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Performance of cassava brown streak disease-tolerant varieties in Zanzibar, Tanzania

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ABSTRACT

Cassava is an important staple food in subtropical regions; however, its production is adversely affected by cassava brown streak disease and poor soil fertility. Five improved and two local cassava varieties were evaluated for three seasons across two sites in Kizimbani, Zanzibar. Highly significant differences were detected among varieties, sites and years for fresh shoot yield, and fresh root yield. For cassava brown streak disease-associated root necrosis, highly significant differences were detected only between varieties but not sites or years. On average, the site that had a slightly higher soil nitrogen level recorded ~126% higher fresh root yield. Two improved varieties, 'Kizimbani' and 'Machui', produced significantly higher fresh root yields than the best local variety, 'Mwari'. However, the local variety 'Boma' is preferred by farmers in Zanzibar because it has better fresh consumption qualities than 'Mwari'. 'Boma' is highly susceptible to cassava brown streak disease and produces a poor yield. The four released varieties, 'Kama', 'Kizimbani', 'Mahonda' and 'Machui' were superior to 'Boma' in cassava brown streak disease resistance and yield. Further, soil fertility improvement and production system intensification are needed to enhance productivity.

Key words: Cassava, cassava brown streak disease, soil fertility, Tanzania.

INTRODUCTION

Cassava is grown throughout the state of Zanzibar and is the second most important food staple, after rice. Although cassava is a very hardy crop that grows well under marginal conditions in which few other crops could survive, to achieve its full potential, productivity must be improved (Ceballos, 2; Dixon and Ssemakula, 4; FAO, 7). Cassava is grown on 12,480 ha in Zanzibar, with an estimated production of 187,213 tonnes/ year (FAO, 6). This implies that the average yield is ~15 t/ha. However, cassava mosaic disease (CMD), cassava brown streak disease (CBSD) and low soil fertility are the key limiting factors for its production (Spittel and Van Huis, 14).

CBSD is presently the most important cause of food insecurity in the coastal and lake zones of eastern Africa (Mohammed *et al*., 9). CBSD has been endemic in the coastal lowlands of eastern Africa since the 1940s, but no serious outbreaks had been reported in Zanzibar, despite the occurrence of foliar incidences (Nichols, 11; Thresh and Mbwana, 15). For reasons not yet known, CBSD devastated cassava crops in Zanzibar during the early 2000s. Farmers in Zanzibar had only two popular local varieties, 'Boma' and 'Kibiriti', which have very good cooking qualities when fresh. Unfortunately, these varieties are highly susceptible to CBSD. By 2003, most farmers were abandoning the cultivation of these varieties and desperately looking for resistant varieties. One of the few promising local varieties was 'Mwari', which, although inferior to 'Boma' and 'Kibiriti' in cooking qualities, produced a higher yield. However, it was not widely available.

The Ministry of Agriculture in Zanzibar officially released four new high-yield, CBSD-tolerant and CMD-resistant varieties in 2007. These varieties have been under evaluation, both on-station and on-farm, since then.

MATERIALS AND METHODS

Five promising breeding lines that were in the pipeline for official release were evaluated on-station at the Agricultural Research Institute (ARI), Kizimbani, Zanzibar, at two sites that differed in soil fertility (Table 1). The sites, Michikichini (06.08617 S; 039.26360 E, 59 m above sea level) and Mibunini (06.08845 S, 039.2646 E, 62 m above sea level) were less than 1 km apart within the research station. The lines being evaluated were KBH 2002/477, KBH 2002/482, KBH 2002/494, KBH 2002/517 and KBH 2002/344. The first four were officially released in 2007 under the names 'Kama', 'Kizimbani', 'Mahonda' and 'Machui', respectively. Two popular local varieties, 'Boma' and 'Mwari', were also included.

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Table 1. Soil chemical properties at the two sites, Michikichini and Mibunini, in ARI, Kizimbani, Zanzibar.

