Agronomy and Physiology

Improving the productivity of cassava-based systems by increasing the number of cuttings per stand to enhance farmers adoption

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The National Root Crops Research Institute, Umudike, Nigeria, recommended the planting of cassava at 1m x 1m (Inter-row and interplant) spacing and planting one cutting per stand in cassava/maize/melon system. The adoption of this technology has been very low because farmers preferred planting more than one stake per stand in South East agro-ecological zone. To enhance farmers' adoption of this technology, a modified trial was carried out in 2004 through 2006 cropping seasons. The treatment, consisted of planting 1,2,3 and 4 cassava cuttings per stand at 3 spacings (1m x 1m, 1m x 0.5m and 1x1.5m) in cassava/maize/melon mixture for two seasons in a split split- plot design. Planting of 2 stakes per stand in cassava/maize/melon mixture at the recommended spacing (1m x1m) sustained larger cassava fresh root size- 4(2-5kg) and yields(36t/ha) in both seasons.

Increasing the number of cuttings per stand above 2 cuttings per stand resulted in smaller root sizes-1 (Less than 0.5kg) . Maize (477.7kg/ha) and melon (48kg/ha) yields were lower with increasing number of cuttings above two cuttings per stand. Therefore to enhance farmers adoption of planting cassava in cassava/maize/melon mixture. It is recommended that farmers could use 1m x 1m spacing and plant 2 cassava cuttings per stand.

Keywords: Intercropping, inter and intra row spacing and mixture

Introduction

Intercropping cassava (*Manihot esculenta*) with maize, beans, sweet pepper or melon is common among farmers in the major cassava growing belts of Nigeria, due to economic benefits (Udealor et, al, 1991; Ikeorgu et al 1992 and Eke-Okoro et al 1998).

Studies on cassava/maize/legume (Ikeorgu et. al 1992), cassava/soybean (Cenpukdee and Fukai 1992 and Eke okoro et al 2008) cassava/ beans(Osiru and Hahn, 1988) cassava/maise/ cowpea (IITA 1978),Yam /maize/fluted/pumpkin/ cassava (Udealor et. al. 2005), cassava/groundnut/ soybean/cowpea/bambara (Eke-Okoro et. Al, 1998) showed some significant increase in yields and intercropping efficiency of cassava-based systems.

In intercropping cassava with other crops, farmers plant more than 4 to 6 stakes of cassava of not less than 25cm length per hill or stand. This practice encourages multiple shoot production, production of tiny roots, low cassava yields, faster rate of soil-resources depletion and delay in other farm operations.

The development of the technology of planting one stake of cassava per hill or stand using 1m x 1m spacing, by the National Root Crops Research Institute (NRCRI) Umudike Nigeria, was a major breakthrough in cassava-based farming system practices. This technology encourages the production of larger roots, high yield per stand and makes other farm operations such as weeding and fertilizer application easy. However, farmers feed-back received from some Agricultural Development Programmes in Nigeria (REFILS 2000). Showed that the rate of adoption of this technology is still below 30%. Farmers preferred planting more than one cassava stake per hill or stand using 1m x 1m spacing in cassava-based mixtures in Abia, Enugu, Anambra, Imo, Ebonyi, Bayelsa, Rivers, Cross Rivers, Akwa Ibom States and even in the Guinea Savanna. These states constitute the major cassava growing belts in Nigeria. The reasons advanced for the low adoption was low cassava population, low yield per unit area and weed growth in farms (REFILS, 2000). Therefore farmers are demanding for an increase in the number of cassava states to be planted per hill or stand in cassava-based intercrops.

The Farming Systems Programme of the National Root crops Research Institute, Umudike Nigeria started work between 2004 and 2006 to modify the technology of planting one cassava stake per hill/ stand and to determine the optimum economic stake number per hill/stand that a farmer can plant considering the carrying capacity of the land resources and economic yields in order to enhance farmer adoption. This paper reports results obtained in the modification of the technology of planting one stake per stand on order to enhance farmers adoption.

Materials and Methods

The trial was conducted at the National Root Crops Research Institute, Umudike. Nigeria, in 2004/5 through 2005/6. Umudike is in the tropical rainforest of Nigeria, Latitude 5°29[1] Longitude 7 °32[1]E on an elevation of 122m above sea level. It has an annual rainfall of 1800 to 2200mm with a 59 year average of 2159mm. It has a bimodal rainfall pattern: early rains (April-July and late rains (August-October); and five months of dry season with a dry spell in August. A part of dry season is characterized by a cool dry North-easterly wind called the harmattan. Umudike is noted for tropical root and tuber crops production notably cassava and yam. The dominant soil is acid sandy loamy, classified as oxic paleustult.

Three treatments consisted of planting of 1,2,3, and 4 cassava stakes per hill/stand at 3 spacings (1m x 1m, 1m x 0.5 and 1. x 1.5m) evaluated in a cassava/maize/melon/egusi mixture in 2004 to 2006 cropping seasons. The experimental design was a split-split-plot design with 3 replications. In the design, cassava variety was the main plot, number of stakes per hill/stand was the sub-plot and intra-row spacing was the sub-plot. Cassava stakes were planted on the crest of the ridge, melon was planted between two cassava stands on the crest of ridge while maize was plant on the side of cassava stand.

In planting of 1 stake/hill or stand, the stakes were oriented in one direction. In planting of 2 stakes/hill or stand, the 2 stakes were oriented in opposite directions. In planting of 3 stakes per hill or stand, the 3 stakes were oriented alternatively. In planting of 4 stakes per hill or stand each 2 stands were planted in opposite directions. Based on spacing and number of stakes per hill/stands, the following populations were obtained in this trial;

For 1m x 1m spacing:
10,000pts/ha at 1 stake/hill
20,000 " " 2 "
30,000 " " 3 "
40,00 " " 4 "

For 1m x 0.5m spacing:
20,000 pts/ha at 1Stake/hill
40,000 " " 2"
60,000 " " 3 "
80,000 " " 4 "

For 1m x 1.5m spacing:
15,000pts/ha at 1 stake per hill
30,000 " " 2 "
45,000 " " 3 "
60,000 " " 4 "

The treatments were assigned to experimental plots of 6m x 8m (main plot) and 6m x 4m (sub-plot) with two metre distance between main-plots and one metre distance between sub-plots. After planting, the field was sprayed the following day with herbicide (Primextra) at the rate of 5 litres per hectare to minimize weed growth. A blanket application of NPK 20:10:10 at the rate of 800kg/ha (Udealor et al; 1991) was made in a band between cassava and maize stands at 8 weeks after planting supplementary weeding was done twice manually.

Cassava was harvested at 12 months after planting. Maize cobs were harvested at 5 months after planting in order to allow cobs to dry in the field. melon (Egusi) pods were picked at 4 months after planting. Fresh roots of cassava were weighed, sorted into various sizes (0.5kg to 5kg). Maize were shelled and grains were further dried to 14% and weighed. Melon/egusi seeds were air dried to 14% moisture and weighed with metric balance. Melon yield was estimated only in the second year due crop failure

The data were analyzed according to the procedure for a split-split-plot experiment using a Genstat Computer Package (2003). The significance of treatment effects were estimated at 5% level of probability. Weather data from 2004 to 2006 collected from National Root Crops Research Institute weather station were used to relate how differences in weather conditions of rainfall, temperatures and sunshine influenced the productivity of component crops. The intercrop analysis based on land equivalent ratio (LER) was not done because this has been determined and proved long ago by several authors (Ikeorgu et.al. 1992; Eke-Okoro et. al; 998).

Results

Weather condition

The total rainfall increased from 1911:4mm in 2004 to 2038.3mm in 2006. The mean percent relative humidity increased from 78% in 2006 at 0900 hours and similar trend was observed at 1500 hours. The mean total sunshine hours increased from 4.1 hours in 2004 to 4.9 hours in 2006. The mean maximum air temperature decreased from 32.1°C in 2004 to 31.4°C in 2006. However uniform mean air temperature was received in both seasons (Table 1)

Yield and yield components of intercrops

Maize yields: The main effect of number of stakes per stand on maize yield was significant in both seasons (Table 2). However, the main effects of spacing and variety had no significant effect on maize yield in both seasons (Table 2). Intercropping 2 stakes of cassava per stand with maize irrespective of cassava variety and spacing gave the highest mean Maize yields in both years (Table 2). The interaction of variety, spacing and number of stakes per stand on maize yield were significant in both years (Table 3). The interaction of either NR8082 x 2 stakes x 1 x 1m or TMS 96/03004 x 1 stake x1m x 1.5m gave the highest mean maize yield of 627.0kg/ha and 662.9kg/ha respectively. The interaction of either NR8082 x 4stakes x 1 x 0.5m or TMS 96/0304 x 3 stakes x 1m x 1.5m gave the lowest mean maize yields of 336. 1kg/ha and 361.2kg/ha in both years respectively (Table 3).

Melon yields: The main effects of number of stakes per stand and spacing significantly affected Melon yields in 2005/6 (Table 3). The use of 2 stakes per stand gave the highest mean melon yield 51.7kg/ha while spacing of 1m x 0.5m gave the highest mean melon yield (50.1kg/ha). However, the main effects of variety had no significant effect on melon yields (Table 3). The interaction of NR8082 x 1 or 2 stakes x 1m x 1m and TMS 96/0306 x 1 or 2 stakes x 1m x 1.5m gave a higher melon yields (Table 3)

The yield and yield components of cassava

Root Size

The main effects of spacing and number of stakes per stand significantly affected the size of roots produced (Table 4). Spacing of 1m x 1.5m(15,000 per/ha) gave the biggest rot size (3.6cm following by spacing of 1m x 1m (10,000 per/ha)with root size of (3.0cm.) while spacing of 1m x 0.5m and(20,000per/ha) stakes gave the smallest root sizes. (2.9cm and 2.8) (Table 4). However, main effects of variety on root sizes was not significant. The interaction effects of variety, number of stake and spacing significantly affected root sizes (Table 5).

The interaction of sparsely branching cassava variety (TMS 96/0304,x 1-2 stakes x 1m x 1m gave the highest mean root sizes. The interaction of profused branching cassava variety (NR8082) x1-2 stakes per stand x 1m x 1m sustained larger root sizes. Root sizes were higher as spacing increases (Table 5). but above 2 stakes root size decreased.

The main effect of number of stake and spacing significantly affected the fresh root yields (Table 5). Two stakes gave the highest fresh root yield (31.4t/ha)while three stakes per stand gave the lowest mean fresh root yield (27.6t/ha). Main effects of cassava variety had no significant effect on fresh root yields. The interaction effects of variety, number of stakes per stand and spacing significantly increased fresh root yields (Table 5). The interaction effects of variety, number of stakes and spacing increased mean fresh root yields in the following order

NR8082 x 4 stakes x 1 x 1.5m (37.7t/ha) > NR8082 x 3 stakes x1m x1.5m (376t/ha) >

NR8082 X 2stakes X 1m X 1m (35.6T/ha) and NR8082 x 4 states x 1 x 1m 9306/ha)

The interaction effect of variety TMS 96/0304 x 4 stakes x 1m x 1.5m (39t/ha),> TMS 96/0304 x 1 stakes x 1m x 1.5m (35.1t/ha and TMS 96/0304 x 2 stakes x 1m x 1m (33.6t/ha).

Discussion

Weather elements such as rainfall, relative humidity and sunshine hours increased from 2004 to 2006 while the mean air temperature decreased from 2004 to 2006. (Table 1). This trend influenced the performance of cassava/maize/ egusi intercrops. Eke-Okoro et. al, (1998) and Eke-okoro et. al,(2009) observed that difference in weather conditions influenced in yield in sole and in intercrops.

The main effects of number of stake per stand was significant on maize grain and melon seed yields, in both season (2005 and 2006). The main effect of spacing was significant on melon seed yields in both years (2005 and 2006). Main effects of cassava variety on maize, grain and melon seize yield was not significant. Therefore spacing and number of stakes per stand are major factors that influenced the performance of cassava, maize and melon intercrops as shown by the results obtained.

Yield in cassava/maize/melon intercrop. Intercropping cassava with maize and melon at 1m x 1m spacing and planting of two stakes per stand of cassava gave the maximum fresh root size. Enyi (1987) and Eke-Okoro (1997) obtained significant high yields in cassava when cassava was maintained at two shoots/stakes per stand. In addition, Okeke (1987) obtained higher cassava root sizes and yields when cassava was grown at a spacing of 1m x 1m.

The National root Crops Research Institute, Umudike recommended the planting of cassava at 1m x 1m inter row and inter ridge spacings with one stake cutting per hill or stand in cassava/maize/melon system. However the adoption of this technology has been very low because farmers preferred planting more than one stake/cutting per hill in south-east and south south agro ecologies where cassava/maize/egusi system is predominant.

To enhance farmer adoption of planting cassava at 1m x 1m spacing, This modified trial recommends the intercropping of cassava with maize and melon using the previous recommended spacing of 1m x 1m spacing and a new recommendation of planting of two stakes per stand instead of one stake per stand for optimum root size and yield.

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Table 1: Total rainfall, sunshine, temperature and relative humility in 2004 - 2006 in Umudike

	RAIN FALL			SUNSHINE			TEMPERATURE			RELATIVE HUMIDITY		
MONTH	2004	2005	2006	2004 HRS	2005 HRS	2006 HRS	2004 MAX (°C)	2005 MAX (°C)	2006 MIN (°C)	2004 0900 HRS	2005 15OO HRS	2006 1500 HRS
JAN	17.3	76.7	3	63	4.5	5.7	33	33	24	63	43	59
FEB	126.7	81.9	3	4.8	5.2	6	35	33	24	65	40	61
MAR	64	131.9	6	4	4.2	5.7	34	34	24	66	44	60
APR	141.3	136	9	4.6	4.8	4.8	34	33	24	78	67	62
MAY	222.4	202.8	15	5.7	3.7	5.2	3	31	23	79	66	71
JUN	264.4	237.3	15	4.1	2.1	3	31	31	22	83	76	72
JUL	277	303.4	16	3.6		2.7	29	30	23	85	78	78
AUG	225	133.7	15	1.7		2.4	30	29	22	87	76	77
SEP	336.7	483.1	20	3.2		4.5	31	29	22	85	72	80
OCT	323	237.4	19	5		5.5	31	31	22	82	74	72
NOV	45.4	14.2	1	4.8		6.4	33	31	23	81	67	58
DEC	8.6	0	0	5.6		6.4	32	32	20	80	57	40
MEAN	2051.8	2038.3	122	4.1		4.9	32.1	31.4	22.8	78	63	66

Table 2. Main effects of variety, spacing and number of stake per stand on maize and Melon yields (kg/ha) in 2004 2006.

Treatment	Maize grain yield (kg/ha)		Mean	Melon seed yield
	2004/2005	2005/2006		2005/2006
Cassava Variety	N.S	N.S		NS
NR 8082	536.6	456.1	496.4	46.2
TMS 96/0304	500.2	470.2	485.2	47.4
S.E	22.33	18.72	-	9.22
Number of stake	*	*	*	*
1	563.7	505.1	534.4	45.8
2	573.8	549.4	561.6	50.7
3	466.7	428.6	477.7	48.4
4	469.4	370.0	420.2	42.3
S.E	31.58	24.67	-	4.26
Spacing	N.S	N.S	-	*
1mx 0.5m	513.1	443.1	478.1	50.1
1m x 1m	544.5	464.3	504.4	45.9
1m x 1.5	497.5	492.2	494.9	44.6
S.E	27.35	21.63	-	2.28

Table 3. Interaction effects of variety, spacing and number of stake per stand on maize and melon yields (kg/ha) in 2004-2006.

Treatment combination	Maize grain yield (kg/ha)			Melon seed yield (kg/ha)
	2004/2005	2005/2006	Mean	2005/2006
Cassava Variety 1				
NR 8082 X 1 stake X 1mX 0.5m	458.3	440.7	449.5	41.7
NR 8082 X 1 stake X 1m X 1.0m	538.8	500.7	519.8	50.0
NR 8082 X 1 stake X 1m X 1.5m	568.7	520.5	544.7	53.0
NR 8082 X 2 stake X 1m X 0.5m	629.1	575.6	602.4	38.4
NR 8082 X 2 stake X 1m X 1.0m	668.6	585.4	627.0	45.9
NR 8082 X 2 sta ke X 1m X 1.5m	539.5	487.1	513.3	50.0
NR 8082 X 3 stake X 1m X 0.5m	506.2	420.2	463.2	45.9
NR 8082 X 3 stake X 1m X 1.0m	430.5	400.3	415.4	44.0
NR 8082 X 3 stake X 1m X 1.5m	530.5	540.3	535.4	40.1
NR 8082 X 4 stake X 1m X 0.5m	396.5	275.6	336.1	45.9
NR 8082 X 4 stake X 1m X 1.0m	474.9	340.7	407.8	45.9
NR 8082 X 4 stake X 1m X 1.5m	493.0	385.7	439.4	38.4
Cassava Variety 2				
TMS 96/0304 X 1 stake X 1mX 0.5m	569.4	520.0	544.7	45.9
TMS 96/0304 X 1 stake X 1m X 1.0m	479.1	410.4	444.8	41.7
TMS 96/0304 X 1 stake X 1m X 1.5m	687.4	638.3	662.9	54.2
TMS 96/0304 X 2 stake X 1m X 0.5m	513.8	501.0	507.4	54.2
TMS 96/0304 X 2 stake X 1m X 1.0m	575.6	576.4	546.0	41.7
TMS 96/0304 X 2 stake X 1m X 1.5m	638.8	622.7	630.8	54.2
TMS 96/0304 X 3 stake X 1m X 0.5m	324.3	400.0	362.2	54.2
TMS 96/0304 X 3 stake X 1m X 1.0m	422.2	470.5	446.4	54.2
TMS 96/0304 X 3 stake X 1m X 1.5m	381.9	340.4	361.2	45.9
TMS 96/0304 X 4 stake X 1m X 0.5m	461.7	412.0	436.9	54.2
TMS 96/0304 X 4 stake X 1m X 1.0m	476.3	461.0	468.7	37.6
TMS 96/0304 X 4 stake X 1m X 1.5m	402.7	350.1	376.4	31.7
S.E.	52.4	48.6	-	13.41

Table 4. Main effects of cassava variety, spacing and number of stake per stand on root size (kg/ha) and fresh root yield (t/ha) in 2004 2006

Treatment	Root size (kg)			Yield (t/ha)		
	2004/ 5	2005/ 6	Mean	2004/ 5	2005/ 6	Mean
Cassava variety						
NR 8082	3.4	3.0	3.2	31.1	30.1	30.6
TMS96/0304	3.0	3.0	3.0	32.1	29.0	30.6
S.E	0.16	0.10	-	0.17	0.14	-
Number of Stake						
1	3.6	3.4	3.5	31.5	26.9	29.2
2	3.2	3.0	3.1	32.3	30.4	31.4
3	3.0	3.0	3.0	30.7	24.4	27.6
4	3.0	2.8	2.9	32.5	25.7	29.1
S.E.	0.18	0.19	-	0.18	0.15	-
Spacing						
1m x 0.5m	3.0	2.9	2.9	18.3	24.2	21.3
1m x 1m	3.1	2.9	3.0	33.2	32.4	32.8
1m x 1.5m	3.5	3.7	3.6	43.7	38.6	41.2
S.E	0.09	0.06	-	0.09	0.012	-

