Breeding for Drought Tolerance

SASHA Sweetpotato Action for Security and Health in Africa

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Breeding for drought-prone environments is truly challenging as adaption to drought can be achieved through drought escape, drought avoidance or drought tolerance. In Mozambique, vine vigor has proved to be an essential and straightforward trait to select for.

Technician at the crossing block in Umbeluzi (credit J. Low)

There is tremendous genetic variability in sweetpotato and the crop can exploit three strategies to adapt to drought. Early maturing varieties take great advance of the initial rains to complete their most sensitive developmental stages. This is drought escape. Drought avoidance occurs when the plant can reduce evapotranspiration without affecting yields or has a very deep rooting system to extract water from the deep soil layers. Deep rooting varieties are also able to avoid weevil infestation, which is highly associated with the cracked soils caused by drought. Mechanisms which result in maintaining assimilation (absorption of nutrients) under reduced leaf relative water content are categorized as drought tolerance. In general, progress in research for drought tolerance has been slow due to its complexity and until recently, lack of investment in breeding for this important abiotic trait.

Until to 2005 in Mozambique, all the varietal selection efforts concentrated on adaptive trials with introduced materials often susceptible to drought. In this light, it is important to understand the mechanisms of drought adaptation and to search for drought-tolerant clones adapted to the drought-prone regions of Africa.

What is the problem?

The Southern Africa region is particularly susceptible to climate variability and drought. Most sweetpotato grown by smallholder farmers is under rain fed conditions. Sweetpotato needs adequate water supply at planting and for several weeks thereafter. Early season drought affects storage root initiation and frequent exposure to drought causes decline in yield, weevil infestation and serious shortages of planting material.

What do we want to achieve?

Beginning in 2006, our goal was to demonstrate the ability to produce drought tolerant varieties using the accelerated breeding scheme (ABS) in only 4 years. The details of how ABS works is described in a separate brief. We also aimed to better understand some of the mechanisms underlying the drought tolerance and to identify effective quick screening methods for drought tolerance by evaluating sweetpotato breeding lines/varieties/landraces for drought adaption and to select and develop OFSP germplasm for Southern Africa and potentially other drought-prone areas.

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SPHI Sweetpotato for Profit and Health Initiative
Reaching 10 million African households by 2020

Partners include:

- IIAM (Instituto de Investigação Agrária de Moçambique)
- DNSA (Direcção Nacional de Serviços de Agrários)
- UEM (Universidade Eduardo Mondlane)
- ISPG (Instituto Superior Politécnico de Gaza)
- FAC (Faculdade de Agricultura de Cuamba)
- NGOs (World Vision, ADRA)
- Individual smallholder farmers, commercial farmers, farmer associations and industries

Released varieties displayed at annual agricultural fair in 2013 (credit M. Andrade)

What's next?

During SASHA Phase 2 (2014-2019), drought resistance will be combined with adequate response to rain so that 10% (using traditional population improvement) to 20% (using hybrid populations) of the breeding material show this desired attribute in drought prone regions. We will validate heterosis in drought resilient gene pools. In 2014, 5,242 genotypes are to be planted under irrigated and non-irrigated conditions for the heterosis study. By early 2015, the next round of drought tolerant varieties bred using ABS will be released, including the first purple-fleshed (anthocyanin-rich) sweetpotato variety in Africa. In-ground storage and re-sprouting ability will be included as selection traits in the breeding program. By 2018, we anticipate have the iron content sufficiently high enough in OFSP to conduct multiple meal feeding trial to assess the bioavailability of that iron.

CONTACTS
Maria Andrade (CIP)
m.andrade@cgiar.org
Jose Ricardo (IIAM)
j.ricardo1999@yahoo.com.br

Testing using polyethylene glycol for quick drought screening in Kenya (credit J. Low)

Our objective under the Sweetpotato Action for Security and Health in Africa (SASHA) project is to develop improved breeding methods and establish efficient population improvement programs for drought at Southern Africa sweetpotato support platform (SSP) linked with participatory varietal selection at the national level by providing NARS breeding programs with improved true-seed populations to select new varieties as well as better parents for their own breeding programs. Crossing blocks established in two sites (Umbeluzi and Gurué) with distinct characteristics help to create sufficiently variability within the germplasm. By sharing true seed with national programs, trait selection can be carried out in a broad range of agro-climatic settings.

In addition, the Southern Africa SSP breeding program, which is based at the Instituto de Investigação Agrária de Mocambique (IIAM) in Maputo, Mozambique, is actively linked to the capacity building activities to improve tissue culture laboratory functioning and produce quality pre-basic and foundation planting material management systems.

Where are we working?

