

Farmers' agronomic and social evaluation of the productivity, yield and cooking quality of four cassava varieties

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ABSTRACT

The study evaluated the productivity, yield and cooking quality of four cassava varieties grown on poor soils at Beposo in Wenchi Municipality in the forest/savannah transitional agro-ecological zone of Ghana, between October 2008 and October 2009. The four cassava varieties evaluated included two local varieties selected by the farmers and 2 improved varieties developed by the National Agricultural Research System. Each treatment further received 4 t ha⁻¹ poultry manure, 32-32-32 kg N-P₂O₅-K₂O ha⁻¹ and a control. Mean fresh root yield of cassava ranged from 8.9 t ha⁻¹ with Afosa to 30.6 t ha⁻¹ with Bensre both of which are local varieties. Application of mineral fertilizer resulted in between 140 and 300% increase in fresh root yield for the improved varieties and between 43 and 63% for the local varieties while application of poultry manure resulted in yield increase of between 86 and 124% for the improved varieties and about 48% for the local varieties. Fertilization significantly improved mealiness in all the varieties with the local varieties being the mealier. Farmers' selection criteria for cassava variety for planting included yield, mealiness and maturity. The most preferred cassava variety by farmers was the local variety Bensre while the least preferred variety was the improved variety, Essam. Although the local varieties were less responsive to fertilization, they harbored genes for adaptation to local condition and had preferred tuber quality attributes that can be used for tuber quality and productivity improvement. Mealiness of cassava roots could also be improved on poor soils through fertilization.

Keywords: [dry matter; fertilization; fresh root yield; mealiness; poor soils]

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1. INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is an important starchy staple crop in Ghana with per capita consumption of about 153 kg/year (MoFA, 2010). In Ghana, cassava is cultivated as a monocrop or an intercrop with other food crops such as maize, cocoyam and plantain either as the dominant or subsidiary crop. In terms of quantity produced, cassava is the most important root crop in Ghana followed by yams and cocoyam, but cassava ranks next to maize in terms of area cultivated. Cassava covers about 21.68% of the total area of land grown to food crops in Ghana (MoFA, 2012) and the area cropped to cassava increased from an average of 577,100 ha in 1995-1997 to 889,364 ha in 2011 (MoFA, 2009, 2012). In the forest/savanna transitional agro-ecological zone of Ghana where the bulk of cassava is produced, cassava has multiple uses. Besides, being a major staple food crop, cassava serves as a source of income for most rural dwellers where it is processed into either gari or cassava chips and exported to the neighboring countries including Mali, Niger and Burkina Faso. In the forest/savanna transitional zone in Ghana in general and Wenchi in particular, cassava cropping is also used as a strategy to regenerate degraded soils (Adjei-Nsiah et al., 2004, Adjei-Nsiah et al., 2012).

In Wenchi area, where cassava is the second most important food crop, farmers use little or no fertilizers (Adjei-Nsiah et al., 2004, 2007). In these areas, cropping activities tend to be intensive close to the communities thereby leading to gradient of increasing soil fertility with distance from settlements (Adjei-Nsiah, 2006). Such soils closer to the homesteads and which are intensively cultivated are low in soil organic matter and other nutrients particularly, nitrogen and phosphorus. Owing to their poor nutrients status, fields closer to homesteads are usually cropped to crops like legumes and cassava whose nutrient demand is considered to be minimal by farmers. Most cassava varieties grown on such depleted soils however tend to have poor cooking quality or not mealy and therefore cannot be boiled and eaten as “ampesi” or pounded into “fufu” which are the most common traditional food preparations from cassava. Therefore, traditionally farmers allocate farm plots far away from the homestead and which are relatively fertile to cassava which is meant for preparation of “fufu” while cassava varieties meant for processing into gari or cassava chips for sale are grown on less fertile fields closer to the homesteads. Although cassava has been found to respond to fertilization (Howeler, 2002 and Issaka et al, 2007), farmers hardly apply fertilizers to the crop. This is because cassava has been found to grow on poorer soils where other crops can hardly grow. According to Howeler (2002), the idea that cassava is a ‘scavenger crop’, efficient in nutrient capture and removal, results from its ability to grow on depleted and degraded soils where other crops can hardly grow.

