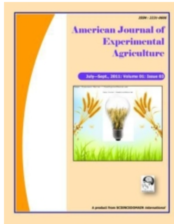

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Farmers' Agronomic and Social Evaluation of the Productivity, Yield and Cooking Quality of Four Cassava Varieties

S. Adjei-Nsiah[1*] and R. N. Issaka[2]

[1]Forest and Horticultural Crops Research Centre, Institute of Agricultural Research, University of Ghana, Legon, Ghana, P.O. Box 68, Legon, Ghana.
[2]Soil Research Institute, Council for Scientific and Industrial Research, Academy Post Office, Kumasi, Ghana.

Authors' contributions

This work was carried out in collaboration between all authors. Both authors SAN and RNI designed the study. Author SAN performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Both authors managed the analyses of the study. Author SAN managed the literature searches. All authors read and approved the final manuscript.

Research Article

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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 zone of Ghana, between October 2008 and October 2009. The trial included two local varieties selected by the farmers and 2 improved varieties developed by the national agricultural research system, and three fertilizer treatments. The fertilizer treatments were 4 t ha^{-1} poultry manure, 32-32-32 kg N-P_2O_5-K_2O ha^{-1} and unfertilized controls. Mean fresh root yield of the four cassava varieties ranged from 8.9 t ha^{-1} (Afosa) to 30.6 t ha^{-1} (Bensre). Application of the 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 the mealiness in all the varieties with the local varieties being the mealiest. Farmers' criteria when selecting a variety for planting included yield, mealiness and maturity. Farmers' most preferred cassava variety was the local variety Bensre; the least preferred variety was the

**Corresponding author: Email: y_nsiah@yahoo.co.uk;*

improved variety, Essam. Although the local varieties were less responsive to fertilization, they appeared to be well-adapted to local conditions and had preferred root quality attributes. These traits can be used for improving root quality and productivity in cassava breeding. Mealiness of cassava roots could also be improved on poor soils through fertilization.

Keywords: Dry matter; fertilization; fresh root yield; mealiness; poor soils.

1. INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is an important starchy staple crop in Ghana with per capita consumption of about 153 kg/year [1]. It 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 followed by yams and cocoyam, but cassava ranks next to maize in terms of area cultivated. Cassava today covers about 21.68% of the total area of land grown to food crops [2]. The area cropped to cassava has increased from an average of 577,100 ha in 1995-1997 to 889, 364 ha in 2011 [3,2]. In the forest/savanna transitional agro-ecological zone where the bulk of cassava is produced, cassava has multiple uses: it is a source of income for most rural dwellers when it is processed into either gari or cassava chips; it is exported to neighboring countries including Mali, Niger and Burkina Faso. In the forest/savanna transitional zone in general and Wenchi in particular, cassava cropping is used also to regenerate degraded soils [4,5], as in some parts of East Africa [6] and in Benin [7].

In Wenchi area, where cassava is the second most important food crop, farmers use little or no fertilizers [4, 8]. In these areas, cropping activities tend to be most intensive close to the communities, creating a gradient of increasing soil fertility as distance from settlements increases [9]. The 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, the fields closer to homesteads are usually devoted to legumes and cassava whose nutrient demand is considered to be minimal by farmers. Most of the cassava varieties grown on such depleted soils tend to have poor cooking quality or are not 'mealy' (i.e. poundable) and therefore cannot be boiled and eaten as "ampesi" or pounded into "fufu" - which are the most common traditional ways of preparing cassava as food. Therefore, traditionally farmers also cultivate cassava intended for fufu in plots far away from the homestead and that are relatively fertile, while growing cassava varieties meant for processing into gari or cassava chips for sale on the less fertile fields closer to the homesteads. Although cassava has been found to respond to fertilization [10,11] farmers hardly apply fertilizers to the crop because cassava still produces a crop on the poorer soils where other crops can hardly grow. According to Howeler [10], the idea that cassava is a 'scavenger crop', efficient in nutrient capture and removal, arises from this ability to grow on depleted and degraded soils.

