Expanded and Sustained Uptake of the Accelerated Breeding Scheme (ABS) Approach

SASHA
Sweetpotato Action for Security and Health in Africa

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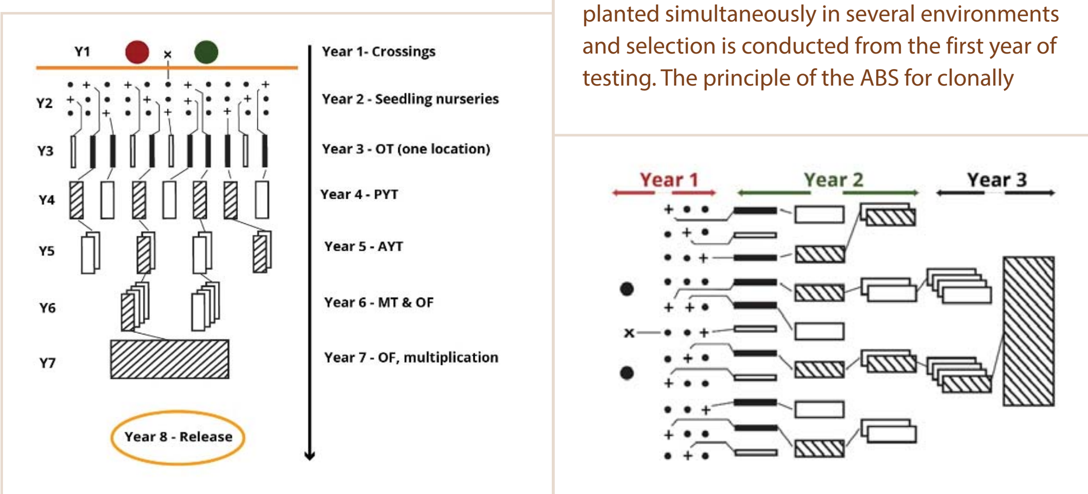
A major milestone in sweetpotato breeding progress was achieved in 2016, with the release of the second cycle of varieties bred in Mozambique using the Accelerated Breeding Scheme (ABS) approach.

Background

The most important constraints to sweetpotato production in Sub-Saharan Africa (SSA) are shortage of high quality planting material and lack of improved OFSP varieties. The conventional breeding approach followed for decades by breeding programs starts with population development (generation of genetic variation through production of botanical seed) and ends with selection of the "best" individuals in the breeding population and variety release. This conventional breeding approach illustrated in Fig. 1 takes 7 to 8 years to release a variety. From our findings and the pressure to make a difference in farmers' lives faster, variety release via the 'conventional' breeding scheme is no longer adequate.



Conventional breeding scheme

Accelerated breeding scheme

Fig. 1. Conventional (left) and accelerated (right) sweetpotato breeding schemes[1]

The first step in the breeding of clonally propagated crops, **crossings**, is to produce botanical seeds. Each botanical seed has a unique genetic makeup qualifying it as a potential new variety. From this point onwards, there will be further genetic change in the plant/vines arising from the botanical seed apart from natural mutations. Gruneberg *et al.* (2007) designed a scheme tailored to release improved varieties in a shorter timeframe than conventional breeding, known as the 'Accelerated Breeding Scheme' (ABS) (Fig 1). The ABS for sweetpotato considers that *temporal* variation of testing environments equals to *spatial* variation of testing environments in the early stages of a breeding program. In the ABS, all clones derived from true seeds are, therefore, planted simultaneously in several environments and selection is conducted from the first year of testing. The principle of the ABS for clonally propagated crops is to accomplish simultaneously the steps that conventional breeding schemes accomplish over several years. In the ABS, selection of parents, the crossing step, seed collection from crossing blocks and establishment of the seedling nursery are accomplished in the first year.