Although, it is usually assumed that the productivity of cassava planted closer to homesteads on less fertile fields are low and have poor cooking quality, the productivity and mealiness of cassava varieties developed by the National Agricultural System (NARS) have not been assessed on such poor soils. Moreover, evaluation of the productivity of improved cassava varieties carried out on research stations where nutrients and other growing conditions may be optimal may bear very little resemblance to situations on farmers’ fields where growing conditions may be sub-optimal. We therefore carried out this study to evaluate the effect of fertilization on productivity, yield and mealiness of four cassava varieties including two varieties released by the NARS. We also analyzed farmers’ preferences and criteria for selecting cassava varieties for use in their cropping systems.

2. MATERIAL AND METHODS

2.1 Study site

The study was conducted in Beposo (7°42'N, 2° 05'W), a farming community in Wenchi Municipality of the Brong-Ahafo Region of Ghana. Wenchi, which is typical of the forest/savanna transition, was originally semi-deciduous forest that has been converted to savanna woodland through intensive cultivation. The soils which developed over Voltaian sandstones are lixisols (Asiamah et al., 2000). The chemical and physical properties of the surface soil of the experimental plots are presented in Table 1.

Table 1. Initial soil characteristics of the 0-20 cm layer of the experimental plot before the commencement of the experiment in 2008

pH	OM	Total N	Bray 1 P	Ca	Mg	K	Sand	Silt	Clay
(1:2.5H ₂ O)	g kg ⁻¹		mgkg ⁻¹	cmol(+) kg ⁻¹			g kg ⁻¹		
4.7	25.5	1.15	1.1	1.54	1.1	0.18	790	40	170

The site has a bimodal rainfall pattern with a 48 year annual mean of 1247.1mm with 111 rainy days. Total rainfall during the 1 year trial period was 1311mm.

2.2 Experimental design and treatments

The field was selected for the experiment by local farmers specifically to represent soil conditions where repeated cropping had led to depletion in nutrient availability and poor soil fertility for crop production. The land where the experiment was carried out had been left for fallow for 1 year and was dominated by *Imperata cylindrical* (spear grass); cassava had been grown on the field earlier. The grass was cleared by slashing with a cutlass. Four weeks later, the land was ploughed and harrowed. After a further four weeks, herbicide (glyphosate) was applied at the rate of 900 a.i. ha⁻¹. Four cassava varieties namely Essam bankye, Nkabom, Afosa and Bensre were planted eight days later between 4 and 6 October, 2008. The four varieties were randomized within three replicate blocks. Two of the varieties, Afosa and Bensre, were selected by the farmers and are among the most widely cultivated local varieties in the area. The remaining two varieties, Nkabom and Essam bankye were new varieties released by the Root and Tuber Improvement Project funded by the International Fund for Agricultural Development (IFAD).

The plot size was 12 by 10 m with 3 m alley between plots and replicate blocks. Cassava was spaced 1 m apart both between and within rows. Two weeks after planting, all plots were split into 3 subplots which received 0, 4 tha⁻¹ poultry manure and 32-32-32 kg N-P₂O₅-K₂O ha⁻¹. First weeding was done 4 weeks after planting and thereafter every 8 weeks. Approximately 52 weeks after planting, an area of 12 m² (2 rows of 6 m) of the cassava plots was harvested. The plants were separated into roots, stems and foliage and weighed. Sub samples of all harvested components were taken and oven dried at 70 °C for 2 days (until constant weight) for dry matter determination.

The beneficial effect of the manuring on the yield was assessed with the farmers by weighing the roots together. Cooking quality or mealiness of the various treatments was done through a sensory evaluation panel on a scale of 1 to 3 (1=very poundable, 2=poundable, 3= fairly poundable and 4=not poundable) after boiling the tubers for approximately 40 minutes

2.1 Statistical analysis

Data were subjected to analysis of variance using Gen Stats.