Table 5. Interaction effects of cassava variety, spacing and number of stake per stand on root size (kg/ha) and fresh root yield (t/ha) in 2004 2006

Treatment Combination	Root size (kg)			Yield (t/ha)		
	2004/5	2005/6	Mean	2004/5	2005/6	Mean
Cassava Variety 1						
NR8082 X 1 stake x 1m x 0.5m	3.7	3.2	3.4	22.2	32.2	27.2
NR8082 x 1 stake x 1m x 1.0m	3.7	4.0	4.0	33.2	24.7	29.0
NR8082 x 1 stake x 1m x 1.5m	4	3.2	4.0	38.5	25.6	32.1
NR8082 X 2 stake x 1m x 0.5m	3	3.0	3.0	19.4	33.2	26.2
NR8082 x 2stake x 1m x 1.0m	3.7	3.9	4.0	34.9	36.4	35.6
NR8082 x 2 stake x 1m x 1.5m	3.7	3.0	3.4	41.1	27.2	34.1
NR8082 x 3 stake x 1m x 0.5m	3	2.8	2.7	17.8	28.6	23.2
NR8082 X 3 stake x 1m x 1m	3	2.7	2.9	31.1	21.9	26.5
NR8082 x 3 stake x 1m x 1.5m	3.3	3.3	3.3	45.2	30.0	37.6

NR8082 x 4 stake x 1m x 0.5m	3	2.4	2.7	15.5	28.4	21.9
NR8082 X 4 stake x 1m x 1m	3	2.6	2.8	32.3	38.9	35.6
NR8082 x 4stake x 1m x 1.5m	3.3	3.0	3.2	51.2	24.0	37.7
Cassava Variety 2						
TMS96/0304 X 1 stake x 1m x 0.5m	3.3	3.0	3.1	18.0	30.5	24.3
TMS96/0304 x 1 stake x 1m x 1.0m	3	3.6	3.3	33.3	28.5	30.9
TMS96/0304 x 1 stake x 1m x 1.5m	3.7	3.4	3.5	41.1	29.1	35.1
TMS96/0304 X 2 stake x 1m x 0.5m	2.6	2.6	2.6	22.8	27.9	25.4
TMS96/0304 x 2stake x 1m x 1.0m	3.4	3.7	3.6	34.6	32.5	33.6
TMS96/0304 x 2 stake x 1m x 1.5m	3	3.3	3.1	42.8	22.0	32.4
TMS96/0304 x 3 stake x 1m x 0.5m	2.6	2.5	2.6	15.8	18.5	17.2
TMS96/0304 X 3stake x 1m x 1m	2.6	2.0	2.3	29.8	34.0	31.9
TMS96/0304 x 3 stake x 1m x 1.5m	3.3	3.3	3.3	48.8	38.8	43.8
TMS96/0304 x 4 stake x 1m x 0.5m	2.3	2.1	2.2	16.2	20.7	19.1
TMS96/0304 X 4 stake x 1m x 1m	3	2.6	2.6	36.6	23.5	30.0
TMS96/0304 x 4 stake x 1m x 1.5m	3.3	2.5	2.9	42.7	33.8	39.0
S.E.	0.36	0.29	-	9.76	6.43	-

Key to Root size

1. = very small (less than 0.5kg)
2. = small (0.5 to 1kg)
3. = medium (1 to 2kg)
4. = large (2 to 5kg)
5. = extra large (more than 5kg)

Cassava (*Manihot esculenta* Crantz) stems quality for root production effectiveness

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Abstract

Four attributes of stem quality: number of nodes[1], diameter[2], and stem weight[3] per 25-cm plantable stake (PS), and the stake position[4] were investigated in field trials at Blocks 4, 18 and 24 of the International Institute of Tropical Agriculture (IITA) Onne, Ajibode, Ibadan, Federal College of Agriculture, Akure and Dogodawa, Zaria, Nigeria to evaluate the relationship between good quality cassava planting material and the stem and root yields and to assess the best stake position that gives the best stem and root yields.

Forty three cassava mosaic disease resistant varieties were planted during the 2005 and 2008 planting seasons in a randomized complete block design with four replicates while two varieties out of the 43 in trial (TME 7 and TMS 30572) were evaluated in a uniformity trial.

The studies found that there is a gradient of number of nodes per stake, weight and diameter in cassava stem from the base to the shoot tip. All cuttings of 25-cm long do not have the same number of nodes (varied from 5-16 nodes), diameter (1.8-3.1 cm) and weight (48-110 g). There was no significant difference ($p>0.05$) in yield among stakes from the basal, basal-middle, top-middle and top of the stem. The effect of the quality of stakes planted was shown on the percentage missing stands and was 18.2% in research farms, 32.7% (trained personnel farms) and 42.0% (traditional farms). Selection of quality stakes did not have any effect on the yields, but very necessary for improving root yield of cassava.

Keywords: Cassava, stems quality, production, effectiveness.

Word count: 249

Introduction

Cassava production in Africa is about 118.0 million tonnes (51 % of the world total production) from 12 million ha. Nigeria is still the largest cassava producer (44.6 million tones) followed by Thailand, Brazil and Indonesia. But the cassava yield in Nigeria (11.8 t/ha) is very low, compared with Thailand (23.3 t/ha), Brazil (14 t/ha), and Indonesia (18 t/ha) (FAO, 2009). Roots yield varies with the input and resources used in production such as: stem quality (24 characteristics see appendix), growth environment (rainfall, soil fertility, dustiness) and field practices (planting date, depth, spacing, shading). During selection of stakes, the woody part and the green top are avoided before being cut into 25-cm stakes. Disease portions are rejected and injured or bruised portions without peels or broken nodes are left out. Three stakes variables still remain and do vary among varieties. The objective of this study was to understand the influence of these three variables on root yield.

Materials and Methods

The study was carried out in 6 locations (table 1) in three agro ecologies (Humid Forest, Derived Savanna, and Northern Guinea Savanna (figure 1)) in Nigeria. Planting materials of the 43 Cassava Mosaic Disease (CMD) resistant varieties used were from the International Institute of Tropical Agriculture's (IITA) fields. They were cut into 25-cm plantable stakes; the number of nodes per stake, stake weight and diameter were recorded. Thirty six stakes (figure 2) were planted per variety at 1 m x 1 m in a Randomized Complete Block Design (RCBD) with 4 replicates. On the other hands, stakes from varieties TME 7 and TMS 30572 were properly numbered from the base of the stem to the top and planted at 1 m x 1 m according to their numbers in a uniformity trial. No fertilizer was applied.

In addition to the pre-emergence herbicide application (200 ml Primextra + 200 ml Gramoxone in 20L of water), manual weeding was done at 3, 6 and 9 months after planting (MAP). Only the 16 central plants were used for the data collection at 12 MAP. Each of the 16 plants was cut into different branches level (figure 2): main stem, primary, secondary, tertiary and other branch levels up to the green-brown point [point of separation between the mature part of the plant and the immature part or the forage], the number of 25-cm PS was measured using a tape rule; the number of nodes per 25-cm PS was counted. A 5 kg electronic balance was used to measure the weight of each of the 25-cm PS while a veneer caliper was used to measure its diameter. All roots were counted and weighed using a 50 kg weighing scale. Sixty seven cassava farms owned by different categories of farmers (*Research farmers* (27), whose know and practice the stake selection protocol, *the trained farmers* (20) whose were trained on how to practice the selection and *the traditional farmers* (20) whose have no knowledge of the selection process) were surveyed to assess the effect of quality planting material on the establishment ability. Data collected were analyzed using descriptive statistics and ANOVA. Multi-Dimensional Analysis (MDA) was used to assess the relationship between good quality of cassava planting materials and the root yield.

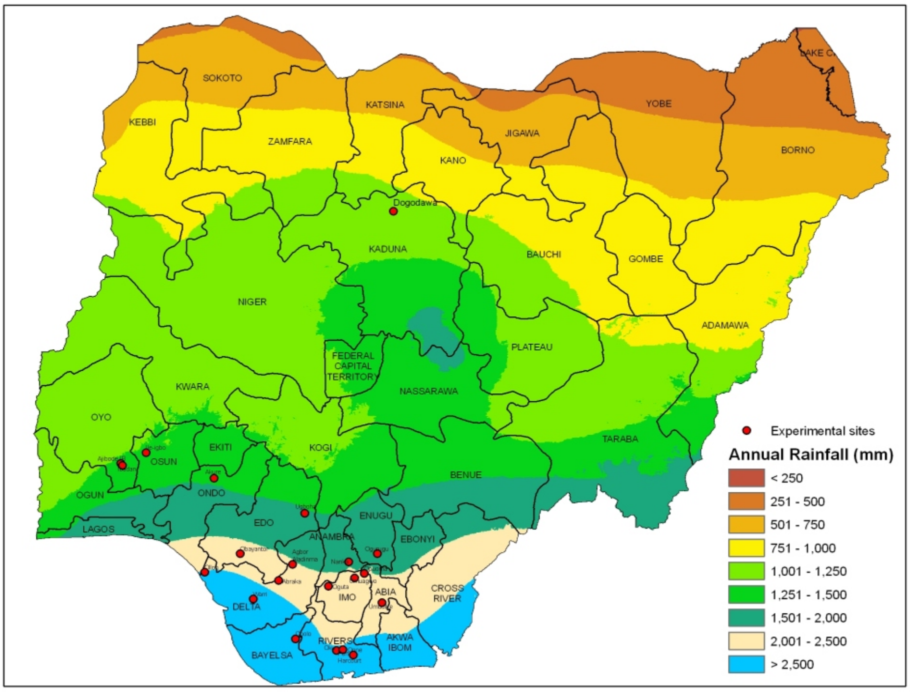

Fig. 1: Agro ecologies where the trial was conducted.

Table 1. Locations and date of planting and harvest of the multi-locational trials for the stem quality assessment during the 2006-2007 cassava cropping season.

Location	Latitude/ Longitude	Date of planting	Date of harvest	Crop growth period (MWD)
Akan Kate plot, Onne	4°71'N/7°09'E	3 March 2005	7 March 2006	12M1W
Demo plot B22, Onne	4°71'N/7°09'E	14 June 2005	13 June 2006	12M
MLT plot B18, Onne	4°71'N/7°09'E	11 May 2005	17 July 2006	13M1W
FCA, Akure	7°96'N/8°76'E	22 April 2005	25 July 2006	15M3D
Ajibode, Ibadan	6°85'N/2°80'E	20 May 2006	21 June 2007	13M1D
Zaria, Dogodawa	9°16'N/8°26'E	4 August 2005	17 August 2006	12M2W

M = Months; W = Weeks; D = Days

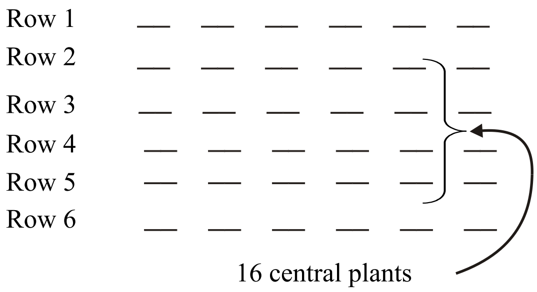

Fig. 2 Sample of a plot as it was laid in the field

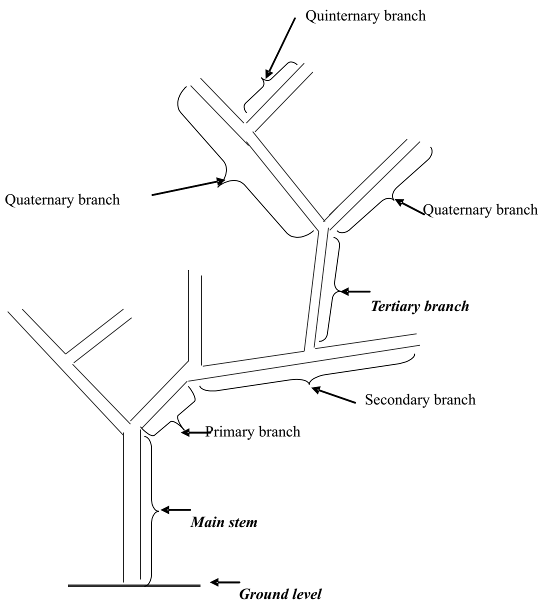

Figure 3: Cassava plant showing different type of branches

Results and Discussion

Cassava stakes quality characteristics (weight, number of nodes and diameter per 25-cm stake of cassava) recommended for planting.

The smoothness of cassava stakes' edges cut with secateur, showing the pith to wood ratio is presented in plate 1. The pith to wood ratio was less than 50 % which implies a good quantity of food reserves in the stem (Okeke, 1994, and Lozano *et al.,* 1977). A sample of the standard 25-cm stakes of CMD varieties with different number of nodes is showed in plate 2. All cuttings of 25-cm long do not have the same number of nodes, diameter and weight.

Variation in stake weight, number of nodes and diameter per stake is showed in figures 4, 5 and 6 respectively. There is a gradient of number of nodes per stake, weight and diameter in cassava stem from the base to the shoot tip. Stakes (25-cm long) of the same length from different parts of the stem may differ in weight, number of node and diameter. However, the recommended 5 to 7 nodes per 25-cm stake by Lozano *et al.,* (1977) may not always stand. Also, the 88 g as weight of standard 25-cm stake recommended by Okeke (1994) and Oke-Okoro (2001) may not always stand because, apart from the gradient mentioned above, all cassava varieties do not have the same characteristics and varied genetically. Differences in weight of cuttings result in differences in food reserves. It is on this reserve that the initial growth of the plant depends.

TMS 97/2205

TMS 30572

Plate 1 Smoothness of cassava stakes' edges cut with Secateur, showing the pith to wood ratio

TMS 92/0067

TME 419

Plate 2 Standard 25-cm stakes of CMD varieties with different number of nodes.

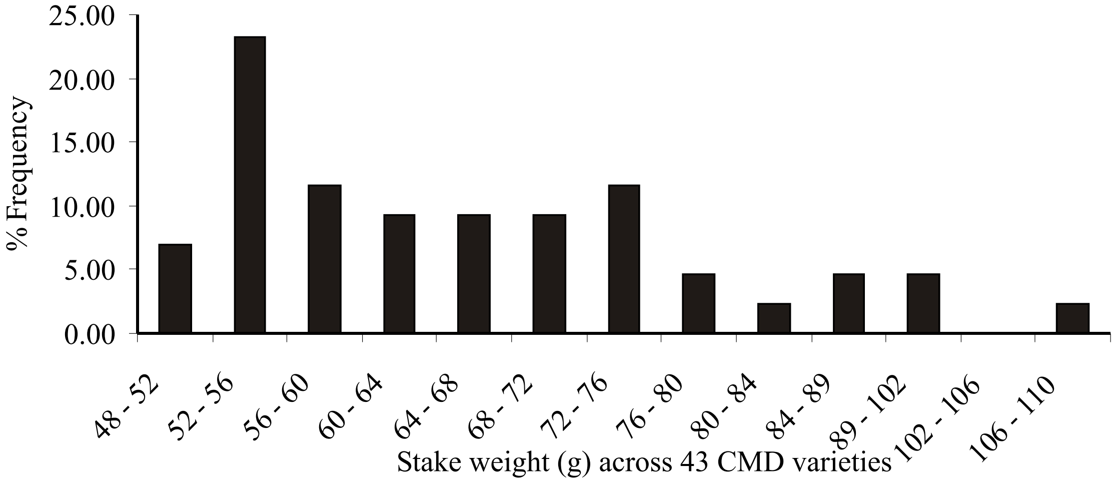

Fig.4 Weight of 25-cm stakes (g) used in the trial

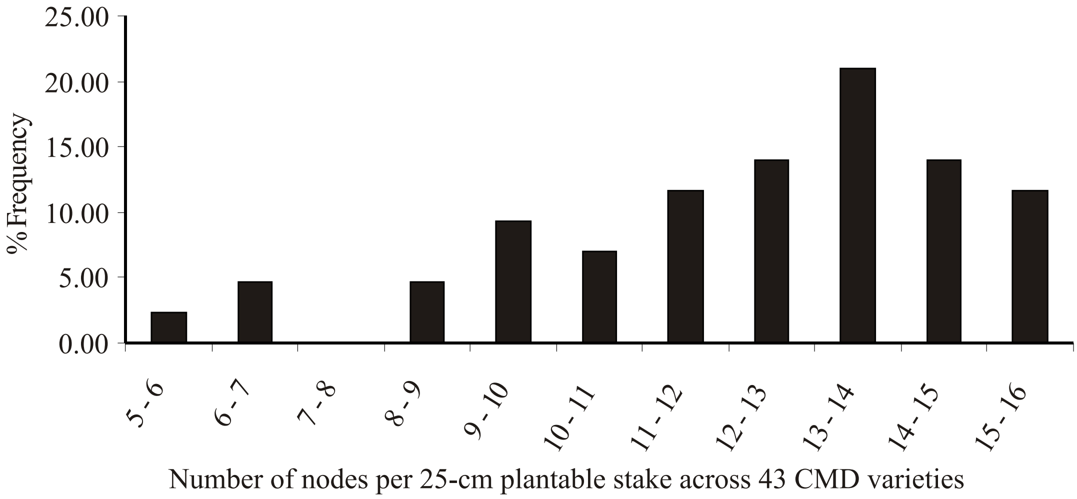

Fig. 5 Number of nodes per 25-cm stake used in the trial.

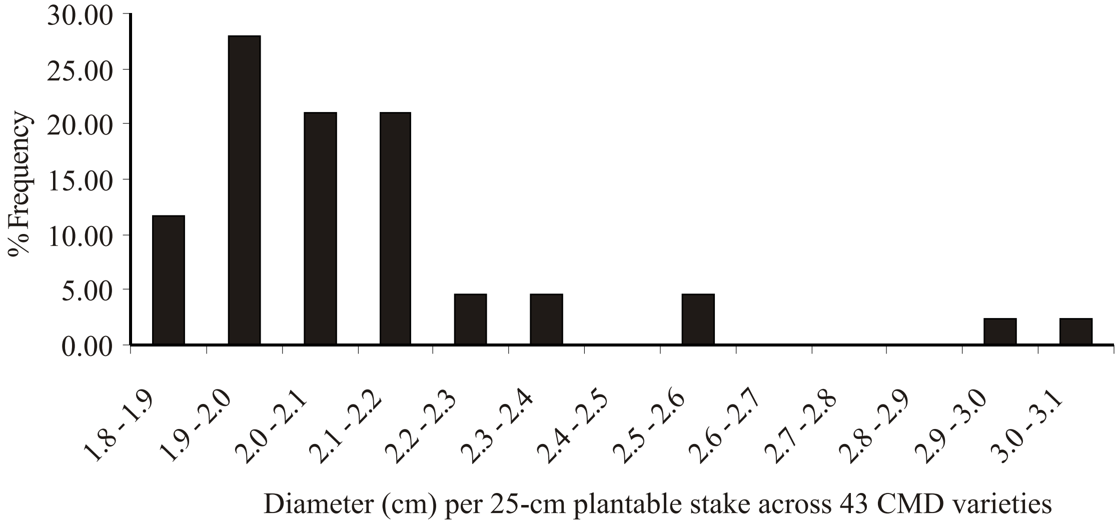

Fig. 6 Diameter (m) per 25-cm stake used in the trial.