1. OT: Observational Trial; PYT: Preliminary Yield Trial AYT: Advanced yield trial; MT: Multi-locational trials; OF: On-farm trials

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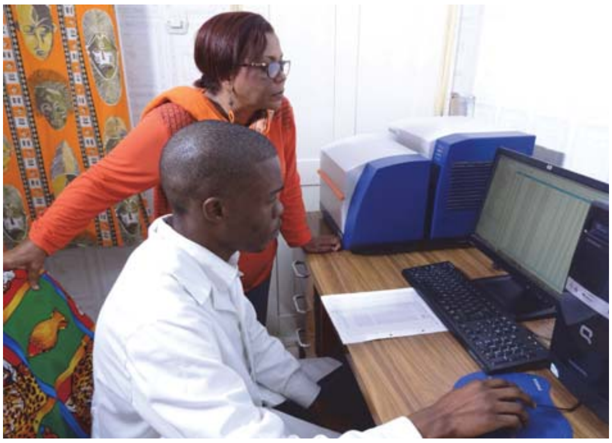

Fig 2. Reading of the NIRS in Maputo quality laboratory 6 (credit G. Makunde)

Observation trials (OTs) commence in the second year by simultaneous planting of all genotypes in the seedling nursery in two to four distinct environments using non-replicated 1 meter plots (3 plants). The Near Infrared Spectrometer (NIRS) is employed to rapidly assess the selected clones for quality traits – including beta-carotene, iron, zinc, protein, starch and sugars (Fig 2). The selected genotypes with satisfactory root yield, form, taste, flesh color and other agronomic data are promoted to preliminary yield trials (PYTs) and subsequently advanced yield trials (AYTs) during the second year. PYTs and AYTs have bigger plot sizes and replicated across environments to assess storage root yield, above ground biomass and storage root quality in years 2 and 3. Multi-location trials (MTs) as well as on-farm trials are simultaneously carried out in the third year across diverse locations for the selected genotypes. Following this scheme, all the crucial agronomic data necessary for cultivar release is available by end of year four.

The first evidence from the Accelerated Breeding Scheme

The ABS was first applied at CIP-HQ, Peru in 2005 where variance component and heritability estimates in early breeding stages were determined. In April 2010, in collaboration with the national program INIA in Peru, the first four ABS bred varieties were released: **Adriano** (CIP 105228.1), **Alexander** (CIP 105240.1), **Arne** (CIP 105086.1) and **Benjamin** (CIP 105085.2). The four varieties were evaluated in OTs in 2006 in several environments in small unreplicated plots.

Adoption of the Accelerated Breeding Scheme in Sweetpotato breeding in Mozambique

Since 2005, two recurrent selection cycles have been conducted using ABS, with the release of 14 varieties in 2011 and 7 additional varieties in 2016.

Seed for the third generation cycle (G3) varieties were generated in 2011 and by 2014 selection of 76 clones with potential for release was done. Further selections were done under multi-locational and on -farm trials and nine were recommended for release by 2015. In February 2016, seven varieties (third generation – G3) were released: **Alisha** and **Ivone** (OFSP); **Lawrence** and **Victoria** (dual-purpose orange-fleshed sweetpotato); **Bie, Bita** and **Caelan** (Fig 3) (purple-fleshed sweetpotato). Testing for all the clones is ongoing at three or four mega-environments in Mozambique (Fig. 4). All these varieties can be traced back to true botanical seed derived either from an open-pollinated polycross breeding nursery or a biparental crossing block. All the released varieties are at different multiplication stages across Mozambique and are promoted by various partners and governmental departments.

Fig. 3. One of the released purple-fleshed varieties in February 2016 in Mozambique (credit G. Makunde)

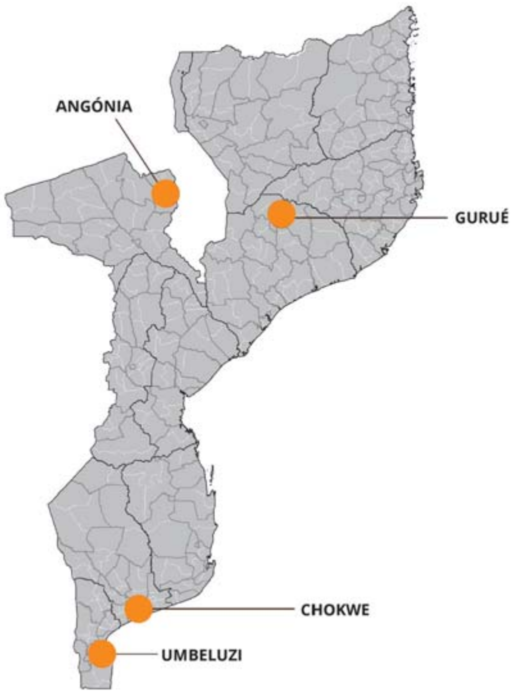

Fig. 4. Main breeding and testing sites for sweetpotato in Mozambique. The G3 varieties were not evaluated at Angonia due to logistic reasons.

