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Screening sweetpotato genotypes for tolerance to drought stress

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ABSTRACT

Soil moisture stress due to drought results in low storage root yield of sweetpotato. Eighty-four sweetpotato clones were evaluated at Kenya Agricultural Research Institute (KARI), Kiboko and Thika between May 2011 and September 2012 for drought tolerance. A split plot design with drought stress and no drought stress conditions as whole plots, and clones as subplots, arranged in a 14 × 6 alpha lattice design with two replicates repeated in two seasons was used. Approximately 30 cm long vine cuttings of each clone were planted 10 cm deep on 25 cm high beds, in single rows of 6 hills spaced at 30 × 90 cm. The field study was also validated in screenhouse box experiments at KARI-Muguga. Data on growth and yield characteristics were recorded and analysed using SAS 9.2 edition. Across sites, data indicated that genotype, environment, and their interaction significantly differed for fresh storage root weight (FSR) (kg plant^{-1}), total fresh biomass weight (FB) (kg plant^{-1}), marketable fresh storage root weight (MFSR) (kg plant^{-1}), harvest index (HI) and chlorophyll content (CC) (8.47%) at ($P \leq 0.05$). Comparing data from both environments, drought stress caused a reduction of FSR (59.3%), FB (72.1%), MFSR (75.5%), NSR (25.6%), but seemed to increase percent root dry matter (%RDM) (−0.29%), and HI (−26.6%). Clones 194555.7, Unawazambane06-01, 189150.1, Tanzania, Chingova, W119, 441725, and Xiadla-xa-kau, had ≥75 days to permanent wilting point (DPWP), drought stress index (DSI) <1 and high FSR yield under drought stress and no drought stress conditions. These clones may be used in a drought tolerance breeding programme. Clones that had low DSI values, also had low FSR yield difference under drought and no drought environment, indicating they were drought tolerant, but had less DPWP. However, high yielding clones under no drought, also had relatively high yield difference between drought and no drought environments, and high DSI values, which implied less drought tolerance. Thus, DPWP demonstrates high discriminative power to identify clones with both drought tolerance and improved yielding ability, especially in root crops such as sweetpotato, which occasionally produce pencil roots instead of edible storage roots even under adequate moisture conditions.

1. Introduction

The increasing population pressure in developing countries has led to increased human activities leading to reduction of agricultural land (Kiage, 2013; VÃgen-Tor et al., 2013). This has led to an expansion of agricultural activities to arid and semi-arid lands (ASALs). These ASALs have frequent droughts resulting in low crop production (Amede et al., 2004). Thus, a remedy for the low crop production in ASALs due to drought stress is urgently required. The most common interventions are water application through irrigation and breeding for drought tolerant crops. The latter approach is more appropriate for sweetpotato farmers in sub Saharan Africa, as it is not capital intensive.

Water or drought stress affects photosynthesis and translocation of assimilates (Mundree et al., 2002), with extreme drought stress leading to crop death. However, some plants have devised mechanisms of tolerating the drought stress to some extent through escape, avoidance, tolerance, or recovery of drought (Cruz De Carvalho, 2008; Ekanayake, 1990). A drought tolerant genotype produces economically good yield under soil moisture stress. Therefore, drought tolerant sweetpotato genotypes should be able to produce higher quantity and quality of yield in the absence of sufficient rains and irrigation compared to other

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genotypes. These drought tolerant genotypes may be identified through screening of germplasm under managed drought stress conditions.

The yield of most crops has been used as an indicator for the capacity to tolerate moisture stress (Anjum et al., 2011). For example, drought stress in sweetpotato reduces both the quantity of storage root yield and above ground vine (foliage) and their respective quality (Mundree et al., 2002). It is against this background that the screening of sweetpotato genotypes under drought and non-drought conditions in this study was conducted.

Several studies have been conducted by other researchers who used different parameters or methods to evaluate drought tolerance in sweetpotato. Anselmo et al. (1998), evaluated local high yielding sweetpotato germplasm in Sweden based on the marketable storage roots yield and were able to distinguish genotypes with drought tolerance. Heerden et al. (2008), on the other hand, reported that drought stress reduced photosynthesis, above ground biomass, and yield of genotypes A15 and Resisto evaluated, but photosynthesis per unit area reduction was more in the less tolerant genotype Resisto. Laurie et al. (2004) used a rapid drought screening box method by planting about 15 cm long vine cuttings of the sweetpotato clones in boxes filled with sterile media and media moisture maintained at field capacity up to 15 days after planting after which irrigation water was withheld. Based on rapid drought screening box method, they identified W119 as tolerant, Excel as neutral to tolerant, A15 as neutral, Resisto as neutral to susceptible and Bosbok as susceptible. Based on field evaluation, Maquia et al. (2013) also reported that the genotypes Chingova, Naspot 5, SPK 004, and Resisto were drought tolerant.