Effect of cassava stake position on the number of 25-cm plantable stake

The performance of cassava stake positions on plantable stakes and root yield of cassava at IITA and UI is presented in table 2. Analysis of variance for the effect of stakes position from the stem on the root and stem yields was not significant. This means that the position of the stakes did not affect the root and stem yields. However, the percentage of bottom (ratio of the yield of the Top, Top-Middle, Bottom-Middle over the Bottom) was less than 100 %, which means that there was an increase in yields with the bottom part of the stem than those taken from the bottom-middle, top-middle and top. These same observations were made by Tongglum *et al.* (1987) and Chankam (1994). Stakes derived from the lower and middle part of the stem had significantly higher germination rates than those derived from the upper part of the stem (George *et al.*, 2001)

Table 2: Performance of cassava stake positions on plantable stakes and root yield of cassava at UI and IITA during the 2007/08 season.

	TME 7 UI		TMS 30572 IITA		TME 7 UI		TMS 30572 IITA	
	Mean Nps*	% of basal	Mean Nps	% of basal	Root yield (kg/plant)	% of basal	Root yield (kg/plant)	% of basal
Basal	8.28	100.0	5.01	100.0	1.66	100.0	2.89	100.0
Basal-Middle	7.84	94.6	5.08	101.2	1.47	88.5	2.81	97.2
Top-Middle	8.26	99.7	4.94	98.6	1.57	94.6	2.88	99.7
Top	7.37	89.0	5.01	99.9	1.55	93.4	2.91	100.7
Stake Position[b]		ns		ns		ns		ns

Nps* = No. of 25-cm plantable stakes, UI = University of Ibadan;
IITA = International Institute of Tropical Agriculture, b[ns]=non significant.

Multi-Dimensional Analysis (MDA)
Multi-Dimensional Analysis is defined as follows: coefficient * weight of variable

Where:

Coefficient = Variate of each clone/ Variate of best clone

MDA was calculated with the following weight of variables:

No. of plantable stakes = 5; No. of nodes = 4; Stake weight = 3; Stake diameter = 3

Results of the MDA show that the three variables accounted only for 4.3 % of the total variation in root yield. This implies that visual selection of plantable stables based on 24 quality standards is adequate because there was no significant change after such selection. Variation on the three variables not used for selection did not result in any substantial effect on root yield.

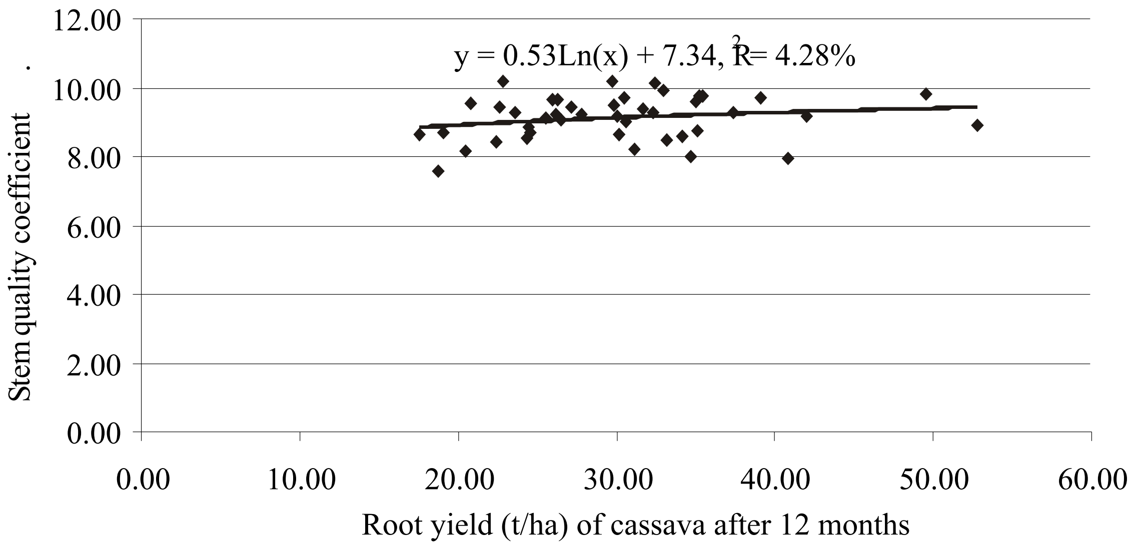

Fig. 7 Relationship between MDA of stem quality and root yield of 43 CMD varieties across 6 locations in Nigeria

Effect of quality planting material on the establishment ability

Table 3 shows that by training the farmers and our collaborators, we can bring the missing stands or loss from 42.0 % to 32.7 %. The effect of missing stands on plot yield may not be noticeable when there are one or two missing plants. The compensatory growth of neighboring plants usually helps to reduce differences in total plot yield (Perez *et al.,* 2009). However, as the proportion of missing plants increases, the compensatory growth of the remaining plants will not be enough to correct the total plot yield (Mead 1968; Gomez and De Datta, 1972; James *et al.,* 1973; Kamidi, 1995). Perez *et al.,* (2009) also found that for every genotype, mean plot yields decreased as the number of missing plant increased.

Table 3: Percentage of missing stands in farms managed by different categories of farmers

Type of farm	No. of farms assessed	Total plant expected	No. plants missing	% missing stands
Research Farms	27	264451	48035	81.2
Trained Personnel Farms	20	352674	115430	32.7
Traditional Farms	20	132317	55545	42.0

Conclusion

Good quality cassava stakes (following the 24 characteristics) is of fundamental importance for high stem and root yields. High germination percentage of cassava is one of the most important factors for cassava production and depends upon the quality of the stakes as well as the growth conditions. Poor quality planting material is often associated with marginal growth and productivity of cassava. Therefore selection of stake is necessary for improving root yield of cassava.

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Appendix. 24 points for cassava stake quality

1. Length of stem cutting (in cm) is a characteristic of a variety. No one length can be adopted generally. The inter-nodal distance affects the optimal length of cutting for each variety. A common range of length of cutting should be within 15-30 cm. When preparing and cutting stems into cuttings, the length is varied to respond to the need for plants as in seed-stem farms (where roots are a secondary concern) or as in root farms where the cuttings are usually much longer.
2. Number of live and intact nodes (a minimum of 5 up to a maximum of 8 nodes). Note that it is very difficult at planting to easily observe the number of nodes damaged visibly or invisibly as pressed nodes look normal even if they are no more viable.
3. colour of skin or outer epithelium (brown is an indicator of maturity). To use all stem portions for preparing cuttings, cut the stem at the juncture point of the green-brown point along the stem.
4. Age of plant from which the cutting was taken should be at least 6 months after planting to get cuttings for root production, but could be less if intended for stem multiplication
5. Preferred cutting weight (75 g 88 g, but usually under twice as much) at the planting time
6. A cutting for root production should relatively be at least one half of basal stem diameter
7. Focus on obtaining cutting for root production from primary branches or main stems; even though it could be derived from any type of

stem from main stem, 1°, 2°, 3°, 4° branch

8. Rank order of the cutting from base-to-tip of the stem, as the basal first cutting is of less quality and the last upper cutting from any stretch of usable stem. There is great advantage in sorting cutting at the point of cutting so that if there is surplus cuttings it will be of the least preferred types.
9. Equal (50-50) proportion of the diameter of pith to hardwood [pith-diameter ratio] of the cutting (a measure of woodiness, and a balance of maturity and meristematic vigour)
10. True to type of the desired variety (no mis-labelling). Mixed cuttings of different varieties is not the best if a target use is intended. Susceptible and resistance varieties cannot be detected at the cutting or stem stage and is loss to cultivation when discovered later in the field; especially when replacements of the missing stands can no more be. This has implication for food safety and quality of products obtained from such plants.
11. Protected against termite (with a chemical); which depends on the duration of treatment in dip solutions and air-drying. This protection is a desired step that has well proven advantage to reducing the percentage of stands that survive at harvest time.
12. Planted in wet soil only is sure to begin early emergence, especially if planted with full contact with soil with a pressed soil around the cutting. The degree of compactness of the soil around the planted cutting determines when planting is complete. Partial contact of soil with buried portion of stem is incomplete planting. Planting in dry soils lead to desiccation of the cutting before it re-hydrates and normalize for emergence of shoot. This delays early sprouting.
13. Planted with buds facing upwards is a requirement for the full quality of any cutting to be realized; although some varieties suffer less from inversion compared to others.
14. Minimum total cut surface area at each end of the cutting should be minimum. Recognizing the cut is a wound on the integrity of the stem, it should be as little as can be. The implication for how stems are cut and the cutting tools employed are to be carefully considered both in terms of smoothness and speed of cut to achieve the right practical throughput in time. Cut surface of both ends should consequently be sharp and smooth without 'splits' or 'teeth'. Freedom from splinters and tears of the hardwood reduces surface area for microbes in soil to initiate rot processes.
15. Sealed cut ends achieved by allowing stem sap to ooze and dry under shade
16. Cover stems or cuttings to avoid the harsh conditions that promote desiccation of the stem or cuttings; so cut one day or two to planting time (once cuttings are prepared, spray them with moisture to stop moisture loss). The fewer the days after preparing the 25cm stem cutting from stem, the better for good growth and field performance.
17. Ensure that you plant-bury half the number of nodes into the soil and the other half above ground. The few above ground would produce one or two or rarely three primary stems.
18. Stems are to be obtained from mother plants that are free from disease/pest. The hidden level of pest and disease symptoms in the cutting should be low. Steps taken to reduce stems with symptoms and cuttings are a good quality control measure. Only well-trained eyes can detect likely signs of ill or sane stems and cuttings. True freedom of stem from blemish of pest or disease implies the crop is inspected at several times during the growth of the field from which stems are to be taken.
19. plant at least to 5 cm, but better 10cm depth to avoid cutting drying or half of the number of nodes on the full axis of the cutting
20. Node integrity is essential, so there should be no breakage or press-injury to any node
21. Guard against any peel loss (by removal, pressure of rope when tied, or pressure against metal containers or other hard surfaces when in-transit on entire length of the cutting. Intactness of the peel or skin of the stem cuttings is sign of cutting integrity and full health. When stems are tied, place grass or rubber foam between the stem and the rope.
22. Mean diameter of stem cutting is best if around 25 mm thick (varies by variety)
23. No dehydration at both end of cutting before planting. To ensure this is helpful, if the time of preparing cuttings are as close to the day of planting as can be logistically achieved. Therefore, cut stems only few days before cuttings are prepared. In all, the level of moisture content of the stem at planting [affected by exposure to sun/wind]
24. Total amount of stored nutrients in the cutting is an invisible aspect of quality. Thus, knowledge of the soil fertility of the stem farm site is helpful. Nutrient deficient soils give nutrient deficient stems and cuttings that

perform far much less than stems from fertile soils with adequate nutrients. Similarly, the longer stored stems contain less stored carbohydrates (after much use of stored reserves for respiration) are therefore affected by such longer storage duration. The shorter the storage period, the better for cutting viability.

Evaluation of commercially available herbicides for weed control in cassava

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Abstract

A trial was conducted in 2008/09 at Chitedze (31° 59' S; 33° 38' E) and Chitala (13° 40' S; 34° 15' E) Research stations in Malawi to evaluate commercially available pre-emergent herbicides for weed control in cassava (*Manihot esculenta* Crantz). Four herbicides, Bullet (chloroacetanilide, dimethanamid, triazine), Harness 90 EC (chloroacetanilide), Codal Gold 412-5 EC (prometryn and S-metolachlor) and Metalachlor 960 EC (S-metolachlor; acetamide), were evaluated with and without follow up hand-hoe weeding (check). *Panicum maximum*, *Elusine indica*, *Rottboellia chochinchinensis* and *Setaria pumila* were the common narrow-leaved weeds while *Commelina benghalensis*, *Bidens pilosa*, *Nicandra physalodes* and *Acanthospermum hispidum* were the common broad leaved weeds. Herbicide application did not affect crop establishment but significantly ($P \leq 0.001$) reduced early weed growth by 74.8 to 91.2 % at Chitedze and 53.7 to 97.9 % at Chitala. Bullet was more effective in early weed control (2.8 weeds m^{-2} at Chitedze and 0.0 weeds m^{-2} at Chitala) than the other herbicides (38.7 weeds m^{-2} at Chitedze and 8.8 weeds m^{-2} at Chitala) and resulted in root yields (12.3 t ha^{-1} at Chitedze and 18.4 t ha^{-1} at Chitala) and returns (MK238,844.00 ha^{-1} at Chitedze and MK360,779.00 ha^{-1} at Chitala) comparable to or higher than hand weeding (root yield of 10.6 t ha^{-1} at Chitedze and 16.3 t ha^{-1} at Chitala and returns of MK201,438.00 ha^{-1} at Chitedze and MK310,448.00 ha^{-1} at Chitala) and other treatments (root yield of 2.2-13.1 t ha^{-1} at Chitedze and 1.3-23.6 t ha^{-1} at Chitala and returns of MK44,000.00 to MK249,078 at Chitedze and MK26,000.00 to MK465,100 ha^{-1} at Chitala), making it a potential alternative to hand hoe weeding in cassava.

Introduction

Cassava (*Manihot esculenta* Crantz), like any other crop, suffers from weed competition especially in the first 3 to 4 months of growth before canopy cover. Weeds can reduce root yields by up to 50 % if the fields are left unweeded during this period (Doll and Piedrahita, 1976). World wide, mechanical weeding using a hand-hoe is the most common form of weeding but is also the most expensive, representing up to half of the total costs of production (Lehiner, 2002). Thus there is need for alternative weeding methods of which use of herbicides is one of them.

In most cassava growing areas very little, if any, herbicides are used to control weeds in cassava, mostly because of the high cost and unavailability of herbicides specifically developed for cassava. However, due to the rising wages for labour herbicides are increasingly becoming the most economical means of weeding, health and environmental concerns notwithstanding. This is particularly so for commercial farmers who require simple to use, low-cost weed control measures, of which herbicides offer the greatest potential.

Malawi has of late experienced an increase in the number of commercial cassava productions which could take advantage of herbicides as an alternative to the traditional hand-hoe weeding. However, there is little information on use of herbicides for weed control in cassava in Malawi. The objective of this study was therefore to evaluate commercially available herbicides for weed control in cassava.

Materials and Methods

The trial was conducted in 2008/09 at Chitedze (31° 59' S; 33° 38' E) and Chitala (13° 40' S; 34° 15' E) Research stations in Malawi. Chitedze lies at 1,146 meters above sea level (m.a.s.l.). Mean annual temperature ranges from 16 to 24 °C and mean annual rainfall is 892 mm, with 85 % of the rain coming in November to March. Chitala lies in the Rift Valley floor at an altitude of 606 m.a.s.l. Mean annual temperature is 16 to 28 °C and mean annual rainfall is 800 mm, which mostly comes in the first 3 months of the rainy season (November to March). The soils (top soil) at both sites are sandy clay loams with acidic pH, medium organic matter (OM) and nitrogen (N) content, medium to high potassium (K) and low to very low phosphorus (P) content (Table 1).

The trial was planted on 10 December at Chitedze and 19 December 2008 at Chitala after receiving adequate planting rains (Fig 1). Treatments comprised four pre-emergent herbicides, Bullet (chloroacetanilide, dimethanamid, triazine), Harness 90 EC (chloroacetanilide), Codal Gold 412-5 EC (prometryn and S-metolachlor) and Metalachlor 960 EC (S-metolachlor; acetamide), applied with and without follow up-hand weeding; hand weeding (check) and no weeding. Hand weeding was done twice, at 1 and 3 months after planting (MAP), using a hand hoe. All the herbicides were applied within a day of planting using a MATABI 16 L knapsack sprayer. Bullet was applied at 4.0 L ha^{-1}, Harness at 1.0 L ha^{-1}, Codal Gold at 3.5 L ha^{-1} and Metalachlor at 1.5 L ha^{-1}, depending on the manufacturers recommendations. The herbicides were sourced locally in Malawi from the Agricultural Trading Company (Bullet and Metalachlor 960 EC), Monsanto (Harness 90 EC) and Chemicals & Marketing Limited (Codal Gold 412-5 EC).

The design was a Randomized Complete Block with four replicates. Plots were 7 ridges by 7 m gross and 3 ridges by 4 m net. Ridges were spaced at 0.9 m and cassava (Mbundumali variety) was planted at 0.9 m within row.

Data was collected on crop establishment, weed density and biomas, plant height, diseases and pests and, at harvest in December 2009, on root yield and yield components. Weed density and biomas were assessed at 1 MAP using a 1 m^2 quadrant. Diseases and pests were assessed at 3, 6, 9 and 12 MAP on a scale of 1 to 5, where 1 is no visible damage symptoms and 5 is severe damage symptoms. The data collected was subjected to Analysis of Variance using the SAS computer package and treatment means were separated using the Least Significant Difference (LSD). A partial budget analysis was used to evaluate the economic feasibility of the treatments.

Results and Discussion

Plant growth: Sprouting rates at 1 MAP ranged from 95.5 to 98.7 % at Chitedze and 98.2 to 100.0 % at Chitala (Table 2). However, the differences were not statistically significant ($P \leq 0.05$). Plant height ranged from 0.81 to 1.07 m at Chitedze and 0.90 to 1.26 m at Chitala and was also not statistically ($P \leq 0.05$) different among treatments, suggesting that the herbicides did not have deleterious effects on cassava sprouting and establishment. According to Leihner (2002) stakes suffer no damage from contact with the herbicides if applied immediately or within 3 days of planting before axillary buds start sprouting. However, there were marked differences in crop stands and plant height at 6 MAP with the no weeding treatment having the lowest stands and the shortest plants, largely due to growth suppression by the weeds in this treatment.

Pests and diseases: Cassava mosaic (CMD) and cassava brown streak (CBSD) were the major diseases observed (Table 3). However, the disease was not severe (mean damage score of <2.0) and no significant differences in severity was observed among treatments.

Cassava green mite (CGM) was the only major pest observed with a mean damage score of 2.3 at Chitedze and 2.4 at Chitala. However, its spread was rather on the higher side as nearly 80 % of the plants at Chitedze and 85 % at Chitala were affected.

Weed situation: The weeds were broadly grouped into narrow or broad leaved. At Chitedze the common narrow leaved weeds were Guinea grass *(Panicum maximum)*, wild finger millet *(Elusine indica)*, itch grass *(Rottboellia chochinchinensis)* and bristle grass *(Setaria pumila)* while the common broad leaved weeds were wandering dew *(Commelina benghalensis)*, black jack *(Bidens pilosa)*, apple of Peru *(Nicandra physalodes)* and star bar *(Acanthospermum hispidum)*. At Chitala wandering dew *(Commelina benghalensis)* and wild finger millet *(Elusine indica)* were the common narrow and broad leaved weeds, respectively.

