Original Research Article

Evaluation and selection of elite cassava varieties for storage root yield in the transition and guinea savannah ecologies of Ghana

ABSTRACT

The study was carried out to identify and select local and improved cassava varieties suitable for cultivation in the transition and Guinea savannah agroecology of Ghana against climate change.Two agroecologies; transition and Guinea savannah ecologies were considered for the study. Four cassava growing communities were chosen in the transition zone whilst three cassava growing communities were chosen for the Guinea savannah ecology. The cassava varieties were arranged in a randomized complete block design with three replications in each location.A total of 13 cassava varieties were used for the study.Cassava cuttings measuring 20-25 cm were planted using a spacing of 1m × 1m. Harvesting was done at 12 months after planting to assess storage root yield of the cassava varieties at the different locations. Data were collected on storage root yield (t/ha), number of roots per plant, harvest index and mean root weight.Analysis of variance indicated significant varietal differences among the local varieties for root yield, harvest index, storage root number per plant and mean storage root weight in Transition zone. However, there were no significant varietal differences between the improved varieties for root yield. The best performing improved varieties in the transition zone were Bankyehemaa (28.06 t/ha), Eskamaye (27.76 t/ha) and Nkabom (26.99 t/ha) whilst Filindiakong (22.65 t/ha) and Nyerikobga (31.17 t/ha) were identified to be suitable for the guinea savannah ecology. The study identified cassava varieties for the different ecologies which can be cultivated to mitigate the effects of climate change on cassava and ensure food security.

Keywords: [improved cassava varieties, climate change, storage root yield, agroecologies)

1. INTRODUCTION

The increased global population and pressure on arable land haveresulted in the extension of farming to marginal and areas with prolonged dry seasons which were not originally used for crop production (Baulcombe et al., 2009; Challinor et al., 2007). It has therefore become necessary to develop improved technologies to sustain crop production and productivity under such moisture limited environments (Alexandratos, 1995; Bergantin et al., 2004). Adaptation which refers to adjustment in natural and human systems in response to actual or expected climatic stimuli is one of the policy options for reducing the negative impact of climate change (IPCC, 2001; Adgeret al.,2003). Common adaptation methods in agriculture include use of new crop varieties and livestock species that are better suited to drier conditions and changing planting dates (Bradshaw *et al.,* 2004; Nhemachera and Hassan 2007). One of the major crops used for combating the effects of climate change in marginal ecologies is cassava (Ifeanyi-Obi and Issa, 2013).

Cassava (*Manihot esculenta* Crantz) the second most important food staple (after rice) in terms of calories per capita in Africa with more than 800 million people depend on it for their calorie needs (Burns et al. 2010). It is mostly preferred by resource poor farmers due to its low input requirements. Cassava has been adjudged in Africa, as a food security crop mainly because of its ability and capacity to yield well in drought-prone, marginal wastelands even under poor management where other crops would fail (Akinwale et al., 2011; Nweke et al., 1994). The crop possesses certain adaptive physiological and morphological features that make it resilient in such stress ecologies (Adjebeng-Danquah et al., 2016; Adjebeng-Danquah et al., 2020). Besides, providing more returns per unit input than other root and tuber crops, cassava has better adaptability to diverse and poor soil conditions and wide flexibility in planting and harvesting times (Sakai et al., 1994; Akoroda, 1995; Fregene et al., 2000).

However, productivity of cassava like most crops is constrained by many factors including drought stress in susceptible cultivars with yield losses of close to 80% being recorded (Aina et al. 2007a). As a result of climate change, moisture will likely become increasingly scarce for rain-fed agriculture and consequently, drought stress will become a major environmental factor affecting cassava production. The performance of cassava like most crops is susceptible to variations in environmental conditions leading to differential response of the crop to different environments (Crossa and Cornelius, 1997; Mkumbira*et al.,* 2003). Dixon and Nukenine (2000) defined this crossover performance as genotype x environmental (GxE) interaction. Otoo*et al.* (2006) and Ntawuruhunga and Dixon (2010) further indicated that GxE affects the selection efficiency in plant breeding thereby resulting in less genetic gain. For this reason, plant breeders often test crops in several environments to eliminate the negative effect of genotype x environment interaction and identify stable and adaptable genotypes (Haldavankar*et al.,* 2009; Ssemakula and Dixon, 2007).