3. RESULTS AND DISCUSSION

3.1 Fresh root yield and mealiness of different cassava varieties

Fresh root yields of the four cassava varieties without fertilization ranged between 6.5 t ha⁻¹ with Afosa to 23.5 t ha⁻¹ with Bensre (Table 2). With the exception of Bensre, all the varieties when cultivated without fertilization yielded lower than the current national average of about 14 t ha⁻¹ (MoFA, 2010). However, mineral or organic fertilizer application sharply increased the yield with the highest increase occurring in the improved varieties, Essam and Nkabom. While the application of 32-32-32 kg N-P₂O₅-K₂O ha⁻¹ resulted in about 300 and 141% increase in yield of the Essam and Nkabom respectively, 4 t ha⁻¹ application of the organic manure resulted in about 124 and 86% increase in yield for the two varieties respectively. The local varieties Afosa and Bensre responded very little to both the mineral and the organic fertilizer application. This observation supports the findings of Issaka et al (2007) who obtained similar results in a fertilizer trial using one local and two improved varieties at Wenchi. Increase in yield as a result of both organic and inorganic fertilizer application was less than 50%. In spite of the low response of Bensre to both mineral and organic fertilizer application, it yielded higher than the improved varieties which were both highly responsive to fertilization. This might account for its wide cultivation by farmers in Wenchi. In rural areas where smallholder farmers hardly apply mineral fertilizers, promoting varieties with high yield potential on poor soils as that used in the present study without fertilization should be encouraged. Root yields of cassava without fertilization reported in this study were however low compared to what has been reported earlier in the same location under similar conditions where root yields ranging between 17 and 31 t ha⁻¹ were reported (Adjei-Nsiah, 2010). The root yields under fertilized condition reported in this study were however comparable to what has been reported in Ghana under fertilized conditions which ranged between 16-32 t ha⁻¹ (MoFA, 2004). Afosa which is low yielding and does not respond to fertilization is highly susceptible to cassava mosaic virus. Its popularity among the farmers is mainly due to its mealiness. According to the farmers, irrespective to where it is cultivated, it is mealy throughout the year.

Poundability (mealiness) of the boiled roots without fertilizer application ranged from 1.3 with Afosa to 3.7 with Essam (Table 2). However, mineral fertilizer application improved the mealiness from 3.0 to 2.0 with the Bensre and from 3.7 to 2.3 with Essam. Mealiness in Nkabom was also increased from 3.3 to 1.7 while mineral fertilizer application did not influence mealiness in Afosa. This finding is however contrary to the general perception of Ghanaian farmers that mineral fertilization adversely affects cooking quality of cassava. With the application of organic manure the mealiness was improved from 1.3 to 1.0 with Afosa and from 3.7 to 2.0 with the Essam. Essam is generally known not to be mealy and was developed for cassava flour production. However, fertilizer application improved its mealiness significantly. This result however contradicts the findings of Adoa (2009) who reported no effect of fertilization on mealiness or cooking quality of cassava.

Table 2 Effect of variety and fertilization on fresh root yield and mealiness of boiled cassava roots

Variety	Fresh root yield (t ha ⁻¹)			Mean	Mealiness (boiled roots)			Mean
	Control	Fertilizer*	4 t ha ⁻¹ PM**		Control	Fertilizer*	4 t ha ⁻¹ PM*	
Afosa	6.5	10.6	9.6	8.9	1.3	1.3	1.0	1.2
Bensre	23.5	33.5	34.7	30.6	3.0	2.0	1.3	2.1
Essam	11.1	33.0	24.9	23.0	3.7	2.3	2.0	2.7
Nkabom	13.6	32.8	25.3	23.9	3.3	1.7	1.3	2.1
Mean	13.7	27.5	23.6		2.8	1.8	1.4	

SED: V=6.3; FA= 3.0 ; V x FA = 7.9

SED: V=0.3; FA= 0.3; V x FA = 0.6

LSD_{0.05} V= NS; FA= 6.3; V x FA = NS

LSD_{0.05} V= 0.7; FA= 0.6; V x FA = NS

*32-32-32 kg N-P2O5-K2O ha⁻¹ **Poultry manure. V:-Variety; FA:-Fertilizer application

3.2 Dry matter content of roots, stems, and leaves, % root dry matter yield and harvest index of the different cassava varieties

The local variety, Bensre had the highest mean dry root yield of 11.9 t ha⁻¹ and was significantly higher than all the other varieties including the two improved varieties, Essam and Nkabom which had mean dry root yield of 8.3 and 9.1 t ha⁻¹ respectively (Table 3). Percent root dry matter (DM) ranged from 32% with Afosa to 38.9% with Bensre (Table 4). Fertilization however did not significantly result in increase in % root dry matter yield.

Stem DM varied significantly among the different cassava varieties with the highest stem DM obtained with the Bensre while the lowest stem DM was obtained in Afosa, both of which are local varieties (Table 3). In situations where the stems are not removed from the field for planting, large amount of nitrogen (N) could be returned to the soil since cassava stems have been found to recycle between 33.5 and 84.5 kg N ha⁻¹ to the soil if they are not removed from the land for planting (Adjei-Nsiah, 2010). Thus varieties with high stem DM such as Bensre has the potential to recycle large quantities of N into the soil through decomposition.