Herbicide application significantly ($P \leq 0.001$) reduced early weed growth by 74.8 to 91.2 % at Chitedze and 53.7 to 97.9 % at Chitala (Figs. 2 and 3) with Bullet being the most effective (2.8 weeds m^{-2} at Chitedze and 0.0 weeds m^{-2} at Chitala) compared to the other herbicides (28.8-48.5 weeds m^{-2} at Chitedze and 6.3-11.3 weeds m^{-2} at Chitala). Weed biomas was also markedly reduced with herbicide application and the reduction was more with Bullet (9.1 g m^{-2} at Chitedze and 0.0 g m^{-2} at Chitala) than with the other herbicides (210.1-448.2 g m^{-2} at Chitedze and 9.7-30.3 g m^{-2} at Chitala).

Visual assessment at 6 MAP showed marked differences in the weed situation with hand weeding, either alone or with an herbicide, being the least weedy and the no weeding treatment the weediest. Except for Bullet, herbicide treatments without follow up hand weeding were equally weedy but did not have as much negative effects on the crop as the no weeding treatment as the crop had already well established due to the lower competition from the weeds during the early part of the crop's growth. These observations suggest a possibility of using some of the herbicides without follow up hand weeding in cassava of which Bullet seem to have the greatest potential.

Root yield and yield components: Table 4 presents root yield and yield components. At Chitedze, there were significant ($P \leq 0.001$) differences in root yield and root number among treatments. Except for Bullet, use of herbicides without follow-up hand weeding gave lower root yield (4.9-7.8 t ha^{-1}) and root number (5.2-7.1 roots $plant^{-1}$) than hand weeding (root yield of 10.6 t ha^{-1} and root number 9.2 roots $plant^{-1}$). On the other hand, Bullet without follow-up hand weeding gave comparable root yield (12.3 t ha^{-1}) and number (9.7 roots $plant^{-1}$) to hand weeding, suggesting its potential as an alternative to hand weeding as there was no yield advantage in following it up with hand weeding. This trend was also reflected in the net benefits (Table 5) where Bullet was the only herbicide without follow up hand weeding that gave comparable or better returns (Mk238, 844.00[a] ha^{-1}) than hand weeding (MK201,438.00 ha^{-1}).

At Chitala the results were similar to Chitedze with Bullet without follow up hand weeding being the only herbicide that gave better root yields (Table 4) and returns (Table 6) than hand weeding. Use of the other herbicides without follow-up hand weeding resulted in lower root yields (6.5-14.2 t ha^{-1}) and returns (MK127,474.00 to MK278,011 ha^{-1}) than the check (root yield of 16.3 t ha^{-1} and return of MK310,488.00 ha^{-1}). These results are in agreement with observations at 1 and 6 MAP where Bullet was observed to be the most effective in weed control.

Conclusions

This study shows that the herbicides did not have deleterious effects on cassava sprouting and establishment. Early weed growth was significantly reduced by use of the herbicides and, among these, Bullet was the most effective and resulted in root yields and returns comparable to or better than those of hand weeding and the other treatments, making it a potential alternative to the traditional hand weeding in cassava.

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[1]US $1.00 = MK150.00

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Table 1. Physical and chemical properties of the top soil at the test sites at Chitedze and Chitala Research stations in 2008/09.

Top soil (0-15 cm)	Chitedze	Chitala
Texture	SCL	SCL
pH	4.59	4.51
OM (%)	3.25	2.33
N (%)	0.15	0.12
P (mg /g)	17.2	2.53
K (me %)	0.34	0.46
Ca (me %)	3.76	5.38
Mg (me%)	0.90	3.13

Table 2. Crop stands and plant height at Chitedze and Chitala, Malawi at 1 and 6 MAP in the cassava herbicide trial in 2008/09

	Stand (%)				Plant height (m)			
	Chitedze		Chitala		Chitedze		Chitala	
Treatment	1 MAP	6 MAP	1 MAP	6 MAP	1 MAP	6 MAP	1 MAP	6 MAP
Bullet	96.4	93.1ab	98.2	97.1	0.96	1.85bcd	1.26	1.64ab
Harness	97.3	94.4a	98.2	100.0	1.07	1.84cd	1.19	1.35b
Codal Gold	96.0	80.6bc	99.1	94.1	1.03	1.85bcd	1.16	1.37b
Metalachlor	95.5	77.8bc	100.0	98.5	0.96	1.69d	1.25	1.44ab
Bullet + HW	96.4	94.4a	99.6	97.1	1.05	2.05a	1.26	1.71a
Harness + HW	96.0	87.5ab	99.6	95.6	0.98	1.97abc	1.09	1.54ab
Codal Gold + HW	97.3	93.1ab	99.6	92.6	0.81	2.02ab	1.12	1.64ab
Metalachlor + HW	98.7	94.4a	99.6	98.5	0.96	1.99abc	1.15	1.59ab
HW	95.5	95.8a	98.7	94.1	0.89	1.86bc	0.94	1.41ab
No weeding	96.4	65.3b	99.6	91.2	0.91	1.22e	0.9	0.95c
Mean	96.6	87.5	99.2	95.9	0.96	1.83	1.13	1.46
S.e. +	1.86NS	5.34**	0.61NS	2.67NS	0.08NS	0.05***	0.09NS	0.10***
LSD(0.05)	5.48	15.5	1.76	7.74	0.22	0.16	0.25	0.28
C.V. (%)	3.91	12.2	1.22	5.56	16.2	5.88	15.2	13.2

*NS = Not statistically significant; ** = Statistically significant at 1 % level; *** = Statistically significant at 0.1 % level*

Table 3. Cassava pest and disease scores at 6 MAP in the cassava herbicide trial at Chitedze and Chitala Research stations, Malawi in 2008/09

	Chitedze			Chitala		
Treatment	CMD	CBSD	CGM	CMD	CBSD	CGM
Bullet	1.10	1.0	2.45abc	1.03	1.68	2.40abc
Harness	1.03	1.0	2.05c	1.00	1.73	1.85c
Codal Gold	1.05	1.0	2.23bc	1.00	1.95	2.28ab c
Metalachlor	1.18	1.0	2.10c	1.03	2.05	2.08bc
Bullet + Hand weeding	1.00	1.0	2.45abc	1.03	2.15	2.68ab
Harness + Hand weeding	1.30	1.0	2.28abc	1.00	1.75	2.73ab
Codal Gold + Hoe weeding	1.00	1.0	2.65a	1.00	1.68	2.68ab
Metalachlor + Hand weeding	1.05	1.0	2.52ab	1.03	1.68	2.55abc
Hand weeding	1.28	1.0	2.33abc	1.05	1.87	2.85a
No weeding	1.03	1.0	2.13bc	1.05	1.90	2.03bc
Mean	1.10	1.0	2.32	1.02	1.84	2.41
S.e. +	1.0NS	1.0NS	0.12*	0.03NS	0.22NS	0.23*
$LSD_{(0.05)}$	0.29	0.0	0.35	0.08	0.64	0.66
C.V. (%)	18.3	1.0	10.5	5.6	24.1	18.8

Figures in a column followed by same letter are not significantly different at 5 % level
*NS = Not significant; * = Statistically significant at 5 % level*

Table 4. Effect of weeding on cassava root yield and yield components at Chitedze and Chitala, Malawi in 2008/09

	Chitedze			Chitala		
Treatment	Root yield (t ha^{-1})	No. of roots /plant	Root size (g /root)	Root yield (t ha^{-1})	No. of roots /plant	Root size (g /root)
Bullet	12.3a	9.7a	125	18.4abc	8.5a	177abc
Harness	7.8bc	7.1b	102	9.1de	6.1ab	124bc
Codal Gold	6.1c	5.7bc	111	14.2cd	7.3ab	211ab
Metalachlor	4.9cd	5.2c	117	6.5ef	4.5bc	107cd
Bullet + hand weeding	12.1a	11.0a	102	20.5ab	8.5a	215ab
Harness + hand weeding	10.6ab	9.9a	108	18.5abc	9.2a	180abc
Codal Gold + hand weeding	13 .1a	11.0a	109	18.6abc	9.1a	187abc
Metalachlor + hand weeding	12.3a	11.0a	96	23.6a	9.6a	213ab
Hand weeding	10.6ab	9.2a	100	16.3bc	9.5ab	231a
No weeding	2.2d	2.7d	107	1.3f	2.0c	75d
Mean	9.19	8.3	108	14.2	7.12	171.9
S.e. +	1.05***	0.62***	15.0NS	1.79***	1.21***	30.0*
$LSD_{(0.05)}$	3.03	1.80	43.6	5.40	3.52	87.0
C.V. (%)	22.7	15.0	27.9	25.3	34.0	34.9

*NS = Not statistically significant; * = Statistically significant at 5 % level; *** = Statistically significant at 0.1 % level*

Table 5. Net benefits of weeding treatments at Chitedze Research Station in Malawi, 2008/09

Treatment	Man-days/ha Herb appl	HW	Total	Cost of herb. (MK)	Cost of labor (MK)	Total cost (MK)	Root yield (t ha^{-1})	Income (MK)	Net Benefits (MK)
Bullet	1.1	-	1.1	6800	356.4	7156	12.3	246,000	238,844
Harness	1.1	-	1.1	1700	356.4	2056	7.8	156,000	153,944
Codal Gold	1.1	-	1.1	5600	356.4	5956	6.1	122,000	116,044
Metalachlor	0.9	-	0.9	2137.5	291.6	2429	4.9	98,000	95,571
Bullet + HW	1.1	14.5	15.6	6800	5054.4	11854	12.1	242,000	230,146
Harness + HW	1.1	23.8	24.9	1700	8067.6	9768	10.6	212,000	202,232
C. Gold + HW	0.9	21.7	22.6	5600	7322.4	12922	13.1	262,000	249,078
Metalachlor +HW	1.2	25.9	27.1	2137.5	8,780.4	10918	12.3	246,000	235,082
HW (check)	0	32.6	32.6	0	10,562.4	10562	10.6	212,000	201,438
No weeding	0	0	0	0	0	0	2.2	44,000	44,000

HW = Hand hoe weeding;US $1.00 = MK150.80

Table 6. Net benefits of weeding treatments at Chitala Research Station in Malawi, 2008/09

Treatment	Man-days/ha Herb appl	HW	Total	Cost of herb (MK)	Cost of labor (MK)	Total cost (MK)	Root yield (t ha^{-1})	Income (MK)	Net Benefits (MK)
Bullet	1.3	-	1.3	6800	421.2	7221	18.4	368,000	360,779
Harness	1.1	-	1.1	1700	356.4	2056	9.1	182,000	179,944
Codal Gold	1.2	-	1.2	5600	388.8	5989	14.2	284,000	278,011
Metalachlor	1.2	-	1.2	2137.5	388.8	2526	6.5	130,000	127,474
Bullet + HW	1.3	6.5	7.8	6800	2527.2	9327	20.5	410,000	400,673
Harness + HW	1.4	11	12.4	1700	4017.6	5718	18.5	370,000	364,282
C. Gold + HW	1.3	15.8	17.1	5600	5540.4	11140	18.6	372,000	360,860
Metalachlor + HW	1.3	13.4	14.7	2137.5	4762.8	6900	23.6	472,000	465,100
HW (check)	0	48	48	0	15552	15552	16.3	326,000	310,448
No weeding	0	0	0	0	0	0	1.3	26,000	26,000

HW = Hand hoe weeding;US $1.00 = MK150.80

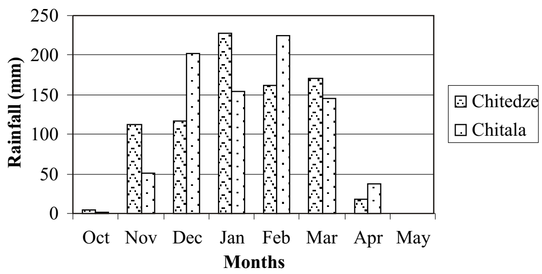

Fig 1: Monthly rainfall totals for 2008/09 at Chitedze and Chitala Research station in Malawi

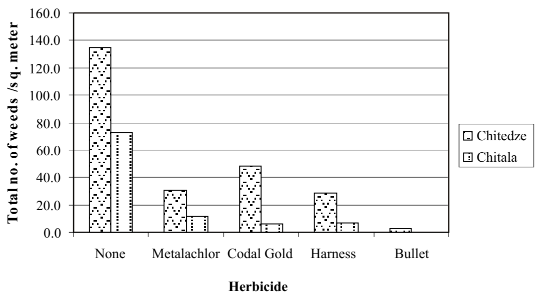

Fig 2: No of weeds/m^2 at Chitedze and Chitala, 4weeks after planting

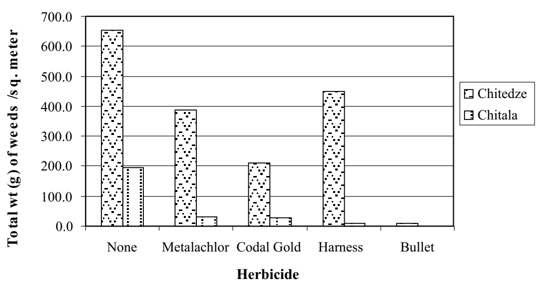

Fig. 3: Fresh weeds biomas /m2, 4 weeks after planting

Growth, yield and tuber quality of sweet potato *(Ipomea batatas L.)* in response to organic and mineral fertilizer

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There is limited information on the fertilizer response and requirements of sweet potatoes in South-western Nigeria especially its effects on tuber quality. Field experiment was conducted at the University of Agriculture Abeokuta, Nigeria in 2009 to determine the optimum rate of organic and inorganic fertilizer on growth and tuber yield of sweet potato. In June 2009, 10cm long vines of two sweet potato varieties; yellow fleshed cv Shaba and orange fleshed cv 199034.1 both are resistant to Sweet Potato Virus Disease (SPVD) were planted at 0.5m distance on ridges 0.75m apart. Five weeks after planting, 'Sunshine'organic fertilizer (SOF) [composted poultry manure + sorted city refuse at 1:2 (NPK 2.58; 1.10; 0.68%)] was applied at 20t/ha, 40t/ha and inorganic NPK+Mg 12-12-17+2 was applied 208kg/ha, 416kg/ha. No fertilizer plots serve as control. The treatments were arranged as a split- split plot complete block design with 4 replicates. Data on vine length (VL), number of leaves (NL), number of branches (NB), leaf area (LA), leaf area index (LAI) and weight of tubers (TW) were collected. Sweet potato plants that received 20t/ha of SOF produced significantly ($p<0.05$) longer vines (286.1cm), larger leaves (57456cm^2), more leaves (58.0), more branches (43.0) and higher tuber weight of 9.9 t/ha than those that received 416 kg/ha NPK+Mg fertilizer and control. 'Shaba' produced significantly longer vines with more branches than cv199034.1, while cv 199034.1 produced significantly more leaves than 'Shaba'. Sweet potato cv. 199034.1 treated with 20t/ha SOF had the highest tuber weight value of 9.9 t/ha, showing significant ($p< 0.05$) differences as compared to the yield values obtained in cultivars that received other fertilizer treatments. This was followed by cv. 'shaba' treated with 208 kg/ha NPK

with tuber yield value of 8.7 t/ha. The least tuber yield value of 1.7t/ha was obtained in 'shaba' with no fertilizer treatment (control).

Since tubers weight is a function of growth parameters (vine length, number of leaves, number of branches, leaf are etc), SOF at 20 t/ha was therefore recommended for adoption in this study. Other sweet potato cultivars need to be evaluated for performance under different rates of organic and inorganic soil amendment.\

Keywords: Growth, yield, quality, organic, sweetpotato

Introduction

Sweet potato (I*pomea batatas* L.) belongs to the family *Convolvulaceae*. It currently ranks as the fifth most important food crop in developing countries after rice, wheat, maize and cassava. It is an important food and vegetable crop that grows throughout the world especially in the tropics, sub-tropics and warm tropical areas for its edible tubers which can be eaten boiled, fried or baked. It is canned, dehydrated, used for flour and as a source of starch, glucose, syrup and alcohol. It is also fed to livestock to support a growing domestic demand for animal protein. Also a number of sweet potatoes like *Ipomea spp, Argyreis speciosa,* O*peralina spp* are grown as ornamental climbers.

It provides significant amount of protein, vitamin, carbohydrate and iron, the carbohydrate constitute about 75% of the total dry matter. It provide 5.30% of daily energy requirement, although sweet potatoes are not usually regarded as protein source because of low protein contain but it contributes 3.40% of total protein intake compared with 4.5%, 4.8% and 5.8% contributed by eggs, fish and cheese respectively (Woolfe 1986).

One of the most limiting factors for sweet potatoes production is the lack of desirable varieties, the choice of varieties depend on yield performance, nutritive value, horticultural characters, eating quality and resistance to pest and diseases. The sweet potato varieties include: Shaba, Blesbok, Ex-oyunga Arrow tip, 199034.1,SPK 004,199004-2, 440293,187016.2, etc (Nwauzor et al; 2005). Most tropical soils are highly weathered and infertile. Thus, continuous cropping on these soils reduces organic matter during the first few years following land cleaning (Brams, 1991; Juo *et, al;* 1995). Therefore external nutrient inputs are essential to improve and sustain crop production on these soils. Nutrient inputs may either be from organic sources or inorganic fertilizers (Juo and Wilding, 1996). Most farmers in the tropics have adopted the use of inorganic fertilizers, but the intensive use of this over time could constitute a setback to soil fertility. Moreso, in Nigeria, inorganic fertilization of sweet potatoes is still the commercial method of production, although they grow faster but they lack useful vitamins and mineral content. Residual effects on the soil, ecological damage, human diseases such as cancer, stomach ulcers and other metabolic disorders may be expected when compared to organically grown sweet potatoes. The use of chemicals in food production has been identified as a major source of health risk and cause of extensive environmental damage (FAO, 2001).

However, organic farming is a production system that avoid or largely excludes the use of synthetically produced fertilizers, pesticides, growth regulators and animal additives but relies as much as possible on crop rotation, crop residues, animal manures, legume and green manure (Salau, 2005). Organic fertilizer improves both the physical and chemical properties of the soil, soil structure, soil tilts, cation exchange capacity, water holding capacity and crumb formation. It also promotes infiltration, protects against erosion and facilitates the spread and penetration of plant roots. The slow release nature of organic fertilizer prevents loss of nutrients through leaching and enhances synchronization of nutrient release with uptake by the crop. And a long term effect or soil fertility. Any crop produced under this system is known as "Organically Grown Crop". Organic crops were safe to eat, rich in vitamins and minerals, good taste and do not cause any adverse effect on consumers.

Sweet potatoes production using organic fertilizer is justified. Therefore, there is need to develop complementary sources of organic fertilizer for farmers in Nigeria. Babalola *et al*., (2002) also reported that very high manure application of about 30t/ha depress growth and yield irrespective of the manure sources. Olojede *et al.,(*2005) recommended 200 kg/ha of NPK 15-15-15 for optimum yield of Livingstone potato for Eastern Nigeria. There is limited information on the fertilizer requirements of sweet potatoes in South-western Nigeria especially its effects on tuber yield. Consequently the aim of this paper is to present results of an investigation to determine the optimum rate of organic and inorganic fertilizer on growth and tuber yield of sweet potato.

