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Cassava mosaic disease resistant clones' growth and yield are prone to early drought stress

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This study was conducted to evaluate the growth and yield stability of cassava mosaic disease (CMD) resistant breeding populations clones against early drought. Field trials were planted using 200 CMD resistant clones and 7 local landraces in a randomised complete block design with 3 replicates at the International Institute of Tropical Agriculture (IITA) station, Sendusu in Namulonge (Central Uganda) during the second rains of 2006 (2006B) and the first rains of 2007 (2007A). The 2007A crop suffered from drought stress in the first 4 months after planting (MAP). Data were taken on the leaf lobe length and width at 6 MAP and plant height at 12 MAP. Harvest was done at 12 MAP during which the number of storage roots per plant and storage root yield were recorded. Data were analysed using the Mann-Whitney U test to compare crop performance between the 2 seasons. The 2006B crop had significantly ($P<0.01$) longer leaf lobes, taller plant heights, higher number of storage roots per plant and higher storage root yield than the 2007A crop. There was no significant difference in the leaf lobe width. In this experiment, it was observed that the CMD resistant breeding clones were susceptible to early drought and thus it was recommended that selections should be done for higher water use efficiency.

Key words: Abscisic acid, *Manihot esculenta* Crantz, Stomatal conductance, water use efficiency, Uganda.

INTRODUCTION

The importance of cassava production as a source of income and household food security in Uganda (Fermont et al., 2009a) and the rest of sub Saharan Africa's (SSA) cannot be over emphasised. Cassava is widely believed to be a hardy crop against several environmental stresses, including drought (Purseglove, 1968; Onwueme, 1978). However, cassava has been reported to be susceptible to moisture stress especially at critical growth stages (Alves, 2002). This is likely to be a major production constraint in SSA smallholder cassava cropping systems in the near future given the predicted increase in extreme weather events with climate change,

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Table 1. Descriptive statistics for the experimental crop in 2006B and 2007A seasons.

Growth/Yield parameter	Minimum		Maximum		First quartile		Median		Third quartile	
	2006B	2007A	2006B	2007A	2006B	2007A	2006B	2007A	2006B	2007A
Leaf lobe length (cm)	10.3	5.4	25.7	26.0	15.0	14.8	16.3	16.2	18.3	17.7
Leaf lobe width (cm)	2.3	1.5	7.9	8.2	4.4	4.4	4.9	5.0	5.5	5.5
Plant height at 12 MAP (cm)	125.0	65.0	316.7	417.0	193.3	123.0	223.3	148.0	250.0	172.0
No. of roots per plant	0.0	0.0	18.0	13.0	4.0	2.0	6.0	4.0	8.0	6.0
Fresh tuber yield (t ha^{-1})	0.0	0.0	60.0	60.0	8.2	2.5	15.0	7.5	25.0	14.5

prolonged drought inclusive.

Breeding has been identified as a key strategy for controlling crop production stresses, especially in the low input cropping systems of the SSA region. A case in point is the cassava mosaic disease (CMD) pandemic that devastated Uganda's cassava production sector in the early 1990's (Otim-Nape et al., 1997), which was controlled courtesy of CMD-resistant materials developed through national and international collaborative cassava improvement programmes. Over forty thousand accessions have since been introduced and evaluated for resistance to CMD. Tolerance to multiple stresses is highly desirable among elite germplasm. It is thus imperative that future cassava improvement programmes have to draw from the CMD resistant breeding materials. This study compared the growth and yield of CMD resistant breeding clones in Uganda with and without early season drought stress as a way of evaluating their general stability against early moisture stress.

MATERIALS AND METHODS

Study was carried out at the International Institute of Tropical Agriculture (IITA) station in Namulonge (Wakiso district), central Uganda (0.53°N, 32.58°E; 1150 m above sea level). The annual rainfall received in the area averages 1200 mm in bimodal distribution. The first rainy season occurs between March and June, while the second one is between September and December. The soils are characterized as Rhodic Acrisols (FAO system of classification) on slopes averaging 4% in steepness.

320 important CMD-resistant clones were selected. These were subjected to cluster analysis based on disease reaction and yield. From each of the resulting 4 clusters, clones were randomly selected to constitute a total sample of 200 clones in direct proportion to each cluster's numerical size. In addition, 7 local landraces (*Alado-alado*, *Bao*, *Bukalasa*, *Njule*, *Nyaraboke*, *Tereka* and *Tongolo*) were included in the study. The selected clones were planted in the second rainy season of 2006. The spacing used was 1 × 1 m in a Randomized Complete Block Design (RCBD) replicated 3 times. For each genotype, a plot consisted of 10 plants in a row. The total trial area was 6300 m^2 with 2 border rows of genotype TMS I92/0067 (*Akena*). The set up was weeded using hand-hoeing whenever necessary. Neither pest nor disease attack on the crop was controlled. The trial was conducted in the second rainy season of 2006 (hereafter referred to as 2006B) and repeated in the first rainy season of 2007 (hereafter referred to as 2007A).