Several studies have reported that moisture stress during the establishment stages of cassava can have severe effect on the production of the crop (Pardales et al., 2001; Santisopasri et al., 2001; Okogbenin et al., 2003; Anderson et al., 2004; Bergantin et al., 2004; Aina et al., 2007a; Bakayoko et al., 2009; Perez et al., 2011). One mechanism of combating the effect of drought on crop production is through irrigation which is often beyond the means of resource poor farmers whose livelihood depends on cassava. Therefore there is the need to identify high yielding cassava genotypes that are well adapted to marginal ecologies. Genotypic variability exists among cassava genotypes in response to water stress, with some varieties having high levels of drought tolerance and others being susceptible (El-Sharkawy, 2007). Aina et al. (2009) also indicated that local germplasm of cassava possess rich source of genetic variability which can be exploited for the improvement of the crop for drought tolerance. This genetic potential can be exploited to identify and develop cassava varieties well adapted to marginal agro-ecological zones. The main objective of this study was to identify and select high yielding adapted local and improved drought-tolerant cassava varieties adaptation to some agro-ecologies of Ghana.

2. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY

2.1. Study sites

Comment [au1]: Justify the selection of communities.

The trials were conducted in the transition ecology; Techiman North (four communities) in the Brong Ahafo region and Guinea savannah ecology; Damongo (three communities) in the Savannah region of Ghana.

2.2 Cassava varieties used

Comment [au2]: Justify the experimental design used.

A total of 13 cassava varieties made up of six improved and seven local farmer-preferred varieties which are grown in the different ecologies. The improved varieties included, Bankyehemaa, IFAD, Essambankye, Nkabom, Filindiakong, Nyerikobga and Eskamaye.

2.3 Land preparation and planting

Appropriate land preparation method was adopted for the different ecologies. In the case of the transition ecology, the land was first slashed and the debri collected and burnt after which planting was done. However, in the Guinea savannah ecology, the land was ploughed and harrowed as is mostly done before cultivation. The field was then divided into plots measuring 10m × 40m for each variety. Ridges were manually raised one metre apart for planting. Planting was done on top of the ridges using a spacing of one metre between plants. This gave a spacing of 1m x 1m and eventually a plantpopulation density of 10,000 plants per hectare. Mature cassava cuttings measuring 20-25 cm were planted on ridges Weeds were controlled when necessary to minimize competition.

2.4 Data collection

2.4.1 Fresh root yield (t/ha) and yield components:

Three subplots measuring 4mx4m were sampled for yield data assessment. Data collected at harvesting (12 months after planting) included storage root yield (t/ha), number of roots per plant. Harvest index was estimated as the ratio of root yield to total biomass. Mean root weight (g) was also estimated as the total root weight divided by the number of roots per plot.

2.5 Data analysis

General analyses of variance were performed for all traits using the GenStat statistical package (Payne et al., 2009). Significant differences between varieties were detected using the least significant difference test (P < 0.05). Two sample t-test was performed to compare the mean performance of all improved varieties versus mean of all local varieties using the GenStat version 12.1 (Payne et al., 2009).

Comment [au3]: Mention that the structure of the treatments is a factorial experiment.