Materials and Methods

A field trial was conducted at the Teaching and Research Plot of University of Agriculture Abeokuta (UNAAB), Southwestern Nigeria in 2009 to determine the optimum rate of organic and inorganic fertilizer on growth and tuber yield of sweet potato. UNAAB is located in forest/Savanna transitional zone (latitude 7^0N, longitude 3^0 23^1E). The area is characterized by bimodal rainfall with peaks in July and September. The crop weather was collected from UNAAB meteorological station. Fifteen composite of the top soil of the experimental site was collected and analyzed for the physico-chemical properties (Table 1). The land was manually cleared and ridges were made at a spacing of 0.75m apart. The entire field was demarcated into 48 plots with individual plot measured 4.5x2.5m separated by 1.0m corridor. The net experiment site was 0.05ha. The treatments were combined following a split- split plot arrangement fitted into Randomized Complete Block Design with 4 replicates. The main plot comprise of: Sunshine Organic Fertilizer (SOF) and NPK+Mg: 12-12-17+2. The sub plot was two sweet potato cultivars: Cv.199034.1 (orange fleshed sweet potato) and cv. 'Shaba' (yellow fleshed sweet potato**).** The sub-sub plot was three fertilizer rates: SOF-: 0t/ha, 20t/ha and 40t/ha, NPK-0Kg/ha, 208kg/ha and 416kg/ha. The sweet potato varieties were planted 0.5cm apart on ridges 0.75cm apart. Three weeks after planting, the two fertilizers type with proximate analyses (Table 2), was spot applied to the sweetpotato plantlets 10cm away in ring form.

Table 1: Pre-planting soil physical and chemical properties of the experimental site

Soil properties	Value
Soil pH(H_2O)	5.70
Organic matter (%)	0.40
Total N (%)	0.07
Available P (ppm)	4.50
Exchangeable K (meq/100g)	0.31
Exchangeable Na (meq/100g)	0.32
Exchangeable Mg(meq/100g)	2.00
Exchangeable Ca (meq/100g)	2.30
Exchangeable acidity	0.40
Exchangeable Zn (ppm)	6.20
Exchangeable Fe (ppm)	10.00
Cation Exchange Capacity (CEC)	0.02
Sand	86.70
Silt	10.00
Clay	3.30

Table 2. Nutrient content of the fertilizer materials

	Fertilizer materials	
Properties	SOF*	NPK+Mg
N (%)	2.58	12
P	1.10	12
K	0.68	17
Ca (mol/kg)	3.62	-
Mg	0.18	2%
C/N ratio (g/kg)	8.97	-
Na (cmol kg^{-1})	1.75	-
Fe (mg kg^{-1})	4.42	-
Mn	3.7	-
Cu	11.45	-
Zn	3.60	-
Mo	0.12	-
B	0.06	-

**SOF = Sunshine Organic fertilizer*

Data Collection

To know the effect of organic and mineral fertilizer on growth performance of sweet potato, data were taken on Vine length, Number of leaves, Number of branches, Leaf Area, Leaf Area Index (LAI) at bi-weekly intervals after fertilizer application. Data on root length, root weight, stem weight, leaf weight; total fresh weight and tuber yield were recorded at harvest. Data generated were subjected to Analysis of variance (ANOVA) at 5% level of probability and the separation of treatment means was done (SAS, version 9.1) by the use of least significance difference (LSD) and Duncan multiple range Test (DMRT) where applicable (Wahua, 1999).

Results and Discussion

The pre-treatment soil nutrient analyses in 2006 revealed that the pH of the soil was slightly acidic 5.97, the soil N (0.07%) was below critical level of 0.25% recommended for citrus. The P, 3.59 mg kg^{-1} and K, 0.14cmol kg^{-1} are lower than 13 mg kg^{-1} and 0.34 cmol kg^{-1} P and K recommended for citrus (Sobulo and Osiname, 1981; Adeoye and Agboola, 1985), and hence justified the need for additional fertilizer treatment. The soils silt, clay and sand contents of between 100-110, 120-130 and 760-780 g/kg respectively are optimal to retain adequate water for normal crop growth. Sunshine Organic fertilizer (poultry manure plus sorted city refuse) contained 2.58, 1.10, 0.68, 3.62 and 0.18% of N, P, K, Ca and Mg, respectively. NPK contained 46% N, TSP contained 60% P while MOP contained 60% K. The organic materials are rich in plant nutrients with C/N ratios of 8.97g/kg being adequate for quick nutrient release.

Effects of different fertilizer treatments on growth and tuber yield of sweet potato

Sweet potato plants that received 20t/ha of SOF produced significantly ($p<0.05$) longer vines, larger leaves, more leaves, more branches and higher tuber weight of 9.9 t/ha than those that received 416 kg/ha NPK+Mg fertilizer and control. (Table 3-7) 'Shaba' produced significantly longer vines with more branches than cv199034.1, while cv 199034.1 produced significantly more leaves than 'Shaba'. Sweet potato cv. 199034.1 treated with 20t/ha SOF had the highest tuber weight value of 9.93 t/ha, showing significant ($p< 0.05$) differences as compared to the yield values obtained in cultivars that received other fertilizer treatments. This was followed by cv. 'shaba' treated with 208 kg/ha NPK with tuber yield value of 8.7 t/ha. The least tuber yield value of 1.7t/ha was obtained in 'shaba' with no fertilizer treatment (control) (Table 5 & 6).

Effect of fertilizer treatments on Tuber yield and yield components (Table 7) indicated that sweet potato plants that received 20t/ha SOF were significant ($p< 0.05$) superior to those plants treated with other fertilizer treatments in root length, root weight, stem weight, leaf weight and total fresh weight with value of 78.1cm, 99.8, 17.4, 20.7 and 38.9 kg/plot respectively except for plants that grown with 208 kg/ha NPK and 40t/ha SOF. The least values of 50.8cm, 54.0, 6.7, 7.7 and 15.2 for root length, root weight, stem weight, leaf weight and total fresh weight respectively were obtained in plants that received no fertilizer treatments. The superiority of fertilizer treated sweetpotato plants over the control in growth performance (vine length, number of leaves, number of branches, leaf area index and yield parameters) indicated that the control plants will be in short supply of nutrients over time with resultant low tuber yield both in quantity and quality. The application SOF at 20 t/ha was in most cases better than NPK in enhancing growth and yield of sweetpotato crop. This is because the organic fertilizer improves both the physical and chemical properties of the soil, soil structure, soil tilts, cation exchange capacity, water holding capacity and crumb formation. It also promotes infiltration, protects against erosion and facilitates the spread and penetration of plant roots. The relatively poor performance of the SOF at 40 t/ha and NPK at 416 kg/ha is due the excess nutrient contain in the fertilizer materials which may be assuming toxicity level. This is in accord with the observation of Babalola *et al*., (2002) and Giwa and Ojeniyi 2005 who reported that very high manure application of about 30 t/ha depress growth and yield irrespective of the manure sources and that the use of mineral fertilizer (e.g. NPK) is beyond the reach of peasant farmers due to high cost and procurement difficulties especially in developing countries like Nigeria. Apart from this, continuous use of mineral fertilizer alone leads to soil acidity, nutrient imbalance and declining crop yield (Tendon, 1992).

Conclusion

Optimum rate of organic and inorganic fertilizer on growth and tuber yield of sweet potato were investigated. Results obtained indicated the superiority of SOF rate at 20t/ha over all other fertilizer treatment for all the growth and yield parameters measured in this study. Also sweet potato cultivar 199034.1 was found to be superior to cv. 'Shaba' in terms of tuber yield and other yield component. Since tubers yield is a function of growth parameters (vine length, number of leaves, number of branches, leaf are etc), SOF at 20t/ha was therefore recommended for adoption in this study. Other sweet potato cultivars need to be evaluated for performance under different rates of organic and inorganic soil amendment.

Table 3: Effect of Fertilizer treatments on vine length of sweet potato

	Vine length of Sweet potato (Weeks after fertilizer application (WAF)					
Fertilizer rate	2	4	6	8	10	12
20thaSO F	129.3a	185.5a	236.5a	273.71a	297.5a	332.4a
40thaSOF	107.9b	155.2ab	214.3b	232.88b	283.4a	317.5b
208KghaNPK	176.8a	183.8b	230.5a	269.63a	290.3a	322.1a
416KghaNPK	70.3c	179.4b	191.13b	224.19b	249.6b	268.3c
Control1	59.9c	103.4b	174.68c	182.69d	198.4c	2 14.6d
Control 2	57.4c	117.5b	173.46c	189.7d	203.8c	221.5d
SE	9.23	10.18	10.50	11.07	11.36	12.39

Table 4: Effect of Fertilizer treatments on number of leaves of sweet potato

	Number of leaves of Sweet potato (Weeks after fertilizer application (WAF)					
Fertilizer rate	2	4	6	8	10	12
20thaSOF	58.5abc	64.9bcd	78.8ab	169.1a	249.1a	324.9a
40thaSOF	73.9ab	85.8abc	96.3ab	125.5ab	198.5ab	312.1a
208KghaNPK	85.6a	102.9a	119.6a	153.6a	223.9a	319.3a
416KghaNPK	82.5a	99.1ab	120.4a	158.1a	208.5ab	288.6ab
Control 1	49.8bc	61.9cd	76.1b	95.3bc	120.9c	239b
Control 2	42.4c	59.6cd	62.6b	85.0c	113.1c	211.5c
SE	8.35	11.24	11.450	12.13	12.54	13.43

Table 5: Effect of Fertilizer treatments on number of vine branches of sweet potato

	Number of Vine branches of Sweet potato (WAF)					
Fertilizer rate	2	4	6	8	10	12
20thaSOF	4.1a	6.8a	10.8a	13.6a	15.2a	20.4a
40thaSOF	3.9a	6.4a	4.5c	7.9b	14.7a	16.5ab
208KghaNPK	4.9a	6.9a	7.0a	8.6b	13.6a	14.9b
416KghaNPK	3.4ab	5.8ab	3.6c	6.9b	12.9ab	14.6b
Control1	1.6b	3.5b	5.6b	6.8b	8.9b	13.8b
Control 2	2.0b	3.4b	4.4c	6.1b	8.4b	12.1b
SE	0.74	0.84	0.99	0.67	0.72	0.51

Table 6: Effect of Fertilizer treatments on leaf area index of sweet potato

	Leaf Area Index of Sweet potato (WAF)					
Fertilizer rate	2	4	6	8	10	12
20thaSOF	2.1a	3.9a	9.3a	11.7a	15.9a	16.9a
40thaSOF	1.6ab	2.7bc	6.4a	10.3a	12.3b	13.8bc
208KghaNPK	1.6ab	3.1ab	4.7b	9.5b	13.8b	15.1b
416KghaNPK	1.0cd	1.9c	5.6bc	8.1cd	13.3b	14.7b
Control1	0.9d	1.7c	4.6bc	7.7cd	11.9b	13.7bc
Control 2	1.1cd	1.7c	3.5c	5.9d	11.3b	13.2c
SE	0.23	0.46	0.93	0.76	0.87	0.84

Table 7: Effect of Fertilizer treatments on tuber yield and yield components of sweet potato variety.

	Yield and yield Components of Sweet potato (WAF)					
Fertilizer rate	Rootlenght (cm)	RootWeight (Wt)	StemWt	LeafWt	TotalFresh (Wt)	Tuber Yield (t/ha)
		-----kg/plot-----				
20thaSOF	78.1a	99.8a	17.4a	20.7a	38.9a	9.90a
40thaSOF	61.3c	82.1b	12.7ab	14.7bc	22.2b	7.50b
208KghaNPK	69.5b	81.5b	14.8a	17.6ab	33.5a	8.40b
416KghaNPK	58.4c	66.5c	10.7b	8.9cd	18.2b	6.15c
Control1	48.0d	59.3cd	7.8a	8.7d	18.0b	3.60d
Control 2	50.8d	54.0d	6.7b	7.7d	15.2b	3.10d
SE	2.43	3.45	1.18	1.60	1.91	0.58

Table 8: Effect of Fertilizer treatments on sweet potato cultivars on vine length, number of leaves, number of vine branches and leaf area index of two sweet potato cultivars

Vine length						
Cultivars	2	4	6	8	10	12
199034.1	87.0	98.2	110.6	128.6	151.8	180.0
Shaba	80.2	90.9	101.8	117.4	134.7	157.9
LSD	7.6	8.1	8.8	9.7	10.8	11.8
Number of Leaves						
Cultivars	2	4	6	8	10	12
199034.1	49.3	63.6	85.3	110.2	151.5	239.9
Shaba	81.6	91.1	99.3	135.3	173.1	325.2
LSD	6.3	7.1	8.5	12.2	14.0	20.1
Number of vine branches						
Cultivars	2	4	6	8	10	12
199034.1	4.4	5.7	7.3	12.3	13.9	18.6
Shaba	1.6	2.5	3.3	5.4	7.9	12.1
LSD	1.17	1.34	1.60	2.01	2.27	2.59
Leaf area index						
Cultivars	2	4	6	8	10	12
199034.1	1.55	2.65	6.08	10.70	15.61	18.45
Shaba	1.22	2.35	5.29	9.02	16.89	21.39
LSD	0.37	0.66	1.49	1.92	4.07	16.85

Table 9: Yield and yield component of sweet potato cultivars at harvest

	Yield	Root Lenght	Root Wt	Shoot Wt	Leaf Wt	Total FreshWt	Root DryWt	Leaf DryWt	Shoot DryWt	Total DryWt
Cultivars	(t/ha)	(cm)	------ ------------------------------			Kg/plot ---				
199034.1	9.93	65.08	6.26	11.06	12.04	2373.83	43.0	451.58	385.67	880.25
Shaba	8.73	56.92	8.51	10.35	13.75	2496.17	47.38	380.42	327.42	755.21
LSD	0.71	3.91	2.48	1.8	3.2 9	4.66	4.08	14.8	37.22	43.51

Acknowledgement
The Authors are grateful to the Department for International Development and Association of African Universities, Ghana [www.aau.mrci.net/files/] for sponsoring this research under Partnership for Regional Food Developers InitiativeA Capacity Building Support Strategy for Poverty Reduction in West Africa and the Establishment of a Food and Organic Agriculture Network.

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Improvement of traits associated with high and early root productivity in cassava (*Manihot esculenta* Crantz)

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Abstract

Late root bulking is a major factor leading to rejection and abandoning of improved cassava genotypes in sub-Saharan Africa. Early Bulking (EB) varieties shorten the growth period from planting to harvesting, better fit into environments with short rainy season, reduce exposure to biotic and abiotic stresses thereby increasing productivity. Nine cassava hybrid populations (COB-1 to COB-9) were developed using six cassava elite varieties. The progenies were evaluated for early bulking and high yielding (EB-HY) at seedling, clonal, and preliminary yield trial stages of breeding programme at seven months after planting (MAP) at Umudike. Thirty-two selected EB-HY genotypes from preliminary evaluation trial with checks (TMS 30572 and TMS 98/0505) were assessed for EB-HY at Umudike, Otobi and Ibadan (all in Nigeria) at 7 MAP in randomized complete blocks with three replications. Collected data were subjected to analysis of variance (ANOVA) and Genotype plus Genotype x Enviroment (GGE) biplot analysis. There were significant differences among the genotypes for all the variables studied at different evaluation stages. GGE biplot analysis identified different elite genotypes at different locations. The significant relationship (r = 1) observed between FRY and DRY at 7 MAP as revealed by the genotype x trait biplot analysis suggests that DRY is highly a function of FRY regardless of differences in dry matter content of the evaluated genotypes. Therefore, a breeder may select with high accuracy for DRY in cassava using the FRY data. The EB-HY cassava genotypes with higher FTRY than the checks across the three locations offer cassava growers high productivity in less than 12 MAP.

Keywords: Cassava, early bulking, high yielding

Word count: 244

Introduction

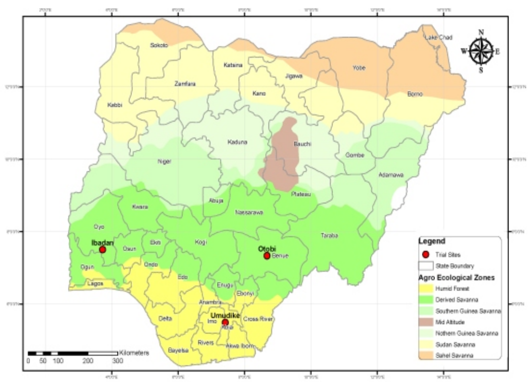
Cassava (*Manihot esculenta* Crantz) is the most important of the root crops in the tropics and ranks fourth after rice, sugarcane and maize as a source of calorie for human needs (CIAT, 1992; IITA, 2000). Its production and processing provide employment and income for the rural poor, especially women and children (Sarma and Kunchai, 1989). Cassava's long growth cycle makes it relatively difficult for the crop to be readily available on time to farmers and consumers for food and income. Late root bulking is a major factor leading to rejection and abandoning of improved cassava genotypes in sub-Saharan Africa. Early Bulking (EB) varieties shorten the growth period from planting to harvesting, better fit into environments with short rainy season; reduce exposure to biotic and abiotic stresses thereby increasing productivity (Nweke *et al*., 1994). Early yield in cassava is highly influenced by each of harvest index, foliage, root diameter and root number (Okogbenin and Fregene, 2002). The expanding demands for cassava as food, feed and industrial raw material have made genotypes with high yield and early bulking attributes to be highly desired, hence, improvement of early bulking may have a dual output of early varieties and improved crop yields (Okogbenin and Fregene 2002). The objective of this study was to develop early bulking and high yielding (EB-HY) cassava genotypes.