Leaf DM ranged from 0.04 t ha⁻¹ with Afosa to 0.5 t ha⁻¹ with Bensre. Since cassava leaf contain as much as 3.5% N (Adjei-Nsiah et al., 2007) cassava varieties with high leaf production has the potential to recycle a large proportion of its N uptake in the soil. In the forest/savannah transitional zone of Ghana (Adjei-Nsiah et al., 2012) and Benin (Saidou et al., 2004) and some parts of East Africa (Fermont, 2011), cassava cultivation is used as strategy for regenerating soil fertility due to its high litter fall and large amount of leafy biomass that are returned to the soil after crop harvest.

The amount of total dry matter produced ranged from 3.9 t ha⁻¹ with Afosa to 18.1 t ha⁻¹ with Bensre. In the same location, Adjei-Nsiah (2010) reported of values ranging from 18 to 24.9 t ha⁻¹ when the cassava was grown for 64 weeks. In the present study the cassava was grown for 52 weeks. The amount of dry matter produced by cassava depends on the crop growth

212 rate and growing duration which in turn depends on the variety, climate, and soil fertility
 213 conditions (Howeler, 2002). The plant part that made the largest contribution to the total dry
 214 matter was the root while the leaf made the least contribution. Lenis et al. (2006) reported
 215 that increased root yield is associated with increased total dry matter production and
 216 increased harvest index. However, in this study, although increased root yield was
 217 associated with increased dry matter production, the variety with the highest root yield and
 218 the highest dry matter production (which in this case was Bensre) gave the lowest harvest
 219 index. This was due to the high stem dry matter production associated with this variety
 220 (Table 3). The percent dry matter removed from the field as storage roots or the harvest
 221 index varied from 68% with the Bensre to 82% with the variety Essam. These values are
 222 however higher compared to what has been reported in Ghana and elsewhere. In the same
 223 location Adjei-Nsiah (2010) reported that with dry matter yields of between 18 and 24.9 t ha⁻¹,
 224 the percent of dry matter removed from the field as storage root ranged from 35.7-57.8%.
 225 In Colombia, Howeler (1985) estimated that percentage dry matter removed from the soil
 226 was about 60% when total dry matter production was 23 t ha⁻¹. In Thailand, Putthachaleon
 227 (1998) reported that with total dry matter production of about 33.5 t ha⁻¹ after four crops of
 228 cassava, the percentage dry matter removed from the field was 45%. Since it is estimated
 229 that about two thirds of total potassium (K) uptake in cassava accumulates in roots and
 230 would thus be removed through crop harvest (Howeler and Cadavid, 1983), cassava
 231 varieties that remove substantial amount of its DM through root harvest as those reported in
 232 this study (which varies from 68 to 82% of total dry matter), could lose large quantities of soil
 233 K which would thus has to be replaced through fertilization especially as in the case of this
 234 soil that contained about 0.18 cmol(+) kg⁻¹. Increasing K input through mineral fertilizer
 235 application is however difficult as potassium fertilizers are not usually readily available in
 236 rural markets and cassava farmers hardly apply mineral fertilizers to cassava. Long term K
 237 balances are therefore needed to address this issue. However, K removal may be reduced if
 238 the stems are not removed from the field for planting (Adjei-Nsiah, 2010).

239 Table 3. Effects of variety and fertilizer interaction on dry matter content of various plant parts

	Root dry matter				Stem dry matter				Leaf dry matter			
	Control	Fertilizer*	4 t ha ⁻¹ Poultry manure	Mean	Control	Fertilizer*	4 t ha ⁻¹ Poultry manure	Mean	Control	Fertilizer*	4 t ha ⁻¹ Poultry manure	Mean
Variety												
Afosa	2.1	3.5	3.0	2.9	0.5	1.2	1.2	1.0	0.04	0.04	0.03	0.04
Bensre	9.1	13.1	13.4	11.9	2.5	7.8	6.7	5.7	0.27	0.78	0.55	0.53
Essam	3.1	12.3	8.9	8.3	0.6	2.2	1.5	1.4	0.16	0.29	0.25	0.23
Nkabom	4.6	13.0	9.5	9.1	1.1	2.3	2.1	1.8	0.16	0.41	0.27	0.28
Mean	4.9	10.5	8.7		1.2	3.4	2.9		0.16	0.38	0.28	
SED: V =2.5; FA = 1.3; V x FA = 3.2					V =0.6; FA = 0.5; V x FA = 1.0				V=0.119; FA= 0.081; V x FA = 0.178			
LSD _{0.05} V= 6.1; FA= 2.7; V x FA = NS					V= 1.5; FA= 1.1; V x FA = NS				V= 0.290; FA= 0.172; V x FA =NS			