However, no research has been conducted to determine sweetpotato drought tolerance using a combination of different soil moisture regimes and days to permanent wilting point using rapid screening techniques. Since only about 20% of the land in Kenya receives adequate rainfall, there is great need for the development of drought tolerant crops including sweetpotato (Jaetzold et al., 2006). Thus, identification of sources of drought tolerance from the locally adapted clones and other germplasm from the region would be useful for establishing a sweetpotato breeding programme. The aim of this study was therefore to identify drought tolerant sweetpotato clones from those obtained from the Kenyan gene bank, smallholder farmers in Kenya and International Potato Centre (CIP) in Nairobi.

2. Materials and methods

2.1. Description of sites

Field experiments were conducted at two sites; Kenya Agricultural Research Institute (KARI)-Kiboko, and KARI-Thika, while the greenhouse experiment was conducted at KARI-Muguga. The KARI-Kiboko research station is located 2°15′S, 37°45′E and 993 m above sea level (m asl) in Makueni county, 187 km east of Nairobi, Kenya. The research station is classified under agro-ecological zone five and receives mean annual rainfall of 560 mm with long-term annual average rainfall of 615 mm and is ideal for dry land research (Jaetzold et al., 2006). It also receives bimodal rainfall with the more reliable short rains falling in late October to December (330 mm), and the poor long rains from March to May (230 mm). The annual mean maximum temperature is 30.6 °C, while the annual mean minimum temperature is 17.4 °C, which translates to an annual mean temperature of 24 °C. The soils are of rhodic ferrasols to ferric luvisols on the old peneplain and eutric fluvisol at the bottom of the river valley (Mwacharo et al., 2004).

KARI-Thika is located 0°59′S, 37°04′E and 1548 m asl, 75 km north east of Nairobi, Kenya with well drained ferric luvisols. The area receives bimodal mean rainfall of about 900 mm annually with long rains of 500 mm falling from March to May and the short rains of 400 mm falling in October to December. The areas has minimum temperature of 13.7 °C, maximum of 25.1 °C, and mean annual temperature of 19.4 °C (Ndegwa et al., 2009).

KARI-Muguga is located 1°13′S, 36°38′E, and 2096 m asl 27 km north west of Nairobi, Kenya. The area receives bimodal mean rainfall of 900 to 1000 mm annually with long rains of 550 mm falling in mid-March to June and the short rains of 400 mm falling in mid-October to December. The area has minimum temperature of 7 °C and maximum of 20 °C, which translates to 15 °C. The area is classified as sub humid with a well-drained, very deep, dark reddish brown to dark red, friable clay soil classified as humic nitisols (UNESCO, 1977) or an oxicpaleustaf (USDA, 1975).

2.2. Sweetpotato germplasm

The germplasm consisted of 84 sweetpotato genotypes sourced from the gene bank of Kenya, the International Potato Centre (CIP) Nairobi, and farmers' fields. The genotypes were selected on the basis of high yield, orange fleshed sweetpotato (OFSP), high dry matter, early maturity, drought tolerance, and sweetpotato virus disease (SPVD) resistance. The germplasm was multiplied in the greenhouse at KARI-Muguga to increase the planting materials. The genotypes Marooko and Gatumbi were obtained from the National Gene Bank of Kenya (NGBK) and used as local checks.

2.3. Field evaluation

The trials were planted when the rains had subsided at KARI-Kiboko in October 2010 and repeated for another season in April 2011, and at KARI-Thika in May 2011 and repeated in December 2011 (Fig. 1a and b). A split plot design was used with irrigation as the main plot and clones as subplots arranged in a 14 × 6 alpha lattice and replicated twice. The genotypes were planted on 25 cm high beds in single rows of 10 plants per plot at a spacing of 30 cm between plants and 90 cm between rows. Each row was separated by one meter planted with two plants of a clone with different vine and root skin colour, to ensure uniform competition within the rows. Distinct clones with coloured vines and roots were planted in four guard rows surrounding the outer rows of the experiment. Six tensiometers were installed in each replication, two at each of the following soil depths; 20 cm, 40 cm and 60 cm to monitor soil moisture content and determine when to irrigate. Vines used for planting were about 25 cm long and had 4–6 nodes. The vines were planted in a 60° slanting position and kept at field capacity soil moisture levels for four weeks until they were established. Thereafter, the drought stress environment received no irrigation water until harvesting, while the irrigated environment received 35 mm equivalent irrigation water every time the tensiometer read 15 cb. The amount of irrigation water was collected and measured using rain gauges and cumulative irrigation water quantified to mm of rainfall.

Soil analysis was conducted before planting to determine nutrient status of the trial site and moisture content (Table 2). Double ammonium phosphate fertilizer was applied during planting at the rate of 50 kg P_2O_5 ha^{-1}, while weeding was done by hand hoe twice in each experiment. The centrally placed six hills were used to collect data leaving two hills each side of the row.

Data on morphological traits were collected following IPGRI (Bioversity) descriptors (CIP et al., 1991). Storage root harvesting was done 150 DAP using hand hoes and data collected on the six plants centrally placed in the rows. Data collected included:

- Number of storage roots (NSR)—a count of storage roots $plant^{-1}$.
- Number of marketable storage roots (MSR)—a count of storage roots weighing between 100 and 500 g $plant^{-1}$.