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Improved varieties increase cassava yields by 50% in heterogeneous smallholder farm conditions on Ultisols in southern Cameroon

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Abstract

Cassava is produced extensively by smallholder producers the forest zone of southern Cameroon in mixed food crop fields and yields are poor. Yet, there is an increased demand for both fresh and processed cassava. A set of on-farm trials in two sites of contrasting land use intensity was carried out to (i) explore production constraints for cassava in these environments and (ii) assess the yield potential of a best-bet variety under the farmer field conditions. Cassava yields were low (10 t ha^{-1}). Soil fertility was generally low with 88% of the fields having soil parameters were below critical levels for cassava production. Other limiting factors identified were low plant density, root rot in the high land use intensity zone and high incidence of CMD in the local, susceptible varieties. Improved varieties showed good potential to increase cassava yields with on average more than 50% higher yields. This can be attributed its ability to produce a higher percentage of marketable roots, a better apparent harvest index, and a lower susceptibility to CMD. Higher CMD severity in the local variety caused a reduction in the ability to outshade weeds, especially after 3 months when farmers normally don't weed anymore. Although, adequate weeding in the first 3 MAP is crucial in general as both varieties, additional weeding is required in the local variety. The use of improved varieties and adequate weed control in the first three months after planting should be promoted to improve yields and revenue potential for farmers and secure food supply urban domestic markets in Cameroon.

Introduction

Cassava (*Manihot esculenta* Crantz) is the main staple food in the southern Cameroonian forest margins. Ninety percent of the total production is grown by smallholder farmer (IFAD, 2005). Cassava is traditionally intercropped with groundnuts (*Arachis hypogaea*) and maize (*Zea mays*) (Mutsaers *et al.*, 1981a), whereby fields are principally managed by women (Guyer, 1984). Farms are small with households planting on average around one ha of food crops per year (Gockowski *et al.*, 2004). Cassava yields in these low-input farming systems are generally low (7.5 t ha^{-1}) (Mutsaers *et al.*, 1981b). Soil productivity is traditionally maintained through long fallow periods and slash-and-burn practices (Büttner and Hauser, 2003). However, higher population densities in certain areas have resulted in intensified land use. In these areas, increased food demand accompanied by shortening fallow periods, which may over time lead to lower soil productivity due to insufficient soil fertility replenishment and arable weed infestation (Hauser *et al.*, 2006).

Traditionally, farmers grew cassava primarily to secure family food requirements while commercializing only small surpluses at domestic markets (Gockowski *et al.*, 2004). However, rapid urbanization and increased sub-regional trade has increased the demand for cassava products on urban markets in Cameroon (IFAD/IRPCM, 2008). A lack of supply has, among other factors, resulted in price increases for fresh and processed cassava, thereby undermining food security for a growing segment of urban poor (Dury *et al.*, 2004). To increase national food production and satisfy urban consumer markets, the cassava breeding programs of IITA and NARES have developed and distributed improved cassava varieties that have the potential to increase production levels and consequently promote cassava commercialization. A set of on-farm trials was carried out to (i) assess the yield potential of a best-bet variety under the heterogeneous conditions found in smallholder farms in southern Cameroon and (ii) explore production constraints for cassava in these environments.

Materials and methods

Site selection

Two locations were selected to represent the contrasting land use intensities found in southern-central Cameroon based on remote sensing estimates of SPOT images ((Nolte *et al.*, 2001): (i) a site located in the forest-savannah transition zone, dominated by young fallows, grass and shrub savannas and a higher estimated population density (51-70 pers km^{-2}) and (ii) a site located in the forest zone, dominated by young and mature secondary forest and a lower estimated population density (11-20 pers km^{-2}) (Gockowski *et al.*, 2004). In the forest-savannah transition site the villages of Nkometou (4°4?N, 11°34?E) and Ekoumdouma (4°6?N, 11°32?E) were selected, while the forest site was represented by the village Nkolmeyang (03° 52?N, 11°39?E). Annual rainfall in the study area is approximately 1650 mm in a bimodal pattern. Mayor soils are acidic to strongly acidic Ultisols and Oxisols. These low-activity clay soils are common throughout the inter-tropical zone of which soil properties depend largely on the soil organic matter content (Feller, 1993). In each site 12 or 13 fields were selected on the basis of the previous fallow length (between 3 to 6 years) and farmers' willingness to participate in the trials.