Although, it is usually assumed that the productivity and cooking quality of cassava planted closer to homesteads on less fertile fields are low, the productivity and cooking quality of cassava varieties developed by the national agricultural system (NARS) have not been assessed on such poor soils. 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' own fields. 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. MATERIALS AND METHODS

The study was conducted in Beposo (7º42'N, 2º05'W), a farming community in Wenchi Municipality of the Brong-Ahafo region. Wenchi is typical of the forest/savanna transitional zone; it was originally a semi-deciduous forest that has been converted to savanna woodland through intensive cultivation. The soils that developed over the Voltaian sandstones are lixisols [12]. The chemical and physical properties of the surface soil of the experimental plots are presented in Table 1.

Table 1. 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$0)	**g kg^{-1}**		**mgkg^{-1}**		**cmol$_{(+)}$ 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 1247.1 mm with111 rainy days/year. Total rainfall during the one year trial period was 1311 mm.

The field was selected for the experiment by local farmers specifically to represent soil conditions where repeated cropping had led to depleted nutrient availability and poor soil fertility. It had been left for fallow for one year prior to the experiment and was dominated by *Imperata cylindrica* (spear grass). 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 were among the most widely cultivated local varieties in the area. Nkabom and Essam bankye were new varieties released by the Root and Tuber Improvement Project funded by the International Fund for Agricultural Development (IFAD). They were developed specifically for the forest and the forest/savannah transitional agro-ecological zones. The planting materials of the two improved varieties were obtained from the Ministry of Food and Agriculture's agricultural station in Wenchi, about seven kilometers away from the community where the study was carried out. Planting materials for the local varieties were obtained from the community where the study was carried out. All the planting materials were harvested on the same day and planted on the following day.

The plot size was 12 by 10 m with a 3 m alley between plots and replicate blocks. Cassava was spaced 1 m apart both between and within the rows. Two weeks after planting, all plots were split into 3 sub-plots that received no fertilizer, 4 tha^{-1} poultry manure and 32-32-32 kg N-P_2O_5-K_2O ha^{-1} respectively. First weeding was done 4 weeks after planting and thereafter every 8 weeks. Approximately 52 weeks after planting, an area of 12 m^2 (2 rows of 6 m) of the cassava plots, excluding the border plants, 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 70ºC for 2 days (until constant weight) for dry matter determination.

The beneficial effect of the manuring on yield was assessed with the farmers by weighing the roots together. Cooking quality i.e. mealiness test was done by a sensory evaluation panel, and assessed on a scale of 1 to 4 (1=very poundable, 2= poundable, 3= fairly poundable and 4=not poundable) after boiling the roots for approximately 40 minutes. The identification of the roots by variety or treatment was not made known to the panel prior to the sensory evaluation. Agronomic data were collected for all plots and subjected to analysis of variance (ANOVA) using the GenStat version 9 statistical software package. The standard analysis procedure for split-plot in randomised complete block design [13] was followed. Least significant difference (LSD) test at 5% probability level was used to compare the treatment means.

3. RESULTS AND DISCUSSION

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} [1]. Mineral or organic fertilizer application sharply increased the yield, with the highest increase occurring in the improved varieties, Essam and Nkabom. Application of 32-32-32 kg N-P_2O_5-K_2O ha^{-1} resulted in about 300% and 141% increase in the fresh root yield of the Essam and Nkabom respectively, 4 t ha^{-1} application of the organic manure resulted in about 124% and 86% increase in the fresh root yield for these two varieties respectively. There was a weaker response by the two local varieties Afosa and Bensre to either the mineral or the organic fertilizer application, at less than 50%. This observation supports the findings of [11] who obtained similar results in a fertilizer trial using one local and two improved varieties at Wenchi. However, in spite of the low response of Bensre to both mineral and organic fertilizers, it yielded higher than both the improved varieties, which were both highly responsive to fertilization. This might account for Bensre's wide cultivation by farmers in Wenchi. Subedi et al. [14] similarly reported that those rice farmers in Nepal who do not have money to purchase mineral fertilizers prefer a cultivar that yields higher under normal to low soil fertility levels. None the less, the unfertilized cassava root yields reported in this study were low compared to those reported earlier in the same location under similar conditions [15]. In the same location [15] reported fresh root yields of between 17 and 31 t ha^{-1}. The fertilized root yields reported in this study were comparable to what has been reported by others for Ghana, ranging between 16-32 t ha^{-1} [16]. Afosa, which is low yielding and does not respond to fertilization, is also highly susceptible to cassava mosaic virus. Its popularity among farmers is mainly due to its mealiness. According to the farmers, irrespective of where it is cultivated or when it is harvested, it remains mealy throughout the year.