*32-32-32 kg N-P₂O₅-K₂O ha⁻¹ V:-Variety, FA:- Fertilizer application

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241
242 Table 4. Effect of variety and fertilizer application on total dry matter, % root dry matter and harvest index

	Total dry matter (t ha ⁻¹)				% Root dry matter				Harvest index			
	Control	Fertilizer*	4 t ha ⁻¹ Poultry manure	Mean	Control	Fertilizer*	4 t ha ⁻¹ Poultry manure	Mean	Control	Fertilizer	4 t ha ⁻¹ Poultry manure	Mean
Variety												
Afosa	2.7	4.7	4.3	3.9	32.8	31.9	31.2	32.0	0.78	0.69	0.72	0.73
Bensre	11.8	21.7	20.7	18.1	38.4	39.0	38.6	38.7	0.77	0.61	0.66	0.68
Essam	4.6	14.7	10.7	10.0	33.7	36.1	34.8	34.9	0.81	0.82	0.84	0.82
Nkabom	5.9	15.8	11.8	11.2	33.4	39.0	37.4	37.4	0.78	0.82	0.80	0.80
Mean	6.2	14.2	8.7		34.6	36.5	35.5		0.79	0.74	0.76	
SED: V=3.0; FA = 1.7; V x FA = 4.1					V=0.6; FA= 0.6; V x FA = 1.2				V=0.028; FA = 0.028; V x FA = 0.054			
LSD _{0.05} V= 7.4; FA= 3.5; V x FA = NS					V= 1.4; FA= NS; V x FA = NS				V= 0.069; FA= NS; V x FA = NS			

*32-32-32 kg N-P₂O₅-K₂O ha⁻¹ V:-Variety, FA:- Fertilizer application

3.4 Farmers' preferences and perceptions of cassava varieties

Farmers evaluated the cassava varieties in terms of fresh root yield, mealiness and maturity period in order of importance (Table 5). Tolerance to diseases such as cassava mosaic virus was not considered by the farmers as an important criteria to consider when selecting cassava variety for planting although most farmers in Ghana are aware of and consider cassava diseases such as cassava mosaic virus as important in cassava production (Tokpo, 2009). According to Tokpo (2009), farmers' choice of variety depends on criteria such as maturity, yield and end-use and therefore even if the planting material is infected, the farmer will go ahead and plant it provided it meets the farmers' specific end-use need. Thus, although Afosa was low yielding and very susceptible to cassava mosaic virus, it is still being cultivated by most farmers because of the farmers' claim that irrespective of the soil on which it is grown, it is always mealy throughout the year. In the present study, it was ranked as the second most preferred variety despite its low yield and severity in symptom expression of the cassava mosaic virus. The farmers ranked the Essam variety as the least preferred variety on the grounds that it was not poundable and therefore not suitable for the preparation of "fufu", the most common traditional food preparations from cassava. In Wenchi, cassava is mainly grown for household food security and the surplus is sold for cash income for the family. Owing to this farmers usually plant varieties that are mealy and could be pounded into "fufu". Bensre was the most preferred variety by the farmers because of its high yielding ability coupled with its mealiness and suitability for processing into gari. Its suitability for gari processing is due to its high dry matter content. These attributes suggest that when developing cassava varieties for farmers, breeders should not only consider yield but also other attributes such as mealiness and others that meet the specific end-use need of the people.

Table 5 Criteria for selection of cassava variety for planting by farmers

Criteria	Scale
Yield	1
Mealiness	2
Maturity	3
Ranking of the various varieties	
Bensre	1
Afosa	2
Nkabom	3
Essam	4

Scale: 1:- highest/best - 4:- lowest/worst

4. CONCLUSION

The study suggests that under low input system as that found in Wenchi, some local varieties of cassava adapted to the environment could yield much higher than improved varieties under poor soil conditions. These local varieties which were less responsive to fertilization and carry genes for adaptation to the local conditions also have preferred tuber quality attributes that can be used for tuber quality and productivity improvement. Cassava varieties with high harvest index such as the improved varieties used in this study has the tendency to remove large quantity of K from K deficient soils such as the one used for the present study which is already suffering from K-limitation. There is therefore the need to study the long term K balances in cassava-based cropping system to address the issue of K losses through crop removal. The study also suggests that mealiness of cassava grown on poor soils could be improved through the application of organic manure to improve the organic matter status of the soil.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