Experimental set-up

In both sites, cassava trials were established between April and May 2007. Fallow vegetation biomass was slashed and burned *in situ* according to farmers' practices before seedbed preparation. Field size was 360 m^2. Cassava cuttings (20-25 cm length, one stick per stand) were planted at a target density of 10,000 plants ha^{-1} in a slanted orientation. Two varieties were used in each trial; the best-bet improved variety TMS96/1414, and the best local variety (*Njuma* in Nkolmeyang, *Automatique* in Nkometou and *Gabon* in Ekoumdouma*)*. Local planting material was obtained from the farmer, whereas improved planting material was obtained from a multiplication plot in Mbalmayo research farm. Manual weeding was carried out by the farmer when deemed necessary, normally at 1 and 3 Months After Planting (MAP). Weed biomass was left on the topsoil around cassava plants. Cassava was harvested at around 12 MAP in early May 2008.

Data collection

Before soil preparation, three soil samples per plot were taken using 100 ml cores of 5 cm length. Samples were bulked and dried at 65°C to constant mass to determine bulk density. The samples were then ground to pass a 2 mm sieve for chemical analysis. Soil pH was determined in a water suspension at a 2:5 soil:water ratio. Exchangeable Ca, Mg and K and available P were extracted by the Mehlich-3 procedure (Mehlich, 1984). The cations were determined by atomic absorption spectrophotometry and P by the molybdate blue colorimetric procedure (Murphy and Riley, 1962). Organic C was determined by chromic acid digestion and spectrophotometric procedure (Heanes, 1984). Total N was determined after wet acid digestion (Buondonno *et al.*, 1995) by colorimetric analysis (Anderson and Ingram, 1993).

Overall weed management throughout the growing season was scored based on frequency and timing of weeding by technicians who visited the fields frequently. The score ranged from 1 (very poor) to 5 (very good). Additionally, in six fields in the forest-savannah site, composite weed samples were taken prior to weeding, using 0.25 m^2 frames and three locations per field. Dry matter of the collected weed biomass was determined by drying at 65°C to constant weight.

The most important cassava pests and diseases in Cameroon include cassava mosaic disease (CMD), cassava bacterial blight (CBB), cassava anthracnose disease (CAD), African root and tuber scale (ARTS), root rot and rodents. Disease severity of CMD, CBB and CAD were scored for 5 plants along a diagonal transect in the harvest area (16 m^2) on a scale of 0 to 4 (based on the 1-5 score (IITA, 1990)) at 3, 6, 9 and 12 MAP, except CAD which not scored at 3 MAP. For each disease and recording date, a mean severity score (MSS) was used to calculate an adapted area under disease severity index progress curve (AUSiPC) for each plot (Madden *et al.*, 2007). This was calculated as:

$$Adapted\ \ AUSiPC = \sum_i \left(\frac{MSS_i + MSS_{i-1}}{2} \right) \times \left(t_i - t_{i-1} \right) \quad (1)$$

whereby MSS_i is the mean severity score at time t_i with t corresponding to the number of MAP after planting. As the MSS ranges from 0 for a plot without disease symptoms to 4 where all evaluated plants had a maximum score, the adapted AUSiPC ranges from 0 to 42 respectively for all diseases, except for CAD which ranges from 0 to 36. An index for ARTS infestation, root rot and rodent damage incidence was calculated per treatment plot as the average score per five randomly selected plants evaluated at harvest. ARTS infestation was scored in five categories of scale presence. 0=absent, 1=1-10 scales, 2=11-25 scales, 3=26-50 scales and 4= more than 50 scales. Root rot incidence was scored as percentage of rot-infected roots per plant, while rodent damage incidence was scored as a percentage of number of plants with rodent damage symptoms.

The cassava harvest area measured 16 m^2 and consisted of five cassava rows of 5 plants each. At harvest total fresh root yield and total fresh weight of above-ground biomass were determined. Roots were separated into marketable and non-marketable, whereby the latter was defined as roots normally left behind on the field. For dry matter determination, a random sub-sample of roots was taken per treatment.

Statistical analyses

Statistical analysis of data was performed using the linear models using the proc linear procedure of SAS software package. Location and variety were taken as a fixed effect and the effect of location nested within block was taken as a random effect. Contrasts were used for pair-wise comparison of treatments using least square means procedure. All the data were checked for a normal distribution and if there was a deviation from this, the data were transformed using square-root or logarithmic functions.