First and second cycle of field experiments – setup and methods

Between August 2005 and December 2009 for the first cycle, a crossing block, 118 trials established with 139,508 clones evaluated using the ABS gave rise to 59 different AYTs planted at Umbeluzi, Chokwe, Angonia and Gurue (Table 1). The second cycle ran from January 2011 to 2014. 30,836 clones were generated from the crossing blocks (Fig 5) which were established at Umbeluzi and Gurue and evaluated. 76 best clones entered the MTs and on-farm trials (Table 2).

Table 1. Trials for the first cycle varieties established from August 2005 to December 2009 at Umbeluzi, Chokwe, Angonia and Gurue. 15 varieties were released from these trials – with Gloria (farmer variety) not being traced back to the crossing block.

Type of sweetpotato trial	N°. of trials	Number of seeds/genotypes
Seedling nurseries	22	139,508
Clonal	16	26,149
Preliminary yield trials	21	3,218
Advance yield trials	59	1,258
	118	**139,508**

Table 2. Trials for the second cycle varieties established from January 2011 to 2014 at Umbeluzi, Chokwe and Gurue. Seven varieties were released in February 2016 from these trials.

Year	2011/12	2012/13	2013/14	2014/15	Total
N°. of trials established	82	68	4	-	154
N°. of on-farm trials established	-	-	88	-	88
N°. of clones evaluated	18,834	11,926	76	76	30,836
N°. of clones for multilocation trials	-	-	-	76	76

Fig. 5. Dr. Maria Andrade in the crossing block at Umbeluzi during a monitoring and capacity building program, July 2016 (credit G. Makunde)

From the selection process carried out during the first cycle trials – 64 best clones emerged from the 59 AYTs and were tested in MTs and on-farm trials at the main agricultural stations and their neighbouring villages in four distinct environments (Fig 4). In the second cycle, 76 best clones were selected for MTs and on-farm trials at Umbeluzi, Chokwe and Gurue including their neighbouring villages.

The experimental design for the MTs was randomised complete block design (RCBD) with four replicates; net plots had four rows each row with 23 plants. The measured traits were storage root yield (t/ha); dry matter (%) and beta-carotene (mg/100gDW); cooked taste (scale of 1 – 5 where 1 = very bad, 2 = bad, 3 = average, 4 = good and 5 = excellent); virus and weevil damage as well as vine vigor. In all the analysis, a principal component was conducted to ensure all attributes used in the selection process were accounted for.

Performance of the released varieties (G2 and G3)

The agronomic performance across multilocation sites of the G2 and G3 varieties are presented in Tables 3 & 4 respectively. Purple-fleshed varieties showed high anthocyanin and suitable sensory quality equal or even better than that of the cultivar checks (Chingova and Jonathan). Melinda had the largest total (27.1 t/ha) and marketable (21.1 t/ha) storage root yield across environments among the G2 varieties. Tio Joe and Erica showed the highest beta-carotene content and above average taste. Jane and Amelia had the best taste among the G2 varieties.

Table 3. Storage root yield (SRY), total biomass, dry matter (DM), beta-carotene, iron (Fe) and zinc (Zn) content, and starch of sweetpotato bred varieties from an orange-fleshed breeding population that was evaluated at four sites (Angonia, Chokwé, Gurué and Umbeluzi) in Mozambique, 2009 to 2011.