3. RESULTS

3.1 Performance of cassava varieties in the Techiman North district (Transition ecology)

Significant differences (*P*= .05) were observed among the improved varieties for all the traits measured except storage root yield (Table 1a). Location effect was also significant for all traits. Variety x location effect was also significant for all traits except harvest index. Variety effect was also significant (*P* = .05) for all traits in the case of the local varieties (Table 1b). Analysis of the average performance of the varieties (Table 1c) identified Bankyehemaa as the highest yielding variety (28.06 t/ha) with Nkabom giving the lowest root yield (26.99 t/ha) among the improved varieties. Essambankye had the highest harvest index (0.66) with Bankyehemaa having the least (0.57). Mean root weight (g) ranged between 310.5 g and 548.5 g for Nkabom and Bankyehemaa respectively. Whiles Bankyehemaa had the highest number of storage roots per plant with Essambankye having the least number of roots per plant. Among the local varieties (Table 1c), Nkomte recorded the highest root yield (29.27 t/ha) whilst AlataRed had the least (11.25 t/ha). Harvest index ranged between 0.46 (Dakware) and 0.75 (AlataRed). However, the minimum and the maximum mean root weight were 307.0 g and 972.4g for Dakware and AlataRed respectively. AlataRed again had the lowest number of roots per plant (2.03) with Dakware producing the highest number of roots per plant (8.36). The improved varieties gave higher average root yield (t/ha), harvest index, MRW and root no/plant respectively than the mean of all the local varieties (Table 1c).

Table 1a Analysis of variance for root yield and yield components of improved varieties in Techiman North

Source	df	Root yield (t/ha)	Harvest index	MRW	Root no/ plant

Variety (V)	2	3.68ns	0.008*	164897.0**	26.95**
Location (L)	3	668.43**	0.050**	112068.0**	21.15**
V x L	6	85.06**	0.001ns	35295.0**	1.08*
Residual	22	15.22	0.002	2643	0.32
Total	35	81.72	0.006	27065	3.76

ns = Not significant, * = Significant at 5%, ** = Significant at 1%

Table 1b Analysis of variance for root yield and yield components of local varieties in Techiman North

Source	df	Root yield (t/ha)	Harvest index	MRW	Root no/ plant
Replications	2	121.15	0.002	3132.00	2.43
Variety	5	107.20*	0.035***	171966.00*	16.36***
Residual	13	38.32	0.002	49264.00	0.38
Total	20	63.82	0.011	75327.00	4.58

ns = Not significant, * = Significant at 5%, ** = Significant at 1%

Table 1c Mean performance of improved varieties in Techiman North

Variety	Root yield	HI	MRW	Root no./plant
Improved				
Bankyehemaa	28.06	0.57	310.5	8.97
Essambankye	27.76	0.66	471.9	6.40
Nkabom	26.99	0.60	548.5	7.05
Mean	27.60	0.617	443.6	7.47
LSD (5%)	3.303	0.083	87.05	0.974
CV	14.13	7.18	10.65	10.09
Local				
AlataRed	11.25	0.75	972.4	2.03
AlataWhite	18.84	0.74	715.9	3.08
Bensere	15.89	0.64	357.7	5.66
Dakware	23.27	0.46	307.0	8.36
Memmawo	18.03	0.57	579.9	4.51
Nkomte	29.27	0.64	465.3	6.53
Mean	18.92	0.64	536.5	5.12
LSD (5%)	9.89	0.09	389.4	1.15
CV	27.47	7.86	38.65	12.55

3.2 Performance of cassava varieties in the Damongo district (Savannah ecology)

Analysis of variance indicated significant main effects of variety, location for all traits measured (Table 2a). Apart from root yield, variety x environment interaction (GxE) effect was not significant (*P*>.05) for the other traits. Nyerikobga was observed to have both highest root yield (t/ha) and highest harvest index whilst (Table 2b). Biabasse had the lowest root yield (19.05 t/ha) and lowest harvest index (0.54). In terms of mean root weight, Biabasse had the highest with Bankyehemaa having the lowest mean root weight. The highest average root number per plant was observed for Bankyehemaa (10.97), whilst Filindiakong produced the lowest average number of roots per plant (7.32).

Table 2a Analysis of variance for root yield and yield components of four cassava varieties from three communities in Damongo district

Source	df	Root yield (t/ha)	Harvest index	MRW	Root no/ plant
Variety (V)	3	73.95*	0.039**	41617.00**	8.14*
Location (L)	2	258.92**	0.004*	12147.00*	28.99**

V x L	6	87.02*	0.001^{ns}	4963.00^{ns}	0.47^{ns}
Residual	22	16.77	0.007	2320.00	1.87
Total	35				

ns = Not significant, * = Significant at 5%, ** = Significant at 1%

Table 2b Mean performance of four cassava varieties from three communities in Damongo district.