Parameter	Michikichini		Mibunini	
	0–20 cm	20–40 cm	0–20 cm	20–40 cm
pH	4.95	5.10	6.05	5.95
Organic C (%)	0.95 (low*)	0.55 (very low)	0.95 (low)	0.75 (low)
Total N (%)	0.129 (low)	0.116 (low)	0.175 (medium)	0.140 (low)
Available P (ppm)	13.5 (medium)	4.0 (low)	7.5 (low)	5.5 (low)
Exchangeable K (meK/ 100 g soil)	0.11(very low)	0.16 (very low)	0.27 (low)	0.125 (very low)
Exchangeable Zn (ppm)	<0.1	<0.1	<0.1	<0.1

*Interpretation as per Hazelton and Murphy (2007).

The first trial, performed in randomized complete block design with two replications for two consecutive years. The plot size was 10 m × 4 m. Planting was performed in March, which is the start of the long rainy season. The experiment was conducted for two consecutive years in three replications. A spacing of 1 m × 1 m was used between ridges and between plants within a ridge. The plots were kept weed-free by hand weeding. Plants were harvested 12 months after planting. At harvest, the following data were recorded: Number of plants harvested from the net plot area, number of roots harvested, weight of roots harvested, weight of shoots (stems with their leaves plus stumps), and plant height. Root weight and plant height are known to be important characters in cassava yield (Padma *et al.*, 13). Roots were sliced transversally into three pieces that were scored for root necrosis on a scale of 1-5, where 1 indicated no visible symptoms and 5 indicated very severe symptoms (Hillocks and Jennings, 8). Data were subjected to an analysis of variance (after being checked for normality) using the General Randomized Block Treatment Structure of the GenStat Discovery Edition 3 software program. Soil samples were taken from the trial fields before planting, and analyzed at the ARI Kizimbani soil laboratory.

RESULTS AND DISCUSSION

Zanzibar has a bi-modal rainfall system and normally receives more than 1,000 mm of rain per year. The long rainy season starts in March and ends in June. The short rainy season starts in October and ends in December. However, throughout the year some rainfall, although small in amount, is expected. This rainfall distribution is very suitable for cassava production (Table 2). The greatest amount of total rainfall was received in 2006 (1,719.1 mm) when the trial started. The least amount of rainfall was recorded in 2008 (1,311.6 mm). This implied that rainfall was not a constraint on cassava crop production during the whole trial period.

Highly significant differences in fresh shoot weight were detected between varieties, sites, and years. The site × year interaction was also highly significant (Table 3) and contributed the highest value of total sum of squares (29%), followed by year (18%). 'Kizimbani' and 'Machui' had significantly higher FSY values than the rest of the lines (Table 4). The Mibunini site produced, on average, significantly higher FSYs than Michikichini (9.2 and 6.5 t/ha, respectively). The higher FSY at Mibunini could be attributed to the slightly higher levels of nitrogen at this site. This is in agreement with findings from other researchers on other root and tuber crops. Research on sweet potato indicated that plants that received 20 t/ha of "sunshine organic fertilizer" [composted poultry manure + sorted city refuse at 1:2 (nitrogen: phosphorus: potassium at 2.58%:1.10%:0.68%)] produced significantly longer vines, more leaves, more branches and greater tuber weights than the control (Adekoya *et al.*, 1).

Table 2. Rainfall (mm) received each month in the three seasons at the research station at Kizimbam.

Month	Rainfall amount (mm)		
	2006	2007	2008
January	65.7	32.6	52.5
February	12.1	9.2	34.8
March	135.1	229.4	150.8
April	486.2	313.7	526.6
May	162.8	402.3	93.3
June	169.5	78.3	64.8
July	39.6	22.3	47.9
August	30.7	79.4	41.3
September	33.3	24.6	43.0
October	112.4	136.7	51.7
November	246.0	112.0	143.6
December	225.7	67.2	61.3
Total	1,719.1	1,507.7	1,311.6

Table 3. Analyses of seven cassava varieties grown for three seasons at two locations in Zanzibar.