- Adjei-Nsiah, S. (2006). Cropping systems, land tenure and social diversity in Wenchi, Ghana. Implication for soil fertility management. PhD Thesis, Wageningen University, The Netherlands.
- Adjei-Nsiah, S. (2010). Yield and N accumulation in five cassava varieties and their subsequent effects on soil chemical properties in the forest/savannah transitional agro-ecological zone of Ghana. *Journal of Soil Sci. and Environmental Management*, 1, 15-20
- Adjei-Nsiah, S., Kuyper, T.W., Leewis, C., Abekoe, M.K., Giller, K.E. (2007). Evaluating sustainable and profitable cropping sequences with cassava and four grain legume crops: Effects on soil fertility and maize yields in the forest/savannah transitional agro-ecological zone of Ghana, *Field Crops Res*, 103, 87-97
- Adjei-Nsiah, S., Leewis, C., Giller, K.E., Sakyi-Dawson, O., Cobbina, J., Kuyper, T.W., Abekoe, M.K., van der werf, W. (2004). Land tenure and differential soil fertility management among native and migrant farmers in Wenchi, Ghana: Implication for inter-disciplinary action research. *NJAS-Wageningen Journal of Life Sciences*, 52, 331-348
- Adjei-Nsiah, S., Sakyi-Dawson, O., Akueteh, L. (2012). Factors influencing uptake of soil fertility management technologies in the forest/savannah transitional agro-ecological zone of Ghana. *Agricultural Research and Reviews*, 1 (4), 89-101
- Adoa, H.M. (2009). Growth, yield and quality of cassava as influenced by Terramend 21, poultry manure, and inorganic fertilizer. MSc. Thesis. Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.
- Asiamah, R.D., Fenning, J.O., Adjei-Gyapong, T., Yeboah, E., Ampontuah, E.O., Gaise, E. (2000). Report on soil characterization and evaluation at four multiplication sites (Manpong, Wenchi, Asuansi and Kpeve) in Ghana. Technical Report No. 200. Soil Research Institute, Kumasi.
- Fermont, A.M. (2009). Cassava and soil fertility in intensifying smallholder farming systems of East Africa. PhD Thesis, Wageningen University, The Netherlands.
- Howeler, R.H. (1985). Mineral nutrition and fertilization of cassava. In: *Cassava: Research, Production and Utilization*. UNDP-CIAT Cassava Programme, Cali, Columbia: pp.249-320.
- Howeler, R.H. (2002). Cassava mineral nutrition and fertilization. In: Hillocks, R.J., Thresh, M.J., Bellotti, A.C. (Eds), *Cassava: Biology, Production and Utilization*. CAB International, Wallingford, pp.115-147.
- Howeler R.H., Cadavid L. F. (1983). Accumulation and distribution of dry matter and nutrients during a 12-month growth cycle of cassava. *Field Crops Res*, 7, 123-139.
- Issaka, R. N., Buri, M. M., Asare, D., Senayah, J. K., Essien, M. A. (2007). Effect of cropping system and mineral fertilizer on root yield of cassava. *Agriculture and Food Science Journal of Ghana*, 6, 445-458
- Lenis, J.I., Calle, F., Jaramillo, G., Perez, J.C., Ceballos, H., Cock, J.H. (2006). Leaf retention and cassava productivity, *Field Crops Research*, 95, 126-134.
- MOFA (2004). *Cassava Production Guide. A resource and Reference Manual*. Root and Tuber Improvement Programme (RTIP), Ministry of Food and Agriculture, Kumasi, Ghana
- MoFA (2009). *Facts and Figures, Agriculture in Ghana*, Ministry of Food and Agriculture, Accra.
- MoFA (2010). *Facts and Figures, Agriculture in Ghana*, Ministry of Food and Agriculture, Accra.
- MoFA (2012). *Facts and Figures, Agriculture in Ghana*, Ministry of Food and Agriculture, Accra.
- Putthacharoen, S., Howeler, R.H., Jantawat, S., Vichukit, V. (1998). Nutrient uptake and soil erosion losses in a Psamment in eastern Thailand. *Field Crops Res.*, 57, 113-126
- Saïdou, A., Kuyper, T.W., Kossou, D.K., Tossou, R., Richards, P. (2004). Sustainable soil fertility management in Benin: learning from farmers. *NJAS-Wageningen Journal of Life Sciences*, 52, 349-469
- Tokpo, S.K. (2009). Analysis of cassava mosaic begomoviruses associated with cassava mosaic disease in Ghana. PhD Thesis. University of Ghana, Legon, Ghana.