higher photosynthate accumulation which in turn improves the yield.

The variety TMS 98 05 05 that gave significantly ($p < 0.05$) higher canopy diameter at the 10 and 12 months after planting and a non- significant higher diameter at 8 month. This indicated that the variety exhibited a full canopy closure. Such variety has the advantage of weed suppression and erosion control because of the vegetation cover. Pellet *et al.* (1977) had noted that once a complete ground cover is reached, cassava shed out weeds. Aneke *et al.* (2010) reported that the application of fertilizer in cassava production ensures that the canopy closes up within approximately three MAP giving potential for weed suppression. Canopy closure has also, been suggested to help to reduce water runoff and consequently reducing soil erosion (Zhang *et al.*, 1998).

The high level of reduction in tuber and garri yield in the late season planting when compared to the early season suggested that the optimum vegetative and tuberization growth period in the late seasons cropping fell into the stress periods of November to March when there was no rainfall. The non-full expression of the leaves and canopy diameter in the late season resulted in lower tuber yield. This is most probable as Lebot (2009) has shown that leaf size and tubers develop simultaneously, also, that increased canopy increases assimilate produced and partitioned between growth and tuberization. The higher tuber and garri yields in TMS 98 05 05 might be as a result of higher canopy cover which increased assimilates produced in the variety for growth and tubers development. The 400 kg NPK/ha that gave significantly higher tuber yield at the ninth and twelfth month is more economical for adoption for production. The non-statistical difference in tuber yield between single and split fertilizer application across the three months of tuber harvest suggested the resilience of the varieties in the utilization of available fertilizer nutrients in their growth and tuberization.

Split-split application of fertilizer to the cassava varieties gave significantly higher tuber yield across some of the varieties used for study at the twelfth month, though it is statistically similar to split application. The result suggested that cassava requires gradual application of fertilizer most probably because of long gestation period of about 12 months. However, the cost of labour should be taken into consideration in the choice of split or split-split for tuber yield compensation from each method. At nine MAP, the non-significantly higher tuber yield at 400 kg/ha of fertilizer rate applied split as against the tuber yield at 600 kg/ha that was applied split-split suggested that 400 kg/ha rate is more adequate and economical for higher tuber yield in the varieties. Similar result of higher tuber yield at 400 kg/ha as against 600 kg/ha at the 12 month indicated that 400 kg/ha rate of fertilizer is suitable for production of the varieties in Nsukka environment because it is more economical and gave high yield. The relatively lower yield from 600 kg/ha might be as result of luxuriant growth of the plants at the expense of tuber formation and development. Many authors have reported luxuriant vegetative growth in cassava against tuber formation because of excess nitrogen and potassium levels (Rao *et al.*, 1986; Onwueme and Charles, 1994; Wilson and Ovid, 1994).

The high level of interaction of the cassava varieties with the rates and modes of fertilizers application suggested that the varieties behaved differently to the rates and modes of fertilizers application. At 6 MAP, in most cases, the single fertilizer application across the levels gave higher tuber and garri yields when compared with the split and split-split. However, single dose application lost its nutrients to leaching over time of growth resulting in lower tuber and garri yields at 9 and 12 MAP. The split – split application of 600 kg/ha fertilizer that gave non-significant higher tuber yield of 60 t/ha when compared with split-split application of 400 kg/ha suggested relatively higher fertilizer utilization in the vegetative and tuber bulking and eventual yields. The higher but no significant differences in the yields of 600 kg/ha rate may not pay for the cost of extra fertilizer when compared with 400 kg/ha fertilizer rate. Hence, the lower fertilizer rate of 400 kg/ha that gave high yield over the two seasons could be recommended based on the native nutrients of the research site. The variety TMS 98 05 05 also responded in a better way to the rates and modes of fertilizer application as it gave mostly higher tuber yield across the rates and modes of fertilizer application. TME 419 characterised as early (6 months) duration cassava did not perform better than other varieties at 6 MAP and did not show rotten tubers at 12 MAP in the seasons in Nsukka environment. Hence, the variety could be grown for 12 MAP harvest as is applicable in some varieties available in Nsukka derived savannah agro-ecology.

Conclusions

The present study showed that TMS 98 05 05 had significantly high growth parameters and high tuber yield so it could be adopted for production in Nsukka environment. The 400 kg/ha rate of fertilizer gave similar growth and tuber yields when compared with 600 kg/ha rate and should be adopted because of lower cost. Split application of fertilizer though statistically similar to split –split application had the high growth and tuber yield and should be adopted because it is more efficient economically to the farmers as it will avoid extra labour cost of the fertilizer application.

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