Source	DF	Mean square	% of total sum of squares
Fresh shoot yield			
Variety	6	37.19***	9.4
Site	1	810.01***	34.1
Year	2	185.32***	15.6
Variety × Site	6	11.28	2.8
Variety × Year	12	8.98	4.5
Site × Year	2	93.38***	7.9
Variety × Site × Year	12	4.57	2.3
Residual	68	7.85	22.5
Plant height			
Variety	6	4560.9***	40.5
Site	1	8211.4***	12.2
Year	6	482.9	1.4
Variety × Site	2	387.3	3.4
Variety × Year	12	672.3**	11.9
Site × Year	2	522.5	1.5
Variety × Site × Year	12	312.5	5.5
Residual	68	229.6	23.1
Fresh root yield			
Variety	6	349.49***	17.3
Site	1	5004.12***	41.3
Year	6	571.94***	9.4
Variety × Site	2	126.58***	6.3
Variety × Year	12	38.58	3.8
Site × Year	2	163.56**	2.7
Variety × Site × Year	12	47.00*	4.7
Residual	68	24.46	13.7
CBSD-associated root necrosis			
Variety	6	9.56***	60.9
Site	1	0.04	0.0
Year	6	1.16**	2.5
Variety × Site	2	0.51**	3.3
Variety × Year	12	0.47**	6.0
Site × Year	2	1.01**	2.1
Variety × Site × Year	12	1.05***	13.4
Residual	68	0.15	11.1

***,**,* = Significant at p = 0.001, 0.01 and 0.05 levels

Table 4. Mean fresh shoot yield (t/ ha) among cassava varieties evaluated across two sites and three seasons.

Variety	Site		Mean
	Mibunini	Michikichini	
Boma	8.31 (5)	3.83 (6)	6.07
Kama	9.72 (4)	5.00 (2)	7.36
KBH 2002/344	8.09 (6)	3.95 (5)	6.02
Kizimbani	13.00 (2)	6.38 (1)	9.69
Machui	13.12 (1)	4.50 (4)	8.81
Mahonda	10.06 (3)	4.99 (3)	7.53
Mwari	7.63 (7)	3.66 (7)	4.64
Mean	9.99	4.61	7.30
CV (%)	34.5	47.5	38.4
$LSD_{0.05}$	3.50	2.23	1.98

*No. in brackets indicates the ranking of the variety within the site.

Highly significant differences were detected between varieties, sites, and years for FRY. Highly significant differences were detected for variety × site interactions. In addition, variety × year and variety × site × year interactions were significant (Table 3). Sites and varieties contributed the highest percentages to the total sum of squares (41 and 17%, respectively). Similar results have been reported by other researchers, underscoring that cassava, as a crop, is widely adaptable to a variety of environmental conditions, but that the usual ranges of most varieties are narrow and have large genotype by environment (G × E) interaction effects (Dixon *et al.*, 3; Ngeve, 10; Ntawuruhunga *et al*., 12). 'Kizimbani' had, on average, the highest FRY (24.6 t/ha) among the varieties (Table 5). The FRY of the local variety 'Boma' was significantly lower, at 9.5 t/ha, than those of the other varieties. Mibunini was a significantly a higher yielding site (24.0 t/ha) than Michikichini (10.6 t/ha), producing a yield increase equivalent to ~126%. The same argument regarding the higher level of nitrogen that was made for the higher FSY applies here. This difference in the soil fertility within such a short distance highlights that the traditional farming systems producing cassava are characterized by highly variable edaphic and biological conditions. The large G × E interaction makes it difficult for breeders to identify cultivars suitable for such farming systems (Eyzaguirre and Iwanaga, 5). Extensive trials reviewed by the Food and Agriculture Organization of the United Nations have shown that many cassava varieties respond very well to fertilization. The ability of cassava to produce on low-fertility soils has given rise to the misconception that cassava does not require, nor even respond to, the application of mineral fertilizers (FAO, 7). The preliminary results

Table 5. Mean fresh root yield (t/ ha) among cassava varieties evaluated across two sites and three seasons.

Variety	Site		Mean
	Mibunini	Michikichini	
Kizimbani	36.36 (1)*	12.76 (1)	24.56
Machui	28.73 (2)	10.97 (4)	19.85
Kama	24.44 (4)	11.89 (3)	18.17
Mahonda	25.27 (3)	12.04 (2)	18.66
Boma	13.25 (7)	5.86 (7)	9.55
KBH 2002/344	19.49 (6)	10.15 (6)	14.82
Mwari	20.40 (5)	10.69 (5)	15.54
Mean	23.99	10.62	17.31
CV (%)	23.00	41.20	28.6
$LSD_{0.05}$	5.62	4.45	3.49

*No. in brackets indicate the ranking of the variety within the site.