Results and discussion

Difference in soil properties between sites

Soils were generally of low fertility irrespective of land use intensity, even for cassava which is generally more tolerant to low soil fertility levels than other crops (Table 1). In 88% of fields at least one of soil fertility parameters was below critical levels identified for cassava (e.g. SOC-18 g kg^{-1}; K-0.18 $cmol_+$ kg^{-1}; P-8.0 mg kg^{-1} as described by Howeler, 2002). SOC was most frequently below the critical level for cassava (64% of fields). Management of soil carbon stocks in low-activity clay soils (Ultisols) is essential to create cation exchange capacity and maintain adequate supply of nutrients to crops (Giller, 2001). Conserving soil organic carbon in general but especially on more sandy soils is however very difficult in the prevailing warm and wet conditions, where organic matter decomposes rapidly (Feller, 1993). Although varying considerably between fields within the sites, average soil carbon and exchangeable K values were not significantly different between sites, ranging from 16.1 to 16.3 g kg^{-1} for SOC and 0.26 $cmol_+$ kg^{-1} in both sites for K (Table 1). Average available P and total soil N values were significantly higher ($P=0.05$) in the forest-savannah site than in the secondary forest ranging from 11.4 to 6.4 mg kg^{-1} and 1.7 to 1.4 g kg^{-1}, for P and total N respectively. Additionally, soils in this location had a higher sand content ($P=0.01$) while the organic carbon had a higher CN ratio ($P=0.001$) compared to the secondary forest site. No significant differences between sites were found for the other soil variables, although all values were highly variable within fields. Traditionally, long fallow periods were practiced to recharge the soil with carbon. However fallow periods have been shortened due to increasing population pressure (Gockowski *et al.*, 2004), more so in the forest-savannah site than in the forest site. This may explain why fields with P (75 versus 39%), K (42 versus 39%) and multiple limitations (33 versus 23 %) were in general more frequent in the forest-savannah transition site than in the secondary forest site. Although pH is relatively low (5.3), it is not below critical limits for cassava, which can tolerate relatively acidic soils.

Effect of location and variety on yield components

Overall, fresh cassava yields averaged 10.0 t ha^{-1} (Table 2). This is low in comparison to average on-station yields of 18 t ha^{-1} yields in southern Cameroon (Hauser, 2008). Also average plant density at harvest was low with 33% below target density of 10.000 plant ha^{-1}. At harvest the crop had attained an average of 16.1 t ha^{-1} of aboveground biomass, comprising of 9.7 and 6.4 t ha^{-1} of stems and leaves, respectively. Different disease pressures of CMD, CBB, CAD and root rot were recorded but symptoms were present in all varieties with average values of 14.6, 8.9 (scale 0-42), 6.5 (scale 0-36) and 14.4 (% of roots per plant), respectively. Pest incidence was low and not likely to have caused serious yield losses. Although ARTS present in all fields, occurrence at harvest was small with an average around 12 scales per plant (score of 1.5) and a highest occurrence recorded below fifty scales (score 2.8). On average, 6% of plants had signs of rodent damage, primarily caused by grasscutters (*Thyonymys swinderianus*) who can cause damage when the field is not well weeded. Although often cited as a big problem by farmers (Poubom *et al.*, 2005), actual losses caused by rodents were incidental and generally negligible with only one or two roots damaged per plant. Weed management was good with score of 3.8 on a scale of 1 to 5, although three fields received lowest score.

Average yields were 86% higher in the secondary forest site than in the forest-savannah site (15.3 versus 8.6 t ha^{-1}). This was mostly due to a difference in plant density with 26% more plants present at harvest in the secondary forest site. Additional factors that contributed to higher yields in the forest zone include a 148% lower root rot severity value, better chemical (78% higher available P, 21% higher total N) and physical (14% lower sand content) soil fertility, more (+10%) marketable roots, and better weed management (table 1 and 2). Cassava in the secondary forest had a higher apparent harvest index than in the forest-savannah (0.38 versus 0.31, $P=0.005$) and at the same time tended to have more aboveground biomass (19.1 vs 13.1 t ha^{-1}) although the latter was only significant at $P=0.1$,