The assessment of the poundability (mealiness) of the boiled roots grown without fertilizer, ranged from 1.3 for Afosa to 3.7 for Essam (Table 2). However, mineral fertilizer application improved the poundability score, from 3.0 to 2.0 for Bensre and from 3.7 to 2.3 for Essem. Under mineral fertilization, the score for the poundability of Nkabom also increased from 3.3 to 1.7 but did not influence the poundability score for Afosa. This finding is contrary to the general perception of Ghanaian farmers that mineral fertilization adversely affects the cooking quality of cassava. With the application of organic manure the mealiness was improved from 1.3 to 1.0 for Afosa and from 3.7 to 2.0 for 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 contradicts the findings of [17] who reported no effect of fertilization on the mealiness or cooking quality of the cassava varieties tested in the study.

Table 2. Effect of variety and fertilization on fresh root yield, above ground biomass and mealiness of boiled cassava roots

	Fresh root yield (t ha^{-1})			Mean	Above ground biomass (t ha^{-1})			Mean	Mealiness(boiled cassava roots)			Mean
	Control	Fertilizer*	4 t ha^{-1} PM**		Control	Fertilizer*	4 tha^{-1} PM		Control	Fertilizer*	4 t ha^{-1} PM**	
Variety												
Afosa	6.5	10.6	9.6	8.9	0.57	1.28	1.26	1.04	1.3	1.3	1.0	1.2
Bensre	23.5	33.5	34.7	30.6	2.73	8.59	7.28	6.20	3.0	2.0	1.3	2.1
Essam	11.1	33.0	24.9	23.0	0.78	2.45	1.75	1.66	3.7	2.3	2.0	2.7
Nkabom	13.6	32.8	25.3	23.9	1.22	2.76	2.76	2.10	3.3	1.7	1.3	2.1
Mean	13.7	27.5	23.6		1.33	3.77	3.16		2.8	1.8	1.4	
SED: V=6.3; FA= 3.0 ; V x FA = 7.9					SED: V=.70; FA= 0.57 ; V x FA = NS				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= 1.72; FA= 1.20; V x FA = NS				$LSD_{0.05}$: V= 0.7; FA= 0.6; V x FA = NS			

**32-32-32 kg N-P_2O_5-K_2O ha^{-1}; **Poultry manure. V:-Variety; FA:-Fertilizer application*
SED=Standard Error of Difference; LSD=Least Significant Difference.

The highest mean dry root yield for the local variety Bensre of11.9 t ha^{-1} was significantly higher than all the other varieties, including the two improved varieties, Essam and Nkabom which had mean dry root yields of 8.3 and 9.1 t ha^{-1} respectively (Table 3). Percent root dry matter (DM) ranged from 32% for Afosa to 38.9% for Bensre (Table 4). Fertilization did not significantly result in an increased percentage dry matter yield.

Stem DM varied significantly among the four varieties. The highest stem DM was obtained for Bensre and the lowest stem DM were obtained for Afosa; both are local varieties (Table 3). If the stems are not removed from the field for re-planting, a large amount of nitrogen (N) could be returned to the soil since cassava stems have been found to contain about 1.0-1.3% N [15]. Varieties with a high stem biomass such as Bensre, have the potential to recycle large quantities of N into the soil through decomposition.