Variety	Storage Root Yield (t/ha)	Vine vigor (scale 1-9) 1-None, 9-excellent	Total biomass (t/ha)	Dry matter (%)	Beta-carotene	Iron	Zinc	Starch (%)
					(mg/100gDW)			
AMELIA	17.3	7	40.1	31.7	15.9	1.8	1.4	61.3
BELA	25.9	5	30.3	26.8	29.1	2.0	1.5	57.7
CECILIA	18.3	5	39.0	27.5	21.4	1.7	1.3	64.0
DELVIA	23.4	7	37.8	32.8	5.9	1.7	1.3	68.3
ERICA	16.7	6	44.0	24.8	23.9	1.7	1.2	54.7
ESTHER	18.6	2	5.1	26.4	10.5	1.6	1.1	53.5
GLORIA	14.9	5	16.8	31.5	24.6	2.0	1.4	62.5
ININDA	22.2	8	48.6	27.4	13.1	1.9	1.4	64.2
IRENE	19.6	7	30.9	28.6	7.7	1.9	1.5	62.4
JANE	21.2	5	18.6	28.5	26.8	1.7	1.3	62.3
LOURDES	18.3	5	34.4	25.5	30.5	2.0	1.5	56.2
MELINDA	27.1	7	41.3	25.2	10.5	1.7	1.3	61.1
NAMANGA	19.3	5	28.8	26.1	32.8	1.9	1.4	56.9
SUMAIA	21.6	6	43.0	25.9	28.2	1.9	1.4	61.3
TIO JOE	20.0	6	37.5	25.8	38.4	2.1	1.4	52.3
Mean	20.3	6	33.1	27.6	21.3	1.8	1.4	59.9
Min.	14.9	2	5.1	24.8	5.9	1.6	1.1	52.3
Max.	27.1	8	48.6	32.8	38.4	2.1	1.5	68.3

Table 4. Storage root (SRY) and foliage yields (FY), dry matter (DM), harvest index, beta-carotene (BC), iron (Fe) and zinc (Zn) content, and taste of sweetpotato bred varieties from a breeding population that was evaluated at three sites (Chokwé, Gurué and Umbeluzi) in Mozambique, 2011 to 2014.

Variety	SRY (t/ha)	FY (t/ha)	DM [z] (%)	HI [y]	BC	Fe	Zn	Taste [x]
Caelan	17.8	30.9	36.2	0.32	-	1.30	0.86	2.92
Bie	17.5	18.5	27.9	0.46	-	1.50	0.98	2.92
Bita	14.4	28.9	36.6	0.33	-	1.61	1.03	2.00
Lawrence	17.2	12.3	31.0	0.59	20.16	1.81	1.22	2.42
Victoria	16.6	17.0	24.6	0.49	19.37	2.14	1.45	2.67
Alisha	17.7	20.5	29.4	0.45	24.94	1.95	1.29	3.08
Ivone	18.0	24.7	25.6	0.39	27.56	1.63	0.97	3.00
Mean	**17.0**	**21.8**	**30.2**	**0.4**	**23.0**	**1.7**	**1.1**	**2.7**

z Dry matter content (DM, %) was calculated using dry weight as a percentage of fresh weight by taking a sample of about 100 g after bulking three roots and oven drying at 70o C for 72 hours.
y Harvest index was computed as a percentage of root yield over biomass yield (Root yield/root yield + vine yield).
x Root cooking taste (COOT1) with the aid of a 1–5 scale, where 1 = very bad, 2 = bad, 3 = average, 4 = good and 5 = excellent.

It is of note that since 2009, national programs in Burkina Faso, Kenya, Malawi, Mozambique, Rwanda, Uganda and Zambia have released improved sweetpotato varieties following the ABS. Thus, even though the method is management and resource intensive, national programs with grant funds of approximate 60,000 USD/ year were able to successfully apply ABS.

Contrasts among breeding cycles

Notable differences are in dry matter content among the breeding cycles (Table 5). G3 has significantly higher dry matter than the other two generations. The beta-carotene content and the starch levels are also higher in G3 than the other generations.

Table 5. Summary of the most important results from the first generation – conventional breeding release (G1), the first generation of ABS (G2) and the second generation of ABS (G3)

Main attributes									
Statistic	**Total root yield** (t/ha)			**Beta-carotene** (mg/100 DW)			**Dry matter content** (%)		
	G1	**G2**	**G3**	**G1**	**G2**	**G3**	**G1**	**G2**	**G3**
Average	14.7	20.3	17.0	-	21.3	23.0	23.5	27.6	30.2
Min.	2.5	14.9	11.4	-	5.9	13.8	17.2	24.8	21.0
Max.	29.3	27.1	28.0	-	38.4	68.2	27.5	32.8	33.4