From the 8 central plants per plot, data were taken on leaf lobe length and width at 6 months after planting (MAP), and plant height at harvest (12 MAP), as described by Ferguson and Kawuki (2006). The number of storage roots per plant was obtained as an average of the total number of storage roots from each of 3 randomly sampled plants per plot. Fresh storage root yield data were taken at harvest, from the 8 middle plants per plot and extrapolated from the plot area to per hectare basis.

Daily rainfall data were obtained from meteorological station about 1 km away from the experimental field. The total rainfall received per month after planting was computed by summation from the daily records. The 2006B crop received a total of 1220 mm compared to 1400 mm for the 2007A crop. Although the 2006B crop experienced drought stress around 5 MAP, it received 164 mm more rainfall than the 2007A crop in the critical first 4 MAP (Figure 1) thus rendering the 2 crops' dataset ideal for the objective of the current study. The 2 seasons leaf lobe length and width, plant height and storage root yield were compared using Mann-Whitney U (Rank Sum) Test in SPSS 11.0.

RESULTS AND DISCUSSION

Based on the median values, the 2007A plants, which suffered early season drought stress, had leaves that were similar in size to those for the 2006B plants. However, the latter were taller, had more storage roots per plant that translated into higher fresh storage root yield than the former (Table 1).

The Mann-Whitney U test confirmed that the 2006B plants had significantly longer leaf lobes and were significantly taller than the 2007A plants. Furthermore, the test also confirmed that the 2006B plants significantly out-yielded the 2007B plants (Table 2).

Over the 2 seasons during which this study was conducted, 75% of the clones gave storage root yields less than 25 t ha^{-1}, with lower yields being recorded in 2007A than in 2006B (Table 1). The yields are within the range reported by Fermont et al. (2009b) in farmers' fields in Uganda, but are below on-station yields reported by Ntawuruhunga et al. (2006). The 2007A crop suffered drought stress early in the growing season (Figure 1), which depressed its aboveground growth, as is reflected in the significantly($P<0.01$) lower plant heights than in 2006B (Table 2) and lower number of storage roots (Table 2). In 2006B, the plant heights were in the range

Table 2. Comparison of the growth and yield parameters of 2006B and 2007A crops.

Growth/yield parameter	Mean rank		z-value	Significance level
	2006B	2007A		
Leaf lobe length	630.7	576.9	-2.679	0.01
Leaf lobe width	601.2	608.0	-0.339	0.73
Plant height at 12 MAP	835.5	347.2	-24.410	0.00
No. of roots per plant	651.6	445.1	-10.704	0.00
Fresh tuber yield	657.5	428.4	-11.835	0.00

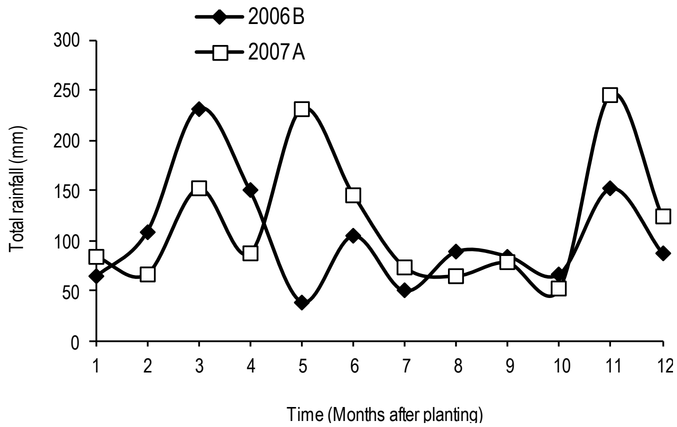

Figure 1. Total rainfall during the seasons 2006B and 2007A in Namulonge, Uganda.

130 to 320 cm (Figure 2). This is comparable to the cassava height range of 120 to 370 cm reported from elsewhere (Ramanujam, 1985; Pinho et al., 1995). In 2007A, 75% of the clones had a height of 130 cm or less.

Drought stress may have reduced both the source supply (that is, the amount of carbohydrates that were available for storage root formation) and the sink demand (that is, the number of storage roots), which resulted into the lower yields observed in the 2007A season. Alves (2002) observed that though cassava is relatively drought tolerant, storage root yield is adversely affected by drought stress within the first 5 months of growth. Connor and Palta (1981) reported that limited soil moisture supply led to lower stomatal conductance, suggesting restricted opening of the stomatal pore. Although this effectively controls further loss of water from the plant and hence maintains the leaf water potential, it comes at the expense of lower assimilate production due to restricted carbon dioxide entry into the leaves. This response has been attributed to the plant stress hormone abscisic acid, with the young leaves accumulating higher concentrations of the hormone than older leaves when water stressed (Alves and Setter, 2000). Cellier et al. (1998) reported genotypic differences in plant sensitivity to the hormone. This suggests that breeding approaches can be employed to improve water use efficiency in cassava so as to attain higher levels of drought tolerance.