Variety	Root yield (t/ha)	Harvest index	MRW (g)	Root no/ plant
Biabasse**	19.09	0.54	429.42	8.91
Bankyehemaa	19.71	0.58	189.4	10.97
Filindiakong	22.65	0.65	385.8	7.32
Nyerikobga	31.17	0.74	384.6	8.37
Mean	23.16	0.63	347.31	8.89
LSD (5%)	7.286	0.05	85.70	2.43
CV	17.70	3.97	15.27	15.78

** = local variety

3.3 Comparison of performance improved varieties and local varieties

The improved varieties generally gave higher root yield root yield (t/ha) in all locations than the local varieties across the different ecologies (Table 3). The average storage root yield for the improved varieties at Techiman North in the transition zone (27.60 t/ha) was higher than the average root yield obtained at Damongo in the Guinea savannah ecology (24.51 t/ha). Compared to the respective average root yield of the local varieties, the margins of differences were 22.11% and 26.7% for the Guinea savannah ecology and transition zone respectively.

Table 3 Comparison of mean root yield of all improved varieties with mean root yield of all local varieties in the different ecologies (T-Test).

Variety	Transition	Savannah
	Techiman	Damongo
Improved (I)	27.60	24.51
Local (L)	20.24	19.09
Yield difference	7.36	5.42
% diff (I/L)$^{\#}$	26.70	22.11
SED	2.381	1.231
P<0.05	0.003	0.021

% diff (I/L)$^{\#}$ = Percentage yield difference

3.4 Selection of high yielding improved and local varieties for different ecologies

The improved and local varieties also exhibited different adaptations to the different agro-ecologies (Tables 4 and 5). Three varieties Bankyehemaa, Essambankye and Nkabom were also selected for the Techiman North district in the forest savannah transition zone whilst Bankyehemaa, Nyerikobga and Filindiakong were selected as the suitable improved varieties in the Guinea savannah ecology.

Table 4 Root yield (t/ha) for best improved varieties for the different ecologies

Variety	Transition	Guinea savannah
	Techiman	Damongo
Bankyehemaa	28.06	19.71
Filindiakong		22.65
Nyerikobga		31.17

Eskamaye		
Essambankye	27.76	
Nkabom	26.99	
Mean	27.60	24.51

Table 5 Root yield (t/ha) for best local varieties for the different ecologies

Variety	**Transition**	**Guinea savannah**
	Techiman	**Damongo**
Dakware	23.27	
Nkomte	25.33	
Biabasse		19.05
Mean	24.30	19.05

4. DISCUSSION

Genotypic variability among cassava varieties for tolerance to biotic and abiotic stresses is a very important opportunity for the improvement of the crop (Aina et al., 2007b; Okogbenin et al., 2003; El-Sharkawy et al., 2007). The results from the study confirmed earlier reported findings about the resilient nature of different cassava varieties. The improved crop varieties generally gave better performance than the local farmer preferred varieties which had low yielding potential and susceptible to common pests and diseases of cassava. However, there were exceptions as some local varieties outperformed some of the improved varieties. This could be due to the fact that these local varieties were mostly adapted to their respective environments and are much better suited than newly introduced varieties. This is because landraces or local varieties serve as rich genetic resources of useful traits of agronomic importance (Aina et al. 2009). The wider the genetic diversity among landraces of a crop, the greater the progress that can be made in itsgenetic improvement (Haussmann et al. 2004; Govindaraj et al. 2014). This suggests that the local cassava varieties contain ample genetic variation that can be utilized for further improvement.