Materials and Methods

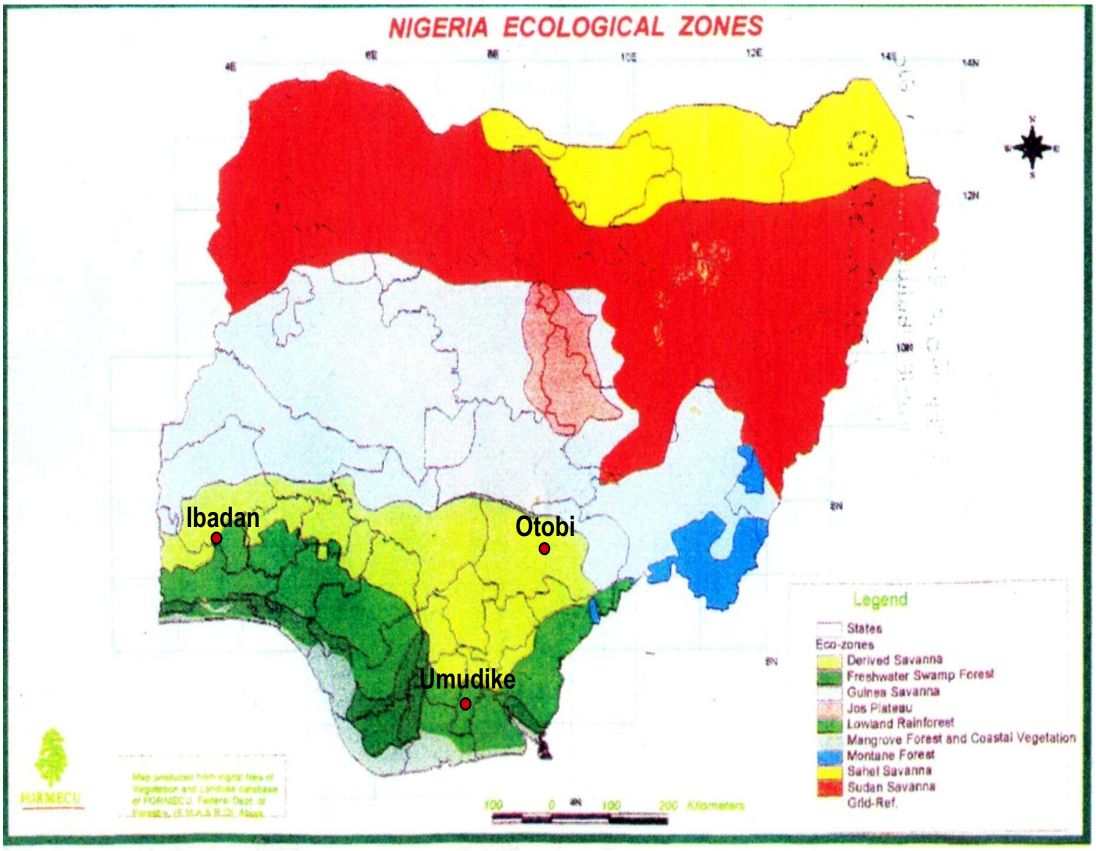
Nine cassava populations (COB-1 to COB-9) were developed using six elite varieties from the African cassava germplasm as parents (Table 1) in 2005. The three female parents have been earlier classified as early bulking varieties and the three male parents as late bulking varieties at NRCRI, Umudike (Unpublished data). The progenies in the nine populations were evaluated for fresh root yield (FRY), fresh shoot weight (FSW), number of tuberous roots (NTR), and harvest index (HI) at seedling, clonal, and preliminary trial stages of breeding programme seven months after planting (MAP) at Umudike between 2006 and 2008. Thirty-two EB-HY genotypes were selected after preliminary evaluation trial for multilocational trial (MLT). The selected genotypes and two checks (TMS 30572 and TMS 98/0505) were assessed for FTRY, FSW, NTR, and HI at Umudike, Otobi and Ibadan (all in Nigeria) (Figures 1A and B) at 7 MAP in randomized complete blocks with three replications in 2008. TMS 30572 is currently the national check while TMS 98/0505 is one of the newly released high yielding and CMD resistant varieties by IITA, Ibadan. White (1983) classified Ibadan to be at transitional zone between lowland rainforest and derived savanna while IITA (2009) classified the site to be in the derived savanna. The collected data were subjected to analysis of variance (ANOVA) and Genotype plus Genotype x Enviroment (GGE) biplot analysis.

Table 1: Nine cassava hybrid populations developed from six elite varieties

Population	Female parent	Male parent	Number of progenies
COB-1	TMS 30572	TMS 30555	181
COB-2	TMS 30572	NR 8212	119
COB-3	TMS 30572	NR 8083	124
COB-4	TMS 97/2205	TMS 30555	148
COB-5	TMS 97/2205	NR 8212	133
COB-6	TMS 97/2205	NR 8083	101
COB-7	TMS 98/0505	TMS 30555	272
COB-8	TMS 98/0505	NR 8212	199
COB-9	TMS 98/0505	NR 8083	217



Source: IITA (2009)



Source: White (1983)

Figure1: Agro-ecological (A) and Ecological (B) maps of Nigeria showing the three locations used for multilocational trial of the selected early bulking cassava genotypes.

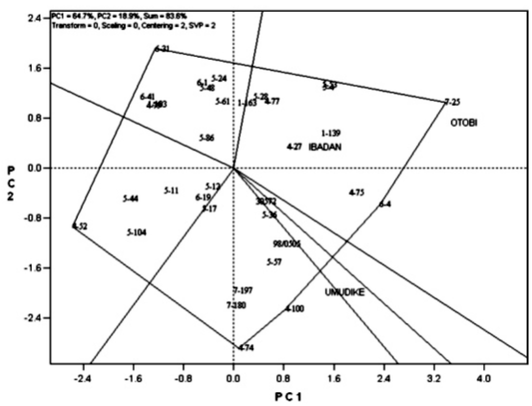
Results and Discussion

There were significant differences (p<0.05) among the progenies for FTRY, FSW, NTR and HI at seedling, clonal and preliminary evaluation stages. Significant genotype x environment interaction (p<0.05) was detected for all the traits studied. The top EB-HY genotypes identified at Umudike (COB-4-74, COB-4-100, COB-6-4, COB-7-180, and COB-7-197), Ibadan (COB-5-53, COB-5-4, COB-4-75, COB-6-1, and COB-6-4) and Otobi (COB-7-25, COB-1-139, COB-6-4, COB-4-75, and COB-5-4) had FTRY of 12.6 - 14.9 t/ha, 16.2 - 20.1 t/ha, and 20.5 - 32.6 t/ha, respectively (data not shown). Table 2 shows the mean dry root yield of the top ten genotypes and the two checks across the three locations. Six of the genotypes performed better than TMS 98/0505 (a newly released high yielding and CMD resistant variety with higher FRY and DRY than TMS 30572, the current national check). However, only COB-7-25 had significantly higher mean DRY than the two checks across the three locations. GGE biplot analysis identified different elite genotypes at different locations (Figure 2). There was a positive association between FRY/DRY and each of number of tuberous roots/plant (NOORT), harvest index (HARVSETI) and total biomass (BIOMASS) as indicated by the acute angle between their respective vectors. The significant relation-ship (r = 1) observed between FRY and DRY at 7 MAP as revealed by the genotype x trait biplot analysis (Figure 3) suggests that DRY is highly a function of FRY regardless of differences in dry matter content of the evaluated genotypes. Therefore, a breeder may select with high accuracy for DRY in cassava using the FRY data.

Table 2: Mean dry root yield (t/ha) of selected early bulking cassava genotypes and two checks evaluated at three locations 7 months after planting

Genotype	Umudike	Ibadan	Otobi	Mean	% Rel. Index
COB -7-25	4.68	6.58	13.15	8.14	128.5
COB -5-53	3.13	8.43	10.44	7.33	115.9
COB -6-4	4.77	6.64	10.27	7.23	114.2
COB -4-75	4.37	7.19	9.59	7.05	111.4
COB -4-100	5.68	6.71	8.07	6.82	107.7
COB -5-4	2.98	7.62	9.45	6.68	105.6
TMS 98/0505	4.02	6.56	8.41	6.33	100.0
COB -5-57	4.84	5.74	8.38	6.32	99.8
COB -5-36	4.24	6.46	8.23	6.31	99.7
COB -4-27	3.76	6.31	8.81	6.29	99.4
COB -7-180	5.39	5.21	7.79	6.13	96.8
TMS 30572	4.47	5.62	8.03	6.04	95.4
LSD	1.80	2.80	2.42	1.42	

% Rel. index = Percentage relative index in relation to better check (TMS 98/0505)



% Rel. Index = Percentage relative index in relation to better check (TMS 98/0505)

Figure 2: Genotype plus genotype x enviroment (GGE) biplot based on the fresh root yield (t/ha) of 32 early bulking cassava genotypes and 2 checks grown at three locations in Nigeria in 2008. (PC1 = 64.7% PC2 = 18.9%; Sum = 83.6%). All genotypes are prefixed by COB- except TMS 98/0505 and TMS 30572. Test sites are given in block letters. PC=Principal component

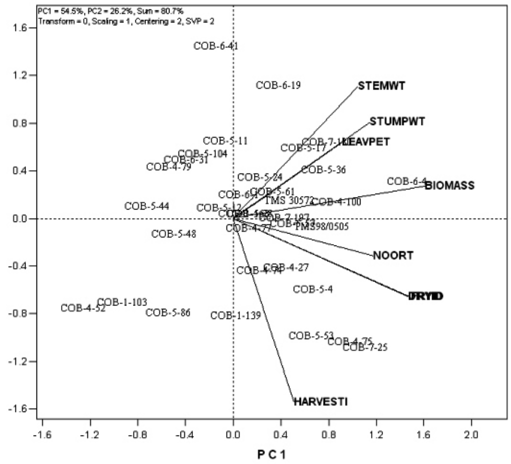


Figure 3: Genotype x trait (GT) biplot of 32 early bulking cassava genotypes and 2 checks evaluated for fresh root yield (FRY), dry root yield (DRY), harvest index (HARVESTI), number of tuberous roots (NOORT), total biomass (BIOMASS), fresh weight of leaves, petiole and non-plantable stems (LEAVPET), stump weight (STUMPWT), and plantable stem yield (STEMWT) at three locations in Nigeria in 2008.

Conclusion and perspectives

The EB-HY cassava genotypes with higher FRY and DRY than the checks across the three locations offer cassava growers high productivity in less than 12 MAP. Early bulking and high yielding (EB-HY) cassava genotypes will ensure shortened production period and thereby solve the problem of drought spell and short rainy season experienced in the dry savanna. This will therefore reduce some of the problems associated with climate change as experienced in the world presently. Cultivation of the EB-HY genotypes will also reduce the period over which farmers wait before they can get some food/income from their farms and thereby improve the role of cassava as a food security crop. Also, early maturing variety may be important to young farmers starting their own farm and requiring early harvest. The selected EB-HY genotypes are currently being evaluated for FRY, DRY and other yield-related attributes at different harvesting age (7 and 12 MAP) at two locations (Umudike and Otobi) in Nigeria to ascertain the potential of the genotypes at 12 MAP.

Acknowledgment
This study was conducted with funding support from Kirkhouse Trust Foundation, UK and with support from University of Ibadan, Nigeria; International Center for Tropical Agriculture (CIAT), Cali, Colombia; National Root Crops Research Institute (NRCRI), Umudike; Federal Ministry of Commerce, Nigeria; and Generation Challenge Programme (GCP).

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Response of sweetpotato genotypes to aluminum toxicity, phosphorus and lime application in acid soils of Zambia

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Abstract
Acid soils are widely distributed in the agro-ecological region III of Zambia, which covers Northern, Luapula and Northwestern Provinces with rainfall exceeding 1000 mm per annum. Maintenance of fertility in such soils is quite problematic due to excessive leaching of nutrients, and low soil pH related problems. This study was therefore conducted to determine the response of sweetpotato to lime and P application, and identify cultivars that are tolerant to aluminum toxicity. Two experiments were conducted. In the first experiment, 15 cultivars of sweetpotato which included Zambezi, K118, Ukerewe, Ejumua, Kakamega, Naspot 1, Tainung 65, Natal red, Lunga, L3-Santamaro/3, Chingovwa, L3-NC 1560/4, Xusha, Chisenga, and Matembele were screened in solution culture containing 0 or 200 μM Al. In both cases 20 Kg/ha N and 20 Kg/ha K were applied. The effects of lime and phosphorus were assessed by applying 2000 Kg of lime and 60 Kg P ha^{-1} in comparison with 1000 Kg of lime and 30 Kg P ha^{-1} to the solution culture. The amount of Al absorbed in the sweetpotato root tips and relative root growth in solution culture were used to classify the genotypes into tolerant or sensitive. Lime and P when applied together were found to increase number of roots and diameter, and vine length by 10 and 20%, and 15% respectively. The amount of Al^{3+} accumulated in leaf tissues ranged from 20 to 200 ppm.

In the second experiment, same cultivars were screened in the field. 2000 Kg of lime and 60 Kg P ha^{-1} were applied and compared with 1000 Kg of lime and 30 Kg P ha^{-1} with no other external chemical inputs. Soils samples taken at planting time had a pH of 4.6, 0.06 total N, 12 ppm P, 0.93% organic carbon, and the exchangeable cations were 0.04 Na^{+}, 0.87 Ca^{2+}, 0.23K^{+}, and 0.4 Mg^{2+} meq/100g. However, 5 months after planting, soils were found to contain high Al levels ranging from 53 to 79% Al^{3+} with an average value of 66.4% and pH 4.36 in the absence of lime, as compared with a

range of 5 to 20% Al^{3+} in plots where lime was applied. Lime application alone did not cause any change in root yield, and there was no yield advantage due to application of 2000 kg of lime over that of 1000 Kg ha^{-1}. Available P ranged from nil to 15ppm. Application of P alone at 30 Kg and 60 Kg ha^{-1} resulted in 10% and 20% increase in root yield, respectively.

The concentration of Al^{3+} in leaf tissues ranged from 25 to 470 ppm. 53.3% of the genotypes were classified as tolerant, of which 37.5% yielded above 20t/ha and were classified both as aluminum-tolerant and high yielding. On the other hand, 46.7% of the genotypes evaluated were found to be sensitive to aluminum toxicity, of which 28.6% were high yielding as well. The study indicates that acid soils contribute to low yields of sweetpotato, and that application of lime and P can contribute to significant yield improvement. Wide variability exists among local and introduced sweetpotato genotypes for tolerance to aluminum toxicity.

Background

Though sweetpotato is reported to be adaptable to a wide range of soils and grows well under marginal conditions of low fertility and low pH (Hahn, 1977), its performance can be improved by optimizing soil conditions. Some of the unfavourable soil conditions that are arising from prevailing climate change include increasing soil acidity and changes in the amounts and types of clay and organic matter, amount and distribution of rainfall, and temperatures. Despite the recent noticeable variations in performance of sweetpotato between low pH and high pH soils, effect of soil acidity on crop productivity is usually ignored in sweetpotato breeding. However, the prevailing and anticipated climate changes demand that suitable varieties and agronomic packages be prepared for the farming communities.

Aluminum is a major constituent of most soils in the high rainfall region of Zambia, which covers Luapula, Northern, and Northwestern Provinces. However, aluminum only becomes a problem at pH below 5.5 (Brown and Johnson 1982) when it moves into soluble or exchangeable form. Soils at Mutanda research station in Northwestern Province are characterized by low pH (4.2), low CEC (ranging from 0.2 to 0.9 meq/100g), high levels of toxic aluminum ions (Al^{3+}) and low available phosphorus. These conditions are suspected to be responsible for low productivity of most crops including sweetpotato in the region. This study was therefore carried out to understand the variations in responses of sweetpotato genotypes to soil acidity, and identify acid tolerant sweet potato genotypes suitable for the high rainfall region of Zambia (region III), which can be used as parents in the hybridization programme.

Materials and Methods

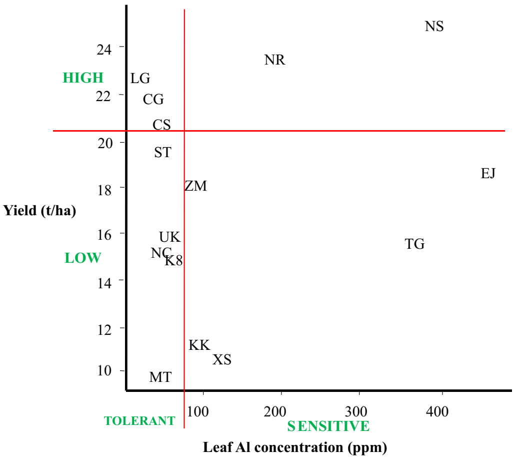
A total of 15 sweetpotato genotypes were evaluated in the field to determine their responses to aluminum toxicity (Figure 1). They were laid out in a randomized complete block experimental design with three replications. At the time of harvest, leaf samples were collected from each clone and ashed in a furnace at 500°C overnight, after which phosphorous determination was done (Bouma et al., 1981). Using correlation graphs for pH against Phosphorous, aluminum content in each clone was estimated. Soil samples were also taken from the experimental site and pH analysed in the laboratory as described by Cheatle and Klooster (1984).

In another experiment, two-node cuttings were obtained from the same 15 genotypes in the field and were planted in a screen house. Initially, the cuttings were planted in cotton wool and watered with distilled water. Three weeks later, all plots were treated with 20 Kg/ha N and 20 Kg/ha K (Simwambana et al., 1998). Additionally, designated plots were treated with 200μM aluminum hydroxide, 60 kg/ha and 30 kg/ha phosphorus, 2000 kg/ha and 1000 kg/ha lime, purely and in various combinations.

Results

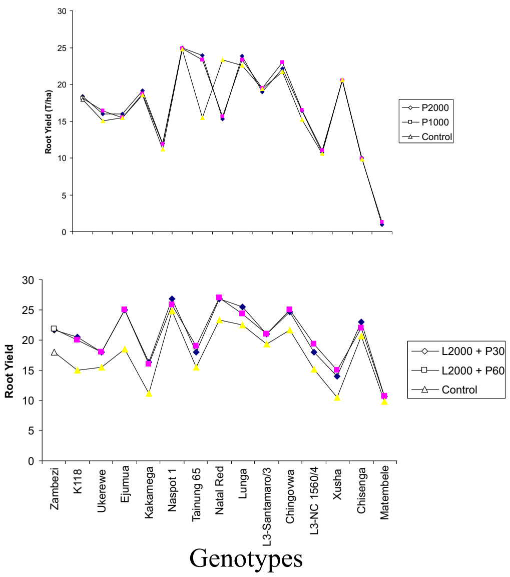
Soils samples taken at planting time of planting sweetpotato had a pH of 4.6, contained 0.06 total N, 12 ppm P, 0.93% organic carbon, and the exchangeable cations were: 0.04 Na^{+}, 0.87 Ca^{2+}, 0.23K+, and 0.4 Mg^{2+} meq/100g. However 3 months later, soil samples obtained from the experimental site were found to contain high levels of Aluminum and literally no phosphorus. Aluminum levels ranged from 53 to 79% Al^{3+} with an average value of 66.4% and pH 4.36. Sweetpotato genotypes exhibited wide variability for tolerance to Al toxicity. 53.3% of the genotypes were classified as tolerant, of which 37.5% yielded above 20t/ha and were classified both as aluminum-tolerant and high yielding. On the other hand, 46.7% of the genotypes evaluated were found to be sensitive to aluminum toxicity, of which 28.6% were high yielding as well (above 20t/ha) (Figure 1).

All the genotypes responded to lime and P which when applied together were found to increase root yield considerably for some genotypes. Lime application alone did not cause any change in yield, and there was no yield advantage due to application of 2000 kg of lime over that of 1000 Kg lime per hectare (Figure 2). However, P alone at 30 Kg and 60 Kg/ha resulted in 10% and 20% increase in root yield, respectively.