CONCLUSION AND RECOMMENDATION

The clones exhibited sensitivity to early drought stress with serious yield decline. Since the clones are used regionally in cassava breeding programme, it is important for future work to focus on selecting for higher water use efficiency and hence drought tolerance, besides resistance to the biotic stresses for which they were developed.

Conflict of Interests

The authors have not declared any conflict of interests.

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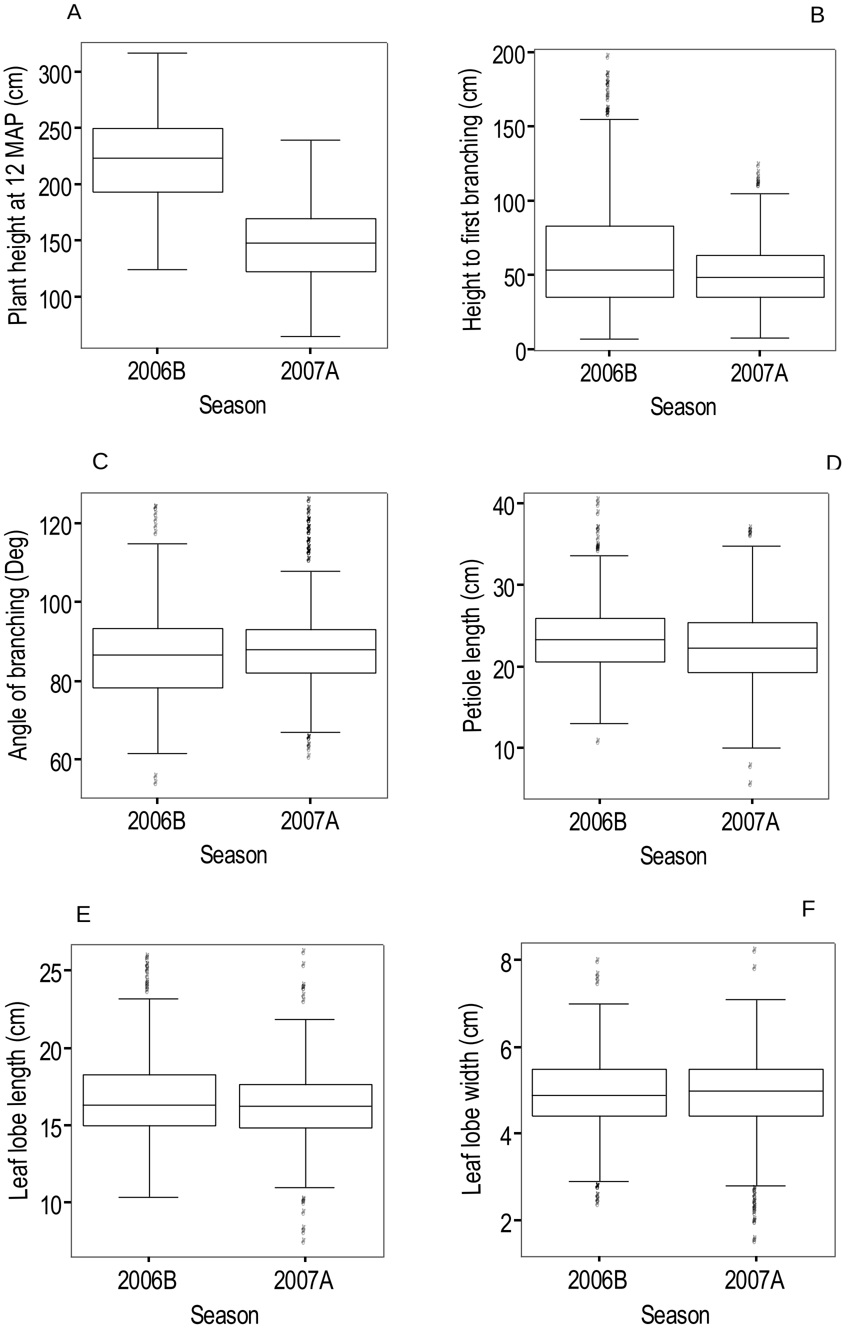

Figure 2. Comparison of cassava plant height (A), height to first branching (B) angle of branching (C), petiole length (D), leaf lobe length (E) and width (F) between seasons in Namulonge, central Uganda.

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