Harvest index which represents the proportion of dry matter that is partitioned into the economic parts (Alves 2002) and for that matter, the efficiency of the different varieties, was also highly significant and varied among the different varieties. In most cases the improved varieties had better partitioning of dry matter into the roots compared with the local varieties. Most local farmer-preferred varieties are tall and non-branching due to several years of careful selection of intercropping-compatible cassava varieties (Nweke 2002; Fajinmi and Fajinmi 2010; Njoku et al. 2010; Njukwe et al. 2013). The improved varieties used were mostly early branching and as such had the tendency to convert most of their assimilates into storage root bulking earlier in the growing season thereby resulting in much higher root yield. Earlier studies have suggested that cassava varieties differ in the partitioning of dry matter into the various plant organs with some preferring stems to roots at a much earlier stage than others (Okogbenin et al. 2002; Alves 2002; El-Sharkawy 2004). It has been suggested that cassava varieties that begin partitioning of dry matter into storage roots at an earlier growth stage (high initial harvest index) eventually give better yield than varieties that channel dry matter into storage roots later (Okogbenin et al. 2008; Adjebeng-Danquah et al. 2016). This has implications on the selection of cassava varieties for climate change mitigation since such varieties are expected to be highly efficient in the utilization of moisture for transpiration and conversion into dry matter (Okogbenin et al. 2011). Average harvest index was also lower in the transition ecology compared to the Guinea savannah due to the ability of varieties to develop more above ground biomass in relatively more humid forest and transition ecologies compared to savannah ecologies (Baafi and Safo-Kantanka 2008).

Varieties also differed in number of storage roots with Bankyehemaa consistently producing high number of storage roots compared with the local varieties and even some of the other improved varieties. This could be due to the high yield potential of Bankyehemaa. Studies have indicated that one of the attributes of high yielding cassava varieties is the ability to produce high number of storage roots (Alves 2002; El-Sharkawy 2004). However having more number of roots implies a larger sink load which will result in several sinks competing for the same amount of assimilates. Therefore varieties that initiate more storage roots than necessary tend to have smaller storage roots after harvest (Alves 2002). This was evident in Bankyehemaa which had the highest number of storage roots per plant but lower mean root weight compared to the other varieties. In considering varieties, efforts should be made to select varieties that combine high number of storage roots with good partitioning efficiency to ensure that big storage roots are obtained after harvest.

Generally the improved varieties performed better in all traits than the local varieties across all locations though some of the local varieties gave comparable yields. The margins of differences were22.11% in the Guinea savannah ecology and 26.7% in Techiman North district the transition ecology. This implies that the transition ecology was relatively more conducive for the expression of the full potential of the varieties (Baafi and Safo-Kantanka 2008). In stress environment, genetic variation for drought tolerance become more pronounced resulting in the wider variation between improved varieties and local varieties in the guinea savannah ecology than the transition ecology. The yield variations among the improved variations did not differ much compared to the variations among the local varieties. Cavatassi et al. (2006) suggested that more diverse crop germplasm (as kept on farmers' fields) guards against total crop failure and provides insurance for food security. Aina et al. (2009) also indicated that landraces provide rich source of germplasm for crop improvement. The results from this study provide opportunity for selection from the pool of local varieties for further improvement to identify drought tolerant varieties to boost cassava production. The study also identified certain cassava varieties as suitable for the transition and Guinea savannah ecologies due to their high yielding potential in the districts in the various ecologies. Agro-ecology specificity of cassava varieties as a result of their adaptability have long been reported by several studies (Aina et al 2009; Dixon and Nukenine 2010; Ntawuruhunga and Dixon 2010) and this need to be considered critically when recommending cassava varieties for farmers. Three varieties were also identified for the Guinea savanna ecology (Nyerikobga, Filindiakong and Bankyehemaa).

5.0 CONCLUSIONS

The study identified high yielding improved and local drought tolerant cassava varieties that are specifically adapted for the different ecologies. The improved varieties generally gave better performance for all traits than the local varieties. Some local farmer preferred varieties also had better performances that make them very good materials for promotion as drought tolerant varieties. These local varieties can further be improved for pests and diseases resistance and recommended to farmers for cultivation.

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