ZM = Zambezi, K8 =K118, UK = Ukerewe, EJ = Ejumua,
KK = Kakamega, NS = Naspot 1, TG = Tainung 65,
NR = Natal red, LG = Lunga, ST = L3-Santamaro/3,
CG = Chingovwa, NC = L3-NC 1560/4, XS = Xusha,
CS = 2N Chisenga, MT = 16M Matembele

Figure 1: Classification of sweetpotato genotypes according to their yield and tolerance to aluminum toxicity



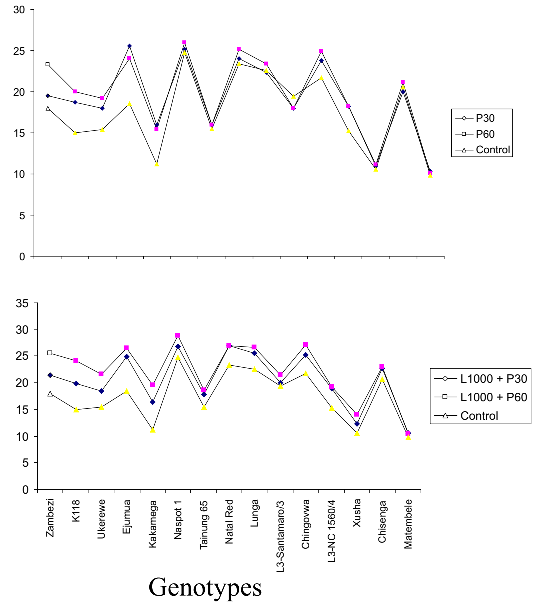


Figure 2: Responses of sweetpotato genotypes to lime and phosphorus application in acid soils of Zambia

On the basis of Al accumulation in leaf tissues, results obtained from the field experiment were similar to those from the greenhouse experiment. Genotypes that proved to be sensitive to aluminum in the screen-house were also classified as such in the field and otherwise (Figure 3).

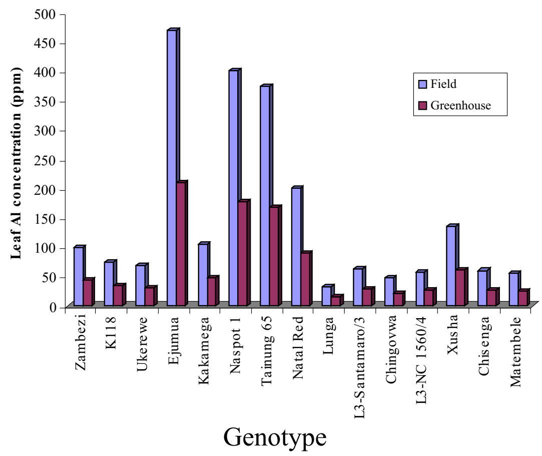


Figure 3: Variability in tolerance to aluminum toxicity among sweetpotato genotypes in Zambia

Discussion

Though phosphorus has earlier been reported to have insignificant contribution to root development (Simwambana et al., 1998), its positive effect was evident when applied to soils which had literally no available phosphorus and very low pH. The levels of aluminum were very high, resulting in reduced root development. Consequently, most of the genotypes yielded more vines at the expense of root yield.

Evidence exist that different amounts and types of clay and organic matter can affect both the potential amount of Al available to go into solution, as well as the amount of Al that can be fixed or tied-up, after it is formed. Certain compounds in soil organic matter have the ability to form Al-chelates which are unavailable to plants thus removing some of the Al^{3+} from soil solution (Brown et al. 1994), suggesting a need for genotype by environment interaction trails (G x E trials). Though generally sweetpotato is a tolerant species, there are variations among genotypes. Gregan (1980) reported variations among species with regard to tolerance to Al toxicity. Lucerne and phalaris are reported to be highly sensitive. On the other hand, subterranean clover and perennial ryegrass are moderately tolerant, while cocksfoot is tolerant. The extremely high concentrations of Al recorded in sweetpotato leaf tissues in all the genotypes also confirm that sweetpotato is a tolerant species. In this study values above 75 ppm Al^{3+} were considered toxic in sweetpotato after considering their limitations on yield. Peverill et al. (1980) report that aluminum levels greater than 15 mg/Kg may be a problem and above 50 mg/kg toxic in Lucerne. Bouma et al. (1981) have cautioned that the concentration of aluminum in leaf tissues when taken in isolation may not be of much value in determining toxicity. However, tolerance makes more sense when measured in relation to yield performance. Genotypes that withstand high levels of Al^{3+} and are only able to accumulate little in their tissues stand high chances of surviving under toxic conditions, as compared to those that accumulate high levels.

Therefore, the best category of genotypes for the high rainfall region of Zambia could be those genotypes that accumulate less Al^{3+} and yield highly in low pH soils. Coincidentally, these are locally collected and locally bred genotype in Zambia namely Lunga, Chingovwa and Chisenga. These are potential donor of genes for tolerance to Al toxicity because they are well acclimatized and better adapted to the local environment than most introductions. They combine tolerance with high yielding ability. Other genotypes that might be considered in the hybridization programme as sources of genes for Al tolerance only would include L3-Santamaro/3, Ukerewe, Matembele, K118, and L3-NC 1560/4.

Though lime is not mobile enough to have a significant and quick effect on subsoil acidity, it appears to have some synergistic effect when applied in combination with phosphorus on sweetpotato.

However, soil tests for aluminum toxicity have not been adequately correlated in the field for many plant species including sweetpotato. Nevertheless, the similarity in the results obtained in the field and greenhouse gives some indication that sweetpotato genotypes can be evaluated for the potential tolerance to Al toxicity in a much cheaper and quicker way in a greenhouse.

Conclusion

Three varieties namely Lunga, Chingovwa and Chisenga combine Al tolerance with high yielding ability, while L3-Santamaro/3, Ukerewe, Matembele, K118, and L3-NC 1560/4 appear only to have genes for tolerance to Al toxicity. Genotypes in these two categories would be potential donors of genes for tolerance to Al toxicity.

The study indicates that acid soils contribute to low yields of sweet potato, and that application of lime and P can contribute to significant yield improvement. Application of only 1000 Kg/ha of lime appeared to be sufficient to mobilize phosphorus in acid solutions. 60 kg/ha of p in combination with 1000 kg/ha of lime may be recommended for sweetpotato production in highly acidic soils of Zambia. There is wide variability in sweet potato germplasm with regard to their response to aluminum toxicity in acid soils. However, we need to conduct Genotype x Environment trials give a better conclusion.

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Improving food security and income and enhancing farmers' livelihoods in Cameroon through the introduction and promotion of improved cassava germplasm

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Abstract

Cassava is an important staple food for consumption and income generation for farming communities in Cameroon with some estimated 204,548 hectares devoted to it and corresponding annual production of 2.5 million tons. However, most cultivated varieties are susceptible to pest and diseases causing significant yield losses. Major pest and disease constraints include the African root and tuber scale (ARTS), cassava green mite (CGM), cassava mosaic virus disease (CMD), cassava anthracnose disease (CAD), and root rots. More than 200 high yielding cassava varieties, with a range of resistance principally to CMD and suitability for *Typhlodromalus aripo*, the principal biological control agent of cassava green mite, were introduced into Cameroon from IITA headquarters in Ibadan, Nigeria for testing under several agroecological conditions across Cameroon. At present, five TMS varieties (92/0057, 92/0067, 92/0326, 96/0023, and 96/1414) have been retained on the basis of their high root yield (>20t/ha), high dry matter content (>35%), high CMD resistance, and a combination of suitability to predatory mites (92/0057, 92/0067, and 92/0326), and resistance to CAD and tolerance to ARTS (96/0023). The latter is being largely promoted in the forest zone where the two constraints are most prevalent. These varieties are being propagated through a three-tier multiplication scheme (primary, secondary and tertiary) to ensure equitable, fast and sustainable distribution of healthy planting materials with two IFAD-funded projects, *Programme National de Développement des Racines et Tubercules* (PNDRT) - implemented by the government of Cameroon, and Cassava IPM implemented by IITA. Through PNDRT, cuttings of the improved varieties (92/0326 and 96/1414) were multiplied and distributed to farmers in 221 villages. The Cassava IPM project emphasized the multiplication and distribution of 96/0023 in the forest zone where ARTS and CAD are major constraints, and 92/0057, 92/0067 and 92/0326 for several regions in Cameroon due to their suitability to the biological control of cassava green mite, in addition to their resistance to CMD. At least 500 farmers in the targeted zones have grown at least 100 plants of each of the varieties in the targeted areas. Presently, more than 550 hectares have been set aside by both projects to produce planting material for distribution. These dissemination schemes have significantly boosted cassava production from 8-10 tons per hectare to 25-30 tons per hectare, and have provoked the need for post-harvest facilities.

Keywords: Cassava, host plant resistance, food security and income.

Introduction

Of the over 16 million inhabitants in Cameroon, 48.6% live in rural areas and depend mostly on agriculture for their livelihoods (Dury et al. 2004). Historically, agriculture in Cameroon relied on primary products such as cocoa, coffee and rubber which are vulnerable to volatile world market prices. In light of increased world food crises since year 2000, increasing cassava production became crucial for both food security and income (Essono et al. 2008). Cassava is the second most important staple crop in Africa after maize. It is a major staple for more than 200 million people in Eastern and Central Africa (ECA) most of them living in rural areas. The crop has been prioritized by NEPAD as a 'poverty fighter'. Cassava is seen to have potential to be transformed from a purely subsistence into a commercial crop providing raw materials to the food, feed, starch, ethanol and bio-fuel industries as has been achieved in other countries such as Brazil and Thailand. However, its production, utilization and realization of this potential is undermined by several factors, the most critical of which is lack of improved varieties resistant to endemic and emerging pests and diseases (Njukwe et al. 2010). Annual consumption in Cameroon exceeds 35kg per person for fresh roots and approaches 60kg for processed products in urban areas with the Centre, East and South regions being the most productive areas (PNDRT, 2005). It is often cultivated as mono-crop or in various combinations with leguminous crops such as groundnut and cowpea or other short season crops such as maize. Some estimated 204,548 hectare is devoted to cassava production with corresponding annual production of 2.5 million tons. However, most cultivated varieties are susceptible to pest and diseases with high cyanide content causing significant yield losses and health problems. Major pests include African root and tuber scale (ARTS), cassava green mite (CGM), cassava mealybug and variegated grasshopper while major diseases include Cassava mosaic virus disease (CMD), cassava anthracnose disease (CAD), cassava bacterial blight (CBB) and root rots. Pests constitute the most serious constraint faced by cassava farmers in Cameroon (Akinbade et al. 2010). The importance attached to cassava production and its constraints in the country led to the inclusion of Cameroon as one of the countries to host the UNDP Ecologically Sustainable Cassava Plant Protection project (ESCaPP), which involved four countries in west and central Africa during 1993 1997. As the project ended without farmers having access to improved cassava varieties as predicted, the International Institute of Tropical Agriculture (IITA) initiated a scheme to rapidly introduce elite germplasm for participatory evaluation, selection, multiplication and distribution. The evaluation and dissemination process started in 2003 when the planting materials were received from Ibadan Nigeria. After two years of on-station testing including numerous consumer assessments, farmers' preferred varieties was distributed to smallholder farmers through the collaboration of national research systems, non-governmental organizations (NGOs) and special government projects. Cuttings obtained from the smallholders' multiplication plots were disseminated in small numbers to farmers for them to establish their own multiplication plots where they could get large numbers of planting materials to grow larger plots. In this project, efforts were geared to disseminating and popularizing the new varieties and at the same time maintaining a constant link between research that continuously generates new technologies and the end-users to increase the impact of the improved interventions on improving the livelihoods of beneficiaries. The purpose of the project was to develop a cost effective and sustainable system for continuous multiplication and timely distribution of quality planting material. It was conceived that this would contribute to alleviating food insecurity and poverty among small-scale farmers in Cameroon through increased production of cassava varieties that are high yielding and resistant to pests and diseases.

Material and Methods

In 2003, over 200 varieties with a range of resistance principally to CMD and suitability for Typhlodromalus aripo, the principal biological control agent of cassava green mite, were introduced into Cameroon from IITA Ibadan for testing under several agroecological conditions across the country. This was in collaboration with official plant quarantine services in Nigeria and Cameroon, which is followed by evaluation and dissemination using a farmer-participatory approach both on station and on farm. This process is backed by (1) establishment of relay centers for the demonstration, multiplication and distribution of best-bet selections and (2) training in rapid multiplication and post-harvest utilization techniques. The transfer of planting material to relay centers is backed by the signing of material transfer agreement (MTA) between suppliers and recipients. Delivery hubs are focal sites or relay centers located and representing agroecological zones Bamenda (high plateau), Ebolowa (forest bimodal), Bertoua (Forest/savannah transition), Kumba (forest monomodal) and Ngaoundere (guinea savannah) and serves as sites where project activities (evaluation, demonstrations, multiplication, training) and products (varieties, techniques, awareness tools) radiates across the target region. Delivery hubs have demonstrated human and logistical capacity for (i) technology evaluation and demonstration, (ii) plant propagation and distribution, and (iii) post harvest processing demonstration and marketing services. Each site is equipped with (i) a model post-harvest processing facility as well as (ii) a plant propagation facility allowing for high throughput production of clean planting material, using low-cost techniques. Five satellite villages are linked to each focal site, comprising five contact farmers targeted for the dissemination of subsets of improved varieties and technologies. Contact farmers receive improved varieties, which they asses along side traditional varieties in order to select those most adapted to their own needs and conditions. Field days are organized to educate and spread the varieties to other farmers. In order to ensure the dissemination of improved varieties beyond the initial intervention site, every contact farmer is expected to return at the end of a crop cycle 25% planting material for each genotype received. It is then propagated and subjected to sanitation at the focal sites and distributed to a new wave of farmers, and so on. Continuing the principle of farmers returning planting material to the focal sites ensures a continual and expanding supply of planting material of improved varieties. Memorandum of Understanding (MOU) is established between IITA and the focal sites and Letter of Agreement between the focal sites and the satellite centers and contact farmers indicating responsibilities, expectations and ownership. The technological pathways and distribution channel of planting material is as shown in Figure 1. Introduced varieties were evaluated at 3, 6, 9 and 12 months after planting (MAP) in Nloubessa alongside two popular cultivars against root scale and the basis for selecting variety 96/0023 as shown in Figure 2. The two local cultivars used in the experiment had contrasting preferences. Cultivar Cam62 was identified as high yielding in Cameroon during a rapid assessment by IRAD but highly susceptible to CMD while local manioc rouge (LMR) is the most preferred cultivar for boil and eat. Cultural practices by the removal of host plant residues two weeks before planting is adopted in the forest zone to reduce ARTS pressure. Initial stocks of planting materials from IITA are multiplied by hubs centres to constitute what is referred to as a Primary Multiplication Site (PMS). From the PMS, planting material of adapted varieties are sent to satellites to establish Secondary Multiplication Sites (SMS) and to the farmers' associations to establish the Tertiary Multiplication Sites (TMS). From tertiary multiplication sites, planting material are distributed and/or sold to individual farmers. This scheme has rapidly changed the status of cassava from subsistence to a commercial commodity through the sale of quality planting material of improved varieties which makes it more profitable than the sale of fresh roots thus improving farmers' incomes and livelihoods.

Results and Discussion

Till date, over 50 NGOs, National research institute (IRAD), National development programme (PNDRT) of the ministry of agriculture and rural development and International partners (FAO, CARE) have benefited from improved planting materials in Cameroon. Cuttings enough for planting 300 hectares have been distributed and the success of this programme is attributed to high commitment by all participating partners, rapid evaluation of the varieties, continuous feedback on the challenges, low cost plant propagation methods and appropriate scheme for rapid dissemination of the improved varieties.

In conclusion, IITA Cameroon station serve as transit points from where best introduced varieties are distributed to partners for evaluation outside IITA in partnerships with IRAD, Universities, Ministry of Agriculture and Rural Development, National Development Programmes, NGOs and Farmer Groups. Steps for evaluation and selection follow a farmer-participatory approach in collaboration with official plant quarantine services. Improved varieties increase yield and provide environmentally sound and economically efficient options for combating pest and diseases. Feedback from farmers converges on the usually good performance of improved varieties (high yield, earliness, disease and pest resistance, ease of peeling, leafiness) with an acute need for more planting materials. The dissemination scheme has improved farmers livelihood from yield increase (8-10 tons per hectare to 25-30 tons per hectare) and increasing market opportunities from processing and utilization and has provoked the need for post-harvest facilities. At present, five TMS varieties (92/0057, 92/0067, 92/0326, 96/0023, and 96/1414) have been retained on the basis of their high root yield (>20t/ha), high dry matter content (>35%), high CMD resistance, and a combination of suitability to predatory mites (92/0057, 92/0067, and 92/0326), and resistance to CAD and tolerance to ARTS (96/0023). The latter is being largely promoted in the forest zone where the two constraints are most prevalent. These varieties are being propagated through a three-tier multiplication scheme (primary, secondary and tertiary) to ensure equitable, fast and sustainable distribution of clean planting materials. More than 550 hectares have been set aside by both PNDRT-MINADER and IPM-IITA projects to produc e planting material for distribution. Presently in Cameroon**, t**he role of cassava is rapidly changing from a traditional fresh human food commodity to an efficient crop for agro-industrial processing. Varietal improvement for higher yield and root dry matter content is bringing additional cash income to a great number of smallholder farmers.

Acknowledgements

The authors wish to acknowledge the financial support of IFAD through the government of Cameroon roots and tuber development programme (PNDRT) and IITA for developing improved and adapted varieties and a scheme for sustainable cassava testing and dissemination.

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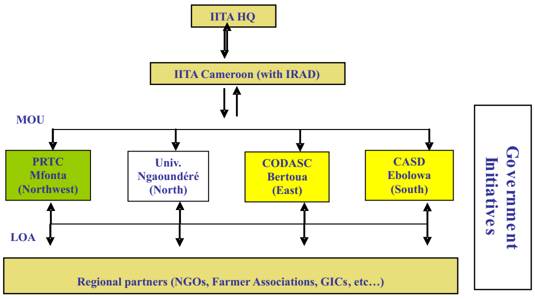

Figure 1: Cassava testing and distribution scheme

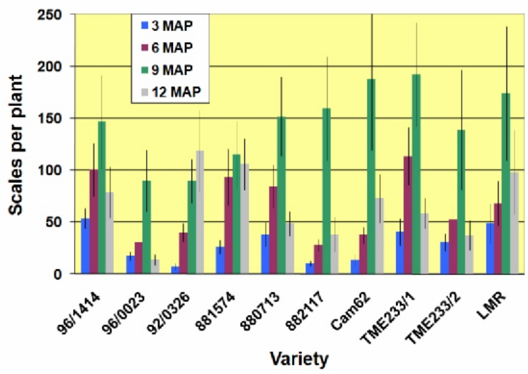

Figure 2: Cassava evaluation at Nloubessa and basis for selecting 96/0023 against the root scale.