Other quality attributes									
Statistic	**Starch** (%)			**Iron** (mg/100 g DW)			**Zinc** (mg/100 g DW)		
	G1	**G2**	**G3**	**G1**	**G2**	**G3**	**G1**	**G2**	**G3**
Average	-	52.3	54.2	-	1.8	1.7	-	1.4	1.1
Min.	-	59.9	47.2	-	1.6	1.5	-	1.1	1.0
Max.	-	68.3	69.4	-	2.1	2.3	-	1.5	1.7

Assessment of beta-carotene, starch, iron and zinc was started in 2011 with the availability of the NIRS machine in Maputo, Mozambique. G1: Varieties released in 2000 before the advent of the accelerated breeding scheme; G2: varieties released in 2011 adopting the accelerated breeding scheme; G3: varieties released in 2011 adopting the accelerated breeding scheme.

Conclusions

In summary, the ABS reduced the time of development of 22 varieties that were released and recommended for production in different areas of Mozambique. These released cultivars combined high levels of beta-carotene, acceptance by consumers and high storage root yield in various sweetpotato-producing areas of Mozambique. The likelihood is high that the ABS will lead to significantly faster breeding progress in national agricultural research systems that are adopting the ABS for sweetpotato. As mentioned before, the ABS enhances the efficiency of selection within a given population and timeframe and is not responsible for high population means of traits. The heterosis exploiting breeding schemes (HEBS) can be utilized for high performance. The ABS and HEBS together appear to be the best tools offered by selection theory to enhance breeding in sweetpotato in this and the decade to come.

References

Maria I. Andrade, Abilio Alvaro, Joana Menomussanga, Godwill S. Makunde, José Ricardo, Wolfgang J. Grüneberg, Raúl Eyzaguirre, Jan Low, Rodomiro Ortiz. 2016. Alisha', 'Anamaria', 'Bie', 'Bita', 'Caelan', 'Ivone', 'Lawrence', 'Margarete' and 'Victoria' sweetpotato. HortScience 51 (5):597-600

Maria I. Andrade, José Ricardo, Abdul Niaco, Abilio Alvaro, Godwill S. Makunde, Jan Low, Roberto Ortize, aand Wolfgang J. Grüneberg. 2016. Release of orange-fleshed sweetpotato (*Ipomoea batatas* [l.] Lam.) cultivars in Mozambique through an accelerated breeding scheme. In press. Journal of Agricultural Sciences, Cambridge.

Gruneberg W.J., R. Mwanga, M. Andrade and J. Espinoza. 2009a. Selection methods Part 5: Breeding clonally propagated crops. In: Plant Breeding and Farmer Participation (S. Ceccarelli, E.P. Guimaraes and E. Weltzien, eds). FAO, Rome, pp 275-332.

Gruneberg W.J., F Diaz, Eyzaguirre, G., Burgos, T. Zum Felde, M. Andrade, R. Mwanga.2009b. Heritability estimates for accelerated breeding scheme for clonally propagated crops- using sweetpotato as a model. Proceedings of the 15th International ISTRC Symposium: Tropical Roots and Tubers in a Changing Climate: A critical Opportunity for the World, CIP, Lima, Peru, November 2-6, 2009.

Gruneberg, W.J., D. Ma, R.O.M. Mwanga, E.E. Carey, K. Huamani, F. Diaz, R. Eyzaguirre, E. Guaf, M. Jusuf, A. Karuniawan, K. Tjintokohadi, Y.S. Song, S.R. Anil, M. Hossain, E. Rahaman, S.I. Attaluri, K. Some, S.O. Afuape, K. Adofo, E. Lukonge, L. Karanja, J. Ndirigwe, G. Ssemakula, S. Agili, J.M. Randrianavoarivony, M. Chiona, F. Chipungu, S.M. Laurie, J. Ricardo, M. Andrade, R. Rausch Fernandes, A.S. Mello, M.A. Khan, D.R. Labonte, and G.C. Yencho. 2015. "Advances in Sweetpotato Breeding from 1992 to 2012." In Potato and Sweetpotato in Africa: Transforming the Value Chains for Food and Nutrition Security, edited by Jan Low, Moses Nyongesa, Sara Quinn and Monica Parker, 3-68. CABI.

Fig 6. The Sweetpotato Speedbreeders of SSA in Uganda (credit C. Bukandia)

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