The improved variety outperformed the local variety with almost 50% higher average yields in both locations, whereby in 48% of fields attained a yield difference of at least 40%. Major factors that contributed to the yield advantage of the improved variety include (i) more marketable roots ($P=0.05$), (ii) a better apparent harvest index ($P<0001$), and (iii) a 68% lower CMD severity (P<0.001) (table 2). Besides it attained more aboveground biomass ($P<0001$) and tuberous roots attained a higher dry matter content. Root rot incidence was higher in the forest-savannah site ($P=0.05$) where the disease affected the improved variety more severe than the local variety ($P<0.001$). This disease is caused by a complex of soil borne fungi and, once infected, greatly reduces in-soil storability of roots. Similar to (Onyeka *et al.*, 2005), our results indicate that the magnitude of yield loss depends on cassava genotype, although we observed the higher susceptibility of the improved variety only under low soil fertility conditions. Although CBB and CAD severity scores were significantly higher on the local varieties than on the improved variety, scores were relatively low and were not likely to cause important yield losses.

Influence of variety on weeds and weed management

Weed biomass present under the local variety was significantly higher at 6 MAP ($P<0.001$) than under improved varieties, but not at 1 and 3 MAP (Fig. 1). Farmers weeded the sampled fields at 1 and 3 MAP. Under good growing conditions and near-optimal plant densities, cassava normally reaches full ground-cover after 3 MAP and out shades weeds (Leihner, 2002). Although plant densities did not vary between the local and improved varieties and growing conditions were the same, the local variety was unable to outshade weeds as efficiently as the improved variety. This is likely related to the higher severity of CMD, which caused an important reduction in canopy size in the local susceptible variety in the months when no more weeding is carried out (Table 2). However root yields of both local and improved variety responded similarly exponential to weed management scores (Fig. 2). This may be due to the fact that weed management score was related to farmers' traditional practices (only two weedings), while our data indicates that with the current prevalence of CMD, additional weeding under susceptible varieties is required. Maximum average yields obtained under weed management score 1 were 4.8 and 6.0 t ha^{-1}, while with very good weed management maximum yields were 19.9 and 21.1 t ha^{-1} for local and improved variety respectively (Fig. 2).

Conclusion

Cassava yields in the heterogeneous conditions found in smallholder farms in southern Cameroon were low. Soil fertility was generally low and in the majority of the fields soil parameters were below critical levels for cassava production. Other limiting factors identified were low plant density, root rot in the forest-savannah zone and CMD for local varieties. Improved varieties showed good potential to increase cassava yields in areas with variable land use intensity. The better performance of the improved variety can be attributed to more marketable roots, a better apparent harvest index, and a lower susceptibility to CMD. Higher CMD severity in the local variety cause a reduction in the ability to outshade weeds, especially after 3 months when farmers normally don't weed anymore. Although, adequate weeding in the first 3 MAP is crucial in general as both varieties showed similar strong yield response to weed management, additional weeding is required in the local variety. The use of improved varieties and adequate weed control in the first three months after planting should be promoted to improve yields and revenue potential for farmers in Cameroon. However, because higher yields increase nutrient exports, to make the system sustainable this should go together with appropriate soil fertility management practices like precision fertilizer application and improved fallow systems.

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Table 1: Soil properties (0-10 cm) of the different sites

Site location		Particle size (%)			pH water	SOC	TotalN	CNratio	P	Exch. bases ($cmol_+ kg^{-1}$)			BD
		Sand	Silt	Clay	(1:2.5)	(g kg^{-1})	(g kg-^{1})		(mg kg^{-1})	K	Ca	Mg	(g dm^{-3})
Secondary	Mean	57	35	8	5.2	16.3	1.7	9.8	11.4	0.26	2.3	1.1	1.12
forest	Min	43	21	0.4	4.0	14.1	1.4	8.7	4.5	0.11	0.35	0.48	0.86
(n=13)	Max	67	43	16	6.2	20.3	2	11.3	33.2	1.1	7.4	1.8	1.21
Forest-savannah	Mean	66	30	4	5.3	16.1	1.4	11.4	6.4	0.26	2.9	1.36	1.15
transition	Min	47	21	1	4.5	9.2	0.9	9.8	2.9	0.07	0.73	0.31	0.64
(n=12)	Max	77	51	9	6.2	23.3	2.1	13.6	17.0	0.64	6.7	3.0	1.31
	p-level	*0.01*	*0.1*	*0.05*	*ns*	*ns*	*0.05*	*0.001*	*0.05*	*ns*	*ns*	*ns*	*0.1*

Table 2: Effect of site and variety of yield components and pest and disease severity and weed management (WM) per location. Data shown as lsmeans.