Leaf DM ranged from 0.04 t ha^{-1} for Afosa to 0.5 t ha^{-1} for Bensre. Since cassava leaves contain as much as 3.5% N [8], cassava varieties with high leaf production have the potential to recycle a large proportion of its plant's N uptake from the soil. In the forest/savannah transitional zones of Ghana [5] and Benin [7] and in some parts of East Africa [6], cassava cultivation is used strategically by farmers for regenerating soil fertility because of some varieties' high litter fall and large amount of leafy biomass, that are returned to the soil after crop harvest. Better results have been reported if the biomass is incorporated into the soil instead of being left on the soil surface to decompose [18].

The amount of total dry matter produced ranged from 3.9 t ha^{-1} for Afosa to 18.1 t ha^{-1} for Bensre. In the same location, [15] has reported DM values ranging from 18 to 24.9 t ha^{-1} when the cassava was grown for 64 weeks (compared to 52 weeks in the present study). The amount of dry matter produced by cassava depends on the crop growth rate and duration of the growing period, which in turn depend on the variety, climate, and soil fertility conditions [10] and farmers' needs. The plant fraction that made the largest contribution to the total dry matter was found to be the root; the leaf made the least contribution. [19] reported that increased root yield is associated with increased total dry matter production and increased harvest index. However, in this study, although increased root yield was associated with increased dry matter production, the variety with the highest root yield and the highest dry matter production (which in this case was Bensre) gave the lowest harvest index. This is explained by the high stem dry matter production associated with this variety (Table 3). The percent dry matter removed from the field as storage roots or the harvest index varied from 68% with the Bensre to 82% with the variety Essam. These values are however higher compared to the optimum harvest index range of 50 to 60% for cassava [20]. [15] has reported for the same location that with dry matter yields of between 18 and 24.9 t ha^{-1}, the percent of dry matter removed from the field as storage roots, ranged from 35.7-57.8%. In Colombia, [21] estimated that percentage dry matter removed from the soil was about 60% when total dry matter production was 23 t ha^{-1}. In Thailand, [22] reported that, with total dry matter production of about 33.5 t ha^{-1} after four crops of cassava, the percentage dry matter removed from the field was 45%. It is estimated that about two thirds of total potassium (K) uptake in cassava accumulates in the roots and would thus be removed through harvesting [23]. We conclude that cassava varieties in which substantial amounts of DM are removed through root harvest, as is the case for the varieties examined in this study (varying from 68% to 82% of total dry matter), could remove large quantities of soil K. In these cases soil K would need to be replaced through fertilization, especially as in the case reported in this paper, the soil contains about 0.18 cmol(+) kg^{-1}.

Table 3. Effects of variety and fertilizer interaction on total dry biomass (tons/ha) of various plant parts

	Root dry matter			Mean	Stem dry matter			Mean	Leaf dry matter			Mean
	Control	Fertilizer*	4 t ha^{-1} Poultry manure		Control	Fertilizer*	4 t ha^{-1} Poultry manure		Control	Fertilizer*	4 t ha^{-1} Poultry manure	
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					SED: V =0.6; FA = 0.5; V x FA = 1.0				SED: V=0.119; FA= 0.081; V x FA = 0.178			
LSD $_{0.05}$:V= 6.1; FA= 2.7; V x FA = NS					LSD: V= 1.5; FA= 1.1; V x FA = NS				LSD $_{0.05}$: V= 0.290; FA= 0.172; V x FA =NS			

**32-32-32 kg N-P_2O_5-K_2O ha^{-1}; **Poultry manure. V:-Variety; FA:-Fertilizer application*
SED=Standard Error of Difference; LSD=Least Significant Difference