Table 6. Mean plant height (cm) among cassava varieties evaluated across two sites and three seasons.

Variety	Site		Mean
	Mibunini	Michikichini	
Boma	151.2 (6)	128.9 (6)	140.1
Kama	171.9 (3)	159.8 (3)	165.8
KBH 2002/344	136.9 (7)	127.4 (7)	132.1
Kizimbani	185.4 (2)	165.0 (1)	175.2
Machui	193.9 (1)	160.1(2)	177.0
Mahonda	168.5 (4)	150.4 (5)	159.4
Mwari	160.0 (5)	156.4 (4)	149.7
Mean	166.8	149.7	158.3
CV (%)	7.3	11.5	9.6
$LSD_{0.05}$	12.4	17.5	10.69

*No. in brackets indicates the ranking of the variety within the site.

from this study highlight the need to investigate and improve natural resource management options to increase cassava yields. Although the Michikichini site had slightly higher levels of phosphorus, the root yields were poor. This corroborates reports that cassava is highly tolerant of soils with low phosphorus levels and can generally grow even without phosphorus-fertilizer applications because cassava forms a mutually beneficial association with a group of soil fungi called vesicular-arbuscular mycorrhizae (FAO, 7).

Highly significant differences were detected between varieties and sites for plant height. The variety × year interaction was also significant (Table 3). The highest contribution to the total sum of squares was attributed to variety (40.0%) followed by site (12.2%) and variety × year (12.0%). 'Machui' had, on average, the tallest plants (177.0 cm), which were significantly taller than the rest of the varieties, except 'Kizimbani' (Table 6). The Mibunini site had, on average, taller plants (166.8 cm) than Michikichini (149.7 cm), arguably for the same reason it had higher FSY and FRY values.

The analysis of variance revealed highly significant differences among varieties. Significant differences were detected between years. The variety × site, variety × year and site × year interactions were significant. The variety × site × year interaction was highly significant (Table 3). The highest percentage of the total sum of squares was attributed to variety (61%), followed by the variety × site × year interaction (13%). Only the local variety 'Boma', which is susceptible to CBSD, had a significantly higher mean severity score (3.1) than the improved varieties and the other local variety 'Mwari' (Table 7). No differences between sites were detected for root necrosis. It is commonly assumed that plants grown in fertilized soils are healthier than those on poor soils. It has been reported that increasing the organic matter content of the soil lowered CMD severity in experiments carried out in Zanzibar (Spittel and Van Huis, 14). This does not appear to apply to CBSD because the Mibunini site has a slightly higher nitrogen level than Michikichini (Table 2).

Two improved varieties, 'Kizimbani' and 'Machui', produced significantly higher FRYs than the best local variety, 'Mwari'. However, the local variety 'Boma' is preferred by farmers in Zanzibar because it has better fresh consumption qualities than 'Mwari'. 'Boma' which are is highly susceptible to CBSD and farmers had almost abandoned its cultivation by the time this

Table 7. Mean CBSD-associated root necrosis values among cassava varieties evaluated across two sites and three seasons.

Variety	Site		Mean
	Mibunini	Michikichini	
Boma	2.70 (1)	3.5 (1)	3.12
Kama	1.00 (3)	1.12 (2)	1.06
KBH 2002/344	1.25 (2)	1.00 (3)	1.12
Kizimbani	1.25 (2)	1.00 (3)	1.12
Machui	1.25 (2)	1.00 (3)	1.12
Mahonda	1.00 (3)	1.12 (2)	1.06
Mwari	1.00 (3)	1.00 (3)	1.00
Mean	1.36	1.39	1.37
CV (%)	36.90	16.00	28.5
$LSD_{0.05}$	0.51	0.23	0.28

*No. in brackets indicate the ranking of the variety within the site.

study was conducted. It also produces a poor yield. The four released varieties, 'Kama', 'Kizimbani', 'Mahonda', and 'Machui' were superior to 'Boma' in CBSD resistance and yield, and should therefore be promoted to replace it.

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