Distribution at primary and secondary sites

Distribution at tertiary site

Root and Tuber Crops Food Surveillance for Food Security in Nigeria

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Abstract

Food from crops and plants and animal sources add up to what makes human diet. In Nigeria, the monitoring of the flows of food stuffs from all sources to gauge the total availability after discounting all losses and wastages is not a usual practice nationwide. The quantitative accounting of all production and imports discounted for exports and smugglings of all forms are to be measured to help regulate what is produced and where these are stored to make the pursuit of food security of a nation feasible. A fragmented approach is suggested where the smallest reasonable administrative land area is delineated and their in-flows and out-flows of food materials from all sources in the food sector of the country understood. A state is too big and a ward is too small. A Local Government Area (LGA) is suggested. The trends in the production and usage of the crops are considered as regards what scenarios emerge with each season of farming. These quantitative understandings only make sense when related to the rate of population growth and ability of the populace to purchase food. Surveillance is more apt in military where all lines of battle are coordinated to ensure victory. The completeness of the coordination leaves no aspect out of the consideration so that the chances of surprises are reduced to a minimum with a maximum-likelihood of advance without retreat in the achievement of set goals. We apply same concept in the follow-through of food from root and tuber crops, from within each administrative unit and from outside it. Here, we estimate the contribution of root and tuber crops to the total food usage in Nigeria. It is pertinent to understand the assumption of one-half loss of all root crops implies that the current rate of production is enough for now if all losses can be stopped. Where are the losses in the food chain? How can these be blocked and/or reduced? These are the focal points of the debate engaged in this paper.

Introduction

Surveillance means: to watch over; more at vigil; watchful; close watch kept over someone or something as by a detective; also supervision (Webster dictionary). It also means vigilant supervision; spy-like watching; superintendence (*Chambers Dictionary*). Applying these definitions to the art and science of watching over what is happening daily on the food sector of each LGA in Nigeria would greatly tell us how to manage and support the food and nutrition sector to cater for the wellbeing of all Nigerians. This is yet to be fully appreciated in the country as we depend on data generated to please the political class without a national network of offices that collect and collate data and information from each LGA and ward in the federation. Journalist would also help to supplement the changes that occur each day as they cover their beats at every level of the community and see and photographs sights and scenes across the nation.

Consider and accountant who has the name of every worker in his or her computer and enters all money paid in or out by each customer. In this way, the totals of all money going out and coming into the treasury are known on a daily basis. Once it is spent by a person, there is a record on that name and the change in the overall situation on finance is known for the group. That is how the currency must also be monitored. Can we do so for food produced and food wasted and the food consumed and imported from all ports and entrances into the national border posts. Just how many border posts (a number is required so that the file for that border post is kept as to bags of each food item that goes or comes), how many ports do we have (a file on how much food items go and comes), so too with the airports, and water ways and creeks in the boundary points).

Only and comprehensive approach to this measuring of flows of food and losses and imports and wastages and rots and spills and flood damages and fire infernos of stores and vehicles and truck accident losses can give us a grip on the statistics of what is available. What is consumed by each family require year-round

Objective of surveillance is to achieve fuller and better control and management of food supply to the people of the country residents. Country residents are the human population that reside within the boundaries of the nation. It includes foreigners who live within its borders and buy food within it. The high population areas are shown in Figure 1.

Figure 1. High population areas of Nigeria (darkened areas)

Surveillance implies a watchman *accounting* for food stocks from root and tuber crops and other food items in al local diet in a defined community. This is based on food items produced, imported, collected from wild vegetation, lost across the chain, and saved in storable forms for use between or over seasons. Nigeria has 37 units (36 states and a federal capital territory. The country has been developed from erstwhile 14 former empires amalgamated by British rule. The 505 languages add diversity which sometimes blocks the flow of goods and services to the nation and the social community. It is important that food consumption averages be determined for each ethnic group and for each LGA in the country so that the commonly consumed food and their frequencies across the weeks of the year are documented. This will then form the basis for nation computations on what people eat. The cumulative is what all production and import and hunting and collection from the wild and forest are to provide for. This is what must be done to fully capture the food and nutrition needs of Nigerians. The recent population of about 156 million people spread over a land area of 924,768 sq-km is covered by farmers' fields scattered over about 32% of the land area.

Based on the regular diet of the peoples of the many villages and food recipes it is from the preferences of 774 local governments that we arrive at about 70 food crop species constituting the major diets.

The annual production of these foods as well as many forest food products are all to be accounted for. The state ADPs and the ministries of agriculture have the primary duty of food production support services as regards:

a) Information generation and dissemination to farmers through the extension services
b) Marketing support through the provision of rural feeder roads for the evacuation of the farm produce to processing centres
c) Measurement and regulation of the spoilage and storage of food for tomorrow or what may be called food reserves against the evil day when floods or droughts or fire or locust or pest attacks can wipe out a whole season of the major staples
d) Regulation of the pricing system such that the cooperatives and the farmer association and groups are well informed of the status of price changes and where the current demand lies

Figure 2. The 37 units for calculating food stocks in Nigeria.

Understanding the techniques for food Stock Management constitutes the background that is essential to handling all operations that will lead to Food Security. Nigeria farm statistics show numerous signs of a high probability of future hunger, if now action is taken today! Consider that there are 92,376,800 ha of land surface in Nigeria 0f these, some 79,000,000 ha are cultivable but only 32,000,000 ha are cultivated yearly.

90% farmers cultivate 0.8-1.2 ha in the south and 2-4 ha in the north. The mean of farms is less than 2 ha per farm household is expected to be cultivated annually. To date, these smallholder farmers have continued to produce most of the food we consume and export from Nigeria.

Watchman *accounting* for Food Stocks from RTC in a defined community based on food items produced, imported, collected from wild vegetation, lost across the chain, and saved in storable forms for use between or over seasons. Nigeria: 37 units.

The basis of future hunger

The lack of welfare has affected the likelihood of an approaching future hunger. Several aspects

- Agro-phobia of the youths: fewer farm workers
- No or low support to agriculture sector especially as relates to access to low interest credit
- Low level of mechanized agriculture and poor land use policy in aggregating villages and liberating land for more organised land use that allow for machines to work the land
- Land tenure that encourage fragmentation
- Research results that are fragmented and full of gaps making the impact inconsequential
- Poor image of food systems operators in the Nigerian society
- Low integrity of agricultural data syndrome to give wrong signals of safety when it is not so
- Holistic understanding is currently low among the leaders of the nation and those who direct policies on food and agriculture and nutrition. This is a recipe for inadequate management of the affairs of the food security of the nation.

Food, Agriculture, and Nutrition Surveillance (FANS)

Nigeria: Human Population Statistics
The population of the country is always changing and should be put in perspective when considering food security.

The rate of rise of population is uncontrolled and this is not a good strategy for sustainable development in a developing country. At the 3.18 % annual increase from 1991 to 2006, it is clear that the need for some form of population control is needed to underpin the mismatch between the hunger and resource capacity gap.

Carrying Capacity of the nation in terms of *food for all* who can afford and those who cannot afford relates to the ability to purchase the food if available. The cost of production and transportation of the food and its marketing and transaction costs make the food too expensive to most Nigerians. The subsidy on food would come as a result of factors that reduce the cost of production and the drive to put food first in government polity as well as the support of private sector to the concept of food for all. Crime rate and Corruption will proportionately rise as the *imbalance* of those who can afford food and those who cannot afford food become more negative with time across the nation.

2006 National Census Data

Education of active Nigerians 15-59 years old was appalling. A pool of 55.5% of women and 43.5% of men are not educated enough to practice modern agriculture in Nigeria. Only about 31% of rural Nigerians are able to engage in any modern farming. Understanding the requirements of such farming and being able to acquire the skills needed to perform are low and inadequate among most rural farmers without a certain level of literacy and numeracy.

Matrices of Numbers

The food of any state is the aggregate of all the mouths to be fed. The spread of the population by age for each LGA is a matrix. If we achieve that we are on the way to achieving a good knowledge of the people to be considered for each type of calorie-protein computation. There would be matrices for:

a) matrices for each food stuff Nigerians consume by state and even by LGA
b) matrices for food losses by all major roads in consultation with offices of the Federal Road Safety Corps
c) intensive information and data exploration and capture from numerous field studies or food research by state and the for information on how to judge and estimate the likely food production. Perhaps there would be need for each university and research institution in Nigeria doing research in Nigeria relating to food and nutrition security to have an office unit in the library where such research report or reprints are regularly deposited and where access is eased for such data and information gathering
d) The consumption patterns to be established by surveys
e) Food prices and the purchasing power and amounts that people buy for family use
f) Storage losses from many studies by NISPRI stations across Nigeria by crop

Credit access

Percentage of bank credit in Nigeria to agriculture progressively declined from 17.5 % in 2002 to 4.0 % in 2007 (Daily Sun, 12 March 2010, page 50). Only the direct effort at understanding the level of support to farmers in the rural areas where food is produced would give the more direct information needed. Banks and credit institutions are important in this regard. Once the true state of food production, processing and transportation and spoilage information are kept, then the volume and capacity for the production of consumable items can be more fully estimated.

As long as long term investment in food is not available, so too would the farmers lack the capacity to engage in any medium-large scale investment. The majority of small fields cultivated now will not be able to sustain the family with a large excess. Consequently, the likelihood of greatly increased field areas under crops is low. Hand-hoe and cutlass farming average 1.5 ha per adult male. Thus, as funds to hire labour remains difficult, the hectares will continue to be shared to all crops that must be cultivated. Credit at 8-10% interest is nominally available but rarely given to farmers because rain-fed farming is considered great risk to bank money on. When would the government and Central Bank of Nigeria take to task each commercial bank for not adhering to the level of bank loans given to agricultural activities and projects? Food security is also a security to banks and bank workers. Food security is also security to all other workers and communities in Nigeria. Bank donation of vehicle and gears to police force is appreciated but that is one aspect of the whole picture.

Understanding Components of the Integral.

The components of the food system is complete when we add up all sources of all food consumed in all units of the country. The components that make for the total food include:

Production of food in gardens and farms

Production of food from Livestock

Collection of food from *flora* and *fauna* of forests, wild vegetation, and water bodies

Import of all food items within the time frame of consideration

Wastage of food from rots, accidents, pests, diseases, unused fragments, burnt food, ...

Export or *Smuggling* of food out of Nigeria's community of 37 administrative units

Poor Policy Support denudes efforts towards achieving food security

Economic Commission for Africa:
In 2009, Africa received foreign aid worth $3 billion but spent $33 billion in food imports and is still largely hungry'. Imports cost of could have been diverted to domestic production to reduce poverty and re-position Africa in the global economy.

Scientists = brain workers who think for the benefits of society

As watchmen, the scattered disjointed mass of trickling data is to be harnessed for articulating the future scenarios. The best bet situation has to be forecast from bits of thousands of data 'tailored' together and the 'resultants' announced as widely as possible to alert those that are positioned and have the *resources to change* things.

Quantifying the Components
The six components of the food stock are not simple variables. Each is a family of sub-components that are to be found or determined in virtually every piece of publication in the country. The bits of

Food stock available for human consumption = F
$F = \Sigma P1 + P2 + C + I - W - Es$

P1: *Production* of food in gardens and farms
P2: *Production* of food from livestock
C: *Collection* of food from *flora* and *fauna* of forests, wild vegetation, and water bodies within the territorial area
I: *Import* of all food items within the time frame of consideration and watching
W: *Wastage* of food from rots, accidents, pests, diseases, unused fragments, burnt food,
Es: *Export* or *Smuggling* of food out of Nigeria's community of 37 administrative units

A good example of Food Surveillance.
In the time of Pharaoh, there were 7 years of food abundance that was followed by 7 years of hunger and the food earlier stored was distributed for all the population and strangers to consume. Joseph the Surveillant, Holy Bible

The use of different root and tuber crops of different crop life duration to optimize the crop season so as to make the best use of the rain water would be a consideration to take more seriously by farmers. The changes in weather and variation in weather should be monitored and the predictions of changes in food crop yields are then used to estimate the likely shortfall in output over the next few seasons.

Wastage, Spillage and Spoilage
Every food produced but not consumed by humans is a waste except it is utilized by industry to make goods. At all fests, funerals, marriages, and at home, there are many occasions that call for mass cooking of food. The overall spillage and at different stages add up to a good percentage of the overall food stock that should have been used as food. These bits add up.

After feeding 4000 people, 12 baskets of food was retrieved from the remnants. This shows that there is much materials that would have thrown off if not collected. The lesson from that biblical parable is that nothing should be wasted. Nothing wasted, nothing wanted. This attitude has to be inculcated into the general public and the essence of giving food for humans to animals is appropriate if there is enough for humans and there are enough left-over for the assurance of healthy human condition.

The issue of affordability is very different of the urban and rural areas. Surveys would tell the state of affairs and enable estimators to more accurately and precisely put figures to the quantities. A single family can estimate just how much food would be required for each week based on how they consume food over the days and weeks. Such a weekly estimate multiplied by 52 weeks of the year would give a fair estimate of the consumption and needed quantities of each food and feeding stuff for the year. That is how the nation as a whole can be considered so as to give the final slate to the needs and how the requirements are met. If there are patterns that are not positive toward the goal of the nation interest, such surveillance report can be published in a column in the major news paper at regular intervals to inform all of the pending trends.

Smuggling of Food Stuff
Any trade that is not documented across all borders of a country and is not monitored as to amount or quality or type may fall under the category of smuggling. This depletion of the food stock may be small or big or significantly critical towards creating and imbalance in the total food stock.

Accidents In-Transit
From production areas to the spot of sale, much mishap does occur. First, vibrations cause degradation of produce and lead to losses. That is not the accident we imply here. When the vehicles that haul the produce collide with other vehicles or objects or fall into rivers along the passage routes to the market, there are accidents that lead to

spillage of materials. Sometimes some but never all the produce can be recovered.

Seasonal weather variability

The deep effects of weather on crop production and other associated activities in the crop value chain. In Mbe Cameroon (Akoroda et al. 1992) weather changes were able to change the cropping patterns and showered that:

1. Losses are more than agronomy and plant breeding can give in a season.
2. Sectoral emphasis is not enough but there is need for a holistic consideration
3. Transport, handling and packaging: accidents as losses of production
4. Peel losses and the shape of tubers were affected by the dryness of the soil
5. Breeding by eco-zones is required rather than one size for all zones approach
6. Breeding by majority benefits
7. Understanding the crop combination complexes of countries and enclaves
8. Mapping and policing and monitoring changes in stocks and sales
9. Consumption patterns and changes with changes in income
10. Inflow and outflows and alternatives

Root crops contribute a part to the total food available to a population. Much data of the individual production exists but only when these are combined with those of other crop classes and all types of losses and exports deducted would our fully understand the status of available foodstuff for the population in a defined community.

Food supplies are the sum of all foods that are used by residents. Residents are all nationalities living in the territory of a nation. Several sources have been identified as:

- Crop and livestock production in gardens of households
- Crop and livestock production in farms near household or far fields
- Flora and fauna production in forests and wild vegetation
- Imported crop and livestock products through trade and smuggling

Data and its analysis with futuristic interpretations

Data accumulates everywhere but that will not tell us what is happening. It is the analysis and its subsequent recommendation for action that would bring the effect desired. Symposia after symposia we generate data. Data un-integrated will remain data with little effects on the practice by scientists and farmers and in fact other stakeholders in the agricultural scene.

Agronomic conditions and yields

The relative suitability of agro-ecologies across the nation has been characterised and the campaign of where what crop should be grown should be a matter of encouragement and leading evidence to show that these should be considered when enterprises are intended to be established.

In records, thorough root and tuber harvest is engaged in during trials, but in reality, some hectares of stands of crop are not harvested though planted.

Food storage and spoilage

Just how much food produced is lost? The percentage of loss is an indication that the food systems could be weak and can be improved not only from production pathway bit also from the preservation pathway.

"*A grain saved is a grain produced*" says the old Indian proverb. The proverb emphasizes the importance of saving or storing all we produce in the smallest amounts so that the usage is maximized. Wastage accompanies an endless struggle to produce and not safe what has been produced. Once this aspect is well understood and implemented, then there can be a change in the attitude of food system operators.

Food losses and accidents

Diet patterns and arrangement for food supply change from place to place. Thus, the step to understanding the food situation across any nation is to dissociate the situation unit by unit. Field outputs have been used in calculations as if all harvested items are intact. Losses, spillages and spoilage of items are to be quantified (no matter how rough) so that the sum of total residue of food is used in assessing where the food is and how they flow to other places in the same unit or between units.

Besides, there are peels, rots, breakage during road and kitchen accidents (burnt food), as well as rodent damage. The overall loss is often put at 30 to 40 % depending on the sources of estimates.

Food changes and price controls

The prices of food items determine to an extent what alternative food items are used.

Food remnants and eating habits.

The quantity of food served on a plate not eaten is a loss. At parties and meals, spillage and drops of bits of food are usual occurrences. How are these accounted for? The earlier we begin to watch our food systems and how to reduce the losses and increase the use of food the better the work to do to feed the many mouths

Population to be feed: rate of increase
Nigeria's population grows at the rate of 1.32 % annually (NPC 2009). The 36 states and the Federal Capital Territory (Abuja) make up 37 units in Nigeria. These units would be the *basis of surveillance*.

Incentives to farmers and agro-phobia
A good proportion of young people (who make up the majority of the population) do not like farming or any hard work. The lifestyle to which they have been bombarded from youth was that of cinema-like free enjoyment n beaches in far countries and travels round the world in search of enjoyment and shopping sprees. TV and Video has never portrayed field and farm work as anything useful. Partying has come to be regarded as a major investment of resources rather than a side-show. Dance and music and lotteries would not fully engage the youth energy for tackling the production of their daily bread. This attitude has affected even the village child who goes to the town believing it to be a subjection to slavery for urban people to farm and produce food. This mind set is wring but required more positive and pro-active programmes by government to show that farming is not an abandoned peoples activity or profession that is be to support all who come and more coordinated support in all areas is to be facilitated. Only by understanding the constraints and challenges to food production and distribution followed by purchasing power of the segments of the population would help in the climb towards greater food

Credit Access Reflects Progress in Food Production
As long as long term investment in food is not available, so too would the farmers lack the capacity to engage in any medium-large scale investment. The majority of small fields cultivated now will not be able to sustain the family with a large excess. Consequently, the likelihood of greatly increased field areas under crops is low. Hand-hoe and cutlass farming average 1.5 ha per adult male. Thus, as funds to hire labour remains difficult, the hectares will continue to be shared to all crops that must be cultivated. Credit at 8-10% interest is nominally available but never given because rain-fed farming is considered great risk to bank money. Consequently, refusal to lend for agriculture is high. Sectoral distribution of loans were: agriculture2%, manufacturing 1%, general commerce 13%, public utilities 1%, mining and quarrying 14%, government 4%, general 21%, transport and communication 9%, RE& construction 10%. This is the case even though agriculture accounts for 40% of the national economy in terms of GDP (Agbo 2011).

The Central Office for Food Surveillance (COFS)
Until the COFS is established, there can be no sure way to measure with good certainty the food stocks in any unit. It is clear the production of food from fields is only one step towards assuring food stock sufficiency of any defined population. To wish off hunger and to politicize food security is an ostrich game. No one is collecting and collating the bits of data from so many micro-studies that are daily published across the Nigeria academia and institutional journals and reports of surveys. Virtually every thesis work contains some data that can be added to the data based to further our understanding of the food system and all the aspects that are closely related to them. The operations of COFS cannot be done in one office. It has to be distributed to all states and LGAs so as to capture the minute bits of information that can help calculate the gains and losses of food from all sources, exits and channels.

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