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

	Total dry matter (t ha^{-1})			Mean	% Root dry matter			Mean	Harvest index (%)			Mean
	Control	Fertilizer*	4 t ha^{-1} Poultry manure		Control	Fertilizer*	4 t ha^{-1} Poultry manure		Control	Fertilizer	4 t ha^{-1} Poultry manure	
Variety												
Afosa	2.7	4.7	4.3	3.9	32.8	31.9	31.2	32.0	78	69	72	73
Bensre	11.8	21.7	20.7	18.1	38.4	39.0	38.6	38.7	77	61	66	68
Essam	4.6	14.7	10.7	10.0	33.7	36.1	34.8	34.9	81	82	84	82
Nkabom	5.9	15.8	11.8	11.2	33.4	39.0	37.4	37.4	78	82	80	80
Mean	6.2	14.2	8.7		34.6	36.5	35.5		79	74	76	
SED: V=3.0; FA = 1.7; V x FA = 4.1					SED: V=0.6; FA= 0.6; V x FA = 1.2				SED: V=2.8; FA = 2.8; V x FA = 5.4			
LSD $_{0.05}$ V= 7.4; FA= 3.5; V x FA = NS					LSD $_{0.05}$: V= 1.4; FA= NS; V x FA = NS				LSD $_{0.005}$: V= 6.9; FA= NS; V x FA = NS			

**32-32-32 kg N-P_2O_5-K_2O ha^{-1} V:-Variety, FA:- Fertilizer application SED= Standard Error of Difference; LSD= Least Significant Difference*

However, increasing K input through mineral fertilizer application is a difficult proposition because potassium fertilizers usually are not readily available in rural markets and cassava farmers hardly apply mineral fertilizers to cassava. Study of the long term K balances is needed to examine this issue under farmers' practices. For instance, it is reported that K removal may be reduced if the stems are not removed from the field for planting [15].

Farmers carried out a final evaluation of the four varieties in terms of fresh root yield, mealiness and maturity period in order of importance (Table 5). Tolerance of diseases such as cassava mosaic virus was not considered by the farmers as an important criterion when selecting stems for planting although most farmers in Ghana are aware of and consider such diseases as important factors in cassava production [24]. According to Tokpo [24], farmers' choice of variety depends on criteria such as maturity, yield and end-use and that, even if the planting material is infected, the farmer will plant the material provided it meets the farmers' specific end-use need. Thus in spite of its low yield and high susceptibility to cassava mosaic virus, Afosa is still cultivated by most farmers. Farmers in our study ranked it as their second preference and claimed that irrespective of the soil on which it is grown, it remained mealy throughout the year. This finding is consistent with the results of a similar study carried out in Nigeria where farmers were unwilling to forego the use of a local variety of cassava because it was less fibrous and therefore suitable for the preparation of fufu though it was low yielding and highly susceptible to diseases and pests [25]. The farmers in our study ranked Essam 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 cassava-based food product. Because in Wenchi cassava is mainly grown for household food security and any surplus is sold for cash income to meet family needs, farmers usually plant varieties that are mealy and can be pounded into fufu. Bensre was the most preferred variety because of its high yield and mealiness, and suitability for processing also into gari. This study confirms the observation made by [26] that farmers do not select cassava varieties purely on the basis of root yield alone but consider other quality traits (taste, appearance, fibre content) that breeders often ignore.

Table 5. Farmers' criteria for cassava varietal selection

Criteria	**Selection score (1:- highest/best - 4:- lowest/worst)**
Yield	1
Mealiness	2
Maturity	3
Ranking of the varieties	
Bensre	1
Afosa	2
Nkabom	3
Essam	4

4. CONCLUSION

The study suggests that under low input systems such as that found in Wenchi, local varieties of cassava adapted to the environment may yield more than improved varieties under poor soil conditions. The two local varieties examined in this study were less responsive to fertilization but well adapted to the local conditions, and also have preferred root quality attributes. It is suggested that breeders need to pay more attention to these adaptive and quality traits. Moreover, the two improved cassava varieties with high root yield in this study were found to remove a large quantity of K from the already K-deficient soils. Our findings indicate the necessity of studying the long term K balances in cassava-based cropping systems to examine the issue of K losses through cassava cropping. The study also suggests that the preferred trait of mealiness, especially in cassava varieties grown on poor soils, could be improved through the application of organic manure in sufficient quantity to improve the organic matter status of the soils.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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