Site	Variety	Yield	Plant density at harvest	Above-gr. biomass	HI fresh	Mrktble roots	Dry matter mrktble roots	Adapted AUSiPC CMD	CBB	CAD	Root rot	ARTS index	Rodent damage	WM
		$t\ ha^{-1}$	$`000\ ha^{-1}$	$t\ ha^{-1}$		%	%				%		%	
Secondary	improved	15.3	8.9	19.9	0.41	86	30.7	3.6	6.9	4	7.8	1.9	12.5	
forest	local	11.2	8.3	18.3	0.35	83	36.1	25.8	8.1	7	8.8	1.6	6	4.38
	p level	*<0.001*	*ns*	*0.1*	*<0.001*	*0.1*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*ns*	*<0.001*	*0.05*	
Forest-savannah	improved	8.6	7	15.2	0.33	70	28.2	4.5	6.2	4.5	28.2	1.3	3.1	
transition	local	4.8	6.6	11	0.28	70	33.2	24.5	14.5	10.6	12.9	1.3	2.3	3.25
	p level	*<0.001*	*ns*	*<0.001*	*<0.001*	*ns*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*ns*	*ns*	
	Anova significances for the effects of:													
	Location (L)	*<0.001*	*<0.001*	*0.1*	*0.005*	*<0.001*	*0.1*	*ns*	*0.001*	*0.05*	*0.05*	*0.1*	*0.05*	*0.01*
	Variety (V)	*<0.001*	*ns*	*<0.001*	*<0.001*	*0.05*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*0.1*	
	V x L	*ns*	*ns*	*0.1*	*ns*	*ns*	*ns*	*0.01*	*<0.001*	*<0.001*	*<0.001*	*0.1*	*ns*	

Figure 1: weed incidence during the growing season of cassava in the forest-savannah transition site. Error bars indicate SEM.

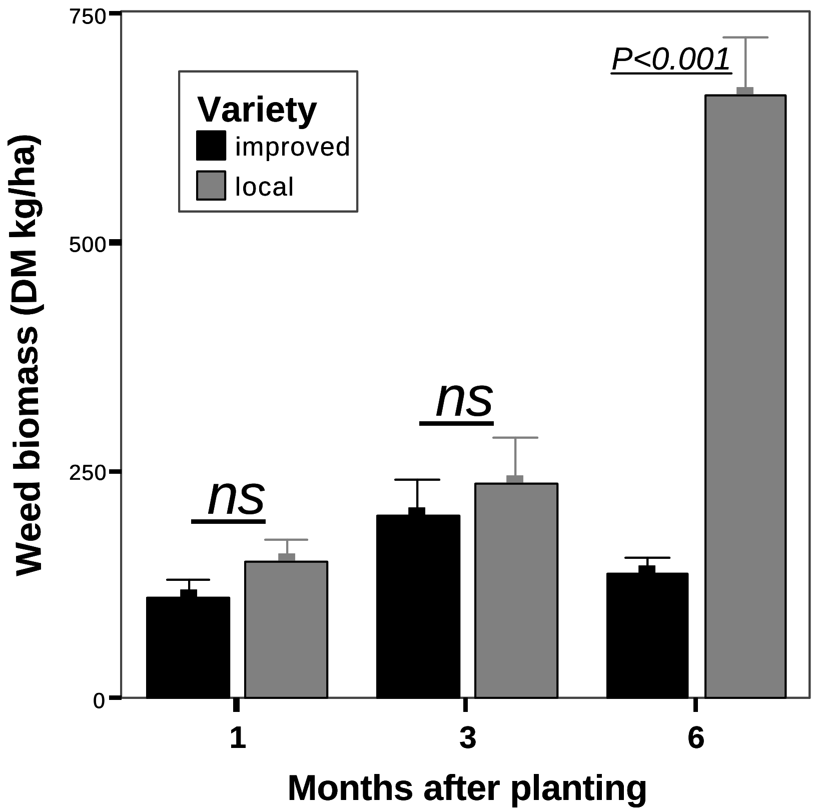

Figure 2: Relationship between fresh root yield and weed management score (WM) per field. Function of lines are Yield = $3.36e^{0.30*WM}$ (R^2=0.59) and Yield = $1.29e^{0.42*WM}$ (R^2=0.54) for improved and local variety, respectively.