The main breeding sites in Mozambique are in Maputo, Gaza, and Zambézia provinces, however, the provinces, Tete, Niassa, and Manica are involved in on-farm trials (OFTs) . In Kenya, the drought field work was undertaken at Kenya Agriculture Research Institute Kiboko and Marigat sub-stations and the laboratory work at the Kenya Plant Health Inspection Service in Muguga.

How are we making it happen?

There were four major activities (the first 3 in Mozambique; the last in Kenya):

1) **Breeding trials were conducted concurrently across agro-ecological zones in Mozambique** that always included one site where the materials were highly likely to be stressed by drought. Crossing blocks were established in two sites to generate genetic variation and distribute seeds to the NARS. Three sets of experimental materials were evaluated for their performance under drought stress.
2) **A study to determine the genetic by environmental interactions (G X E) for yield and the quality traits in drought environments.** The first set of 58 clones (selected from farmer's fields and different advanced yield trials) was tested in 2005 in two environments (with and without irrigation) at Umbeluzi Research Station (URS) for two cropping seasons. Owing to the results in 2006 – very strong G x E interactions due to irrigation treatments–the drought study for a second phase was continued at URS comprising the dry season in 2008 and 2009.
3) **A study to determine associations among yield under drought stress levels in relation to yield stability** and harvest index (root weight/total roots plus foliage weight) stability
4) **Identification of quicker screening methods** to identify clones with drought tolerance

To achieve our breeding goals in Mozambique, a large number of trials have to be conducted in collaboration with national partners. Those conducted under SASHA Phase 1, including the amount of seed collected are summarized in Table 1.

Table 1: Breeding trials conducted from 2009/10 season through 2013/2014 season in Umbeluzi, Chókwè, Manica (6 districts OFT), Niassa (8 districts OFT), and Gurue, Mozambique

Indicator/year	2009/10	2010/11	2011/2012	2012/13	2013/2014	Total
Nr trials established	83	116	82	68	60	409
Nr OFT	206	171	41	40	139	596
Nr Clones evaluated	40,000	13,769	18,834	11,926		84,529
Nr Seeds collected	114,786	70,786	132,654	210,681	124,741	653,657
Nr Variety released	3		15			18
Nr potential Clones for variety release in 2012, 2013 and 2014				77	25+32	134

Additionally, the Near Infrared Spectrometer (NIRS) quality laboratory was established to assist in the selection at observational trial (OT) stage and later for clones with adequate micronutrient (beta-carotene, iron, zinc) and dry matter content.

What have we achieved so far?

The most important achievements so far include:

1) The release of 15 more drought tolerant orange-fleshed sweetpotato varieties in February 2011 in Mozambique represent the first demonstration of sweetpotato varietal development using the accelerated breeding scheme in SSA;
2) The breeding program at the SSP is linked to a number of efforts on the capacity building in the area of improvement of tissue culture laboratory capacity and the establishment of a quality laboratory based on the use of a Near Infrared Spectrometer to quickly determine nutrient composition, the output of which is shown in Table 2;
3) The vine survival trait is a highly heritable;
4) More than 200,000 drought adapted population seed disseminated as true seed to national sweetpotato breeding programs from 12 SSA countries;
5) As expected, yields of roots, vine yield, and biomass overall were lower under drought. High yielding genotypes, however, were observed in both treatments. Harvest index stability might be a key trait to identify clones with yield stability under drought. Some cultivars tolerant to drought did not suppress the above ground biomass accumulation during restricted water supply compared with cultivar susceptible to drought;
6) For the drought study there was very strong G x E interactions due to irrigation treatments, indicating that population improvement for drought must be carried out separately from a program aiming at humid zones. However, it is important that clones identified as drought tolerant also perform well under adequate rainfall conditions. This needs to be kept in mind when designing drought selection protocols;
7) As a fast throughput method, in vitro screening using polyethylene glycol salt was found to be efficient and simple enough to select for drought tolerance in sweetpotato. Salt tolerance is associated with drought tolerance in sweetpotato.

Table 2: Outputs from the work conducted in the tissue culture (TC) and quality laboratory from 2010 to 2014

Indicator/year	2010/11	2011/2012	2012/13	2013/2014	Total
Nr plantlets multiplied (lab)	6,441	8,993	14,489	22,896	52,819
Nr plantlets virus free (lab)	3,246	3,959	1,824	950	9,979
Nr plantlets hardened	696	234	614	612	2,156
Nr Sample processed (NIRS)	1,121	5,029	9,552	9263	24,965
Nr Sample analyzed (NIRS)	820	5,029	8,492	4353	18,694

Breeder Maria Andrade in greenhouse with 15 OFSP varieties maintained (credit A. Naico)