ADVANCED CONVENTIONAL BREEDING STRATEGIES

Wolfgang Grüneberg

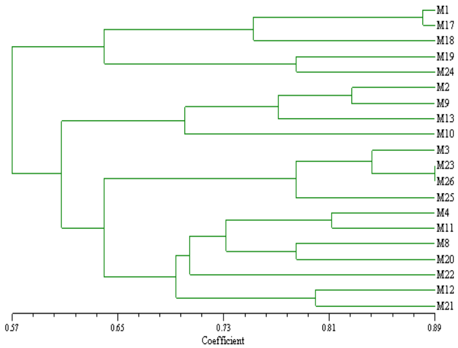
SPHI – Kumasi - 07/10/2013

I. trifida and *(I. triloba)*

CIP 460410 (DLP 4653) x CIP460377 (DLP4597)

News about I. trifida (2x,4x) & other wild relatives sweetpotato

- Roullier et al. 2013. about origin of cultivated sweetpotato (WG of Lebot)
- 2x mapping population - I. trifida clones germinated in vitro (Health status II) 182 clones + parents (M9 x M19) tracing back to accessions 460410 x 460377
- A potentially homozygous *I. trifida* (WG of Craig Yencho) – interesting for sequencing (potential new project "Mol. Tools for Sweetpotato" – lead NCSU)
- **M9** and **M19** clones were used to test genotyping by sequencing (GBS) – together with **Beauregard** and **Tanzania** - Establishment of an optimized GBS protocol **-** 6422 polymorphic SNPs from GBS data of these 4 clones



M9 x M19

300 seeds for 2x mapping population 200 seeds germinated 182 clones maintained – remaining seed stored

Polyploidy and Population Genetics

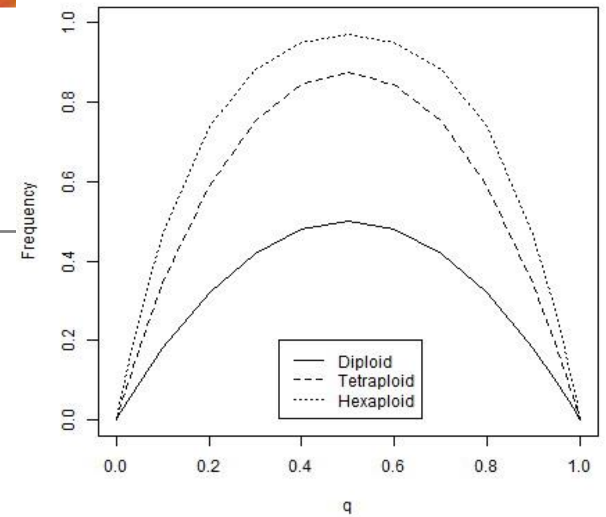


Fig 1a. Effect of ploidy level on the frequency of heterozygous genotypes (modified from Gallais 2003 by introducing to 6x curve

News about Population Genetics

- Gallais, A. 2003. Quantitative genetics and selection theory in autopolyploid plants. France, INRA
- Emphasize **heterozgous genotypes occur at much larger frequencies in 6x** than in 2x (see **Fig. 1a**) => heterosis much more important in 6x than in 2x – for yield and yield stability we want highly heterozygous genotypes
- Recessive inherited traits are much more difficult to fix (see **Fig. b**) – inbreeding much more difficult to achieve in 6x than 2x – for some traits we want strong inbreeding such as SPVD (and quality traits)

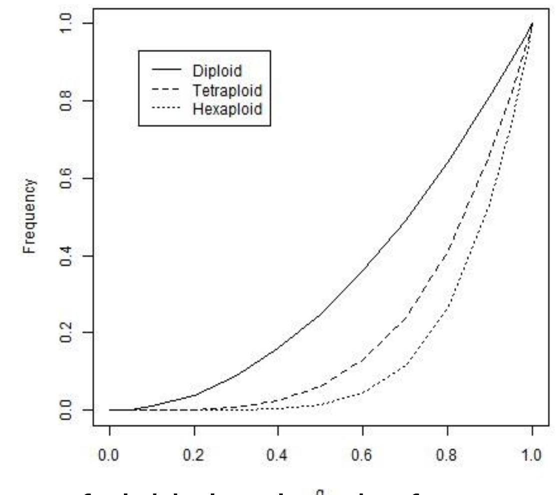


Fig b. Effect of ploidy level on the frequency of phenotypes expressing a one locus recessive inherited trait as a function of the allele frequency of the recessive allele.

Breeding Objectives I – first view might be confusing by the multitude of breeding objectives simply there is only one objective: **the better variety**

Overview on breeding objectives by viewing at (i) variety types, (ii) yield, (iii) quality and (iv) resistance to abiotic stresses

Variety types: i) the white, dry, low-sweet (**bland or stable type** (Baynes, 1972), (ii) the orange, moist, sweet or **desert type** (Martin and Rodriguez-Sosa 1985), (iii) the **orange, dry and starchy type** (Tumwegamire, et al. 2011), (iv) the **purple type**, which is usually dry and low-sweet (in preparation for APA paper).

Yield, Stability & Adaptation: by **a) decentralized breeding and farmer participation** to adapt for a) humid high virus pressure zones, b) drought prone areas, c) non-sweet taste, d) high altitudes (breeding platforms in SASHA) – **(b) new yield component studies** (storage root weight per plant – number of storage root per plant – storage root initiation – harvest index – sink source relations (WG LaBonte and should perhaps more emphasized at CIP WGs)

Storage root yield as a breeding objective has highest priority (Uganda 2006)

Farmer select varieties on basis of much more trait than only yields – those who do not realize this will learn it the hard way

Breeding Objectives II

Taste & Nutrient density:

- OFSP dry and starchy and non-sweet - dry matter, starch, **individual sugars**, and **β-carotene** have such a large Vg and low Vgxe + appropriate genetic correlations =>. you can change sweetpotato into very different types, provided that a large number of genotypes (**N >1000 clones**) is screened in early breeding stages - Fe and Zn more difficult, improved, but further improvement depends on ….
- Extension of simple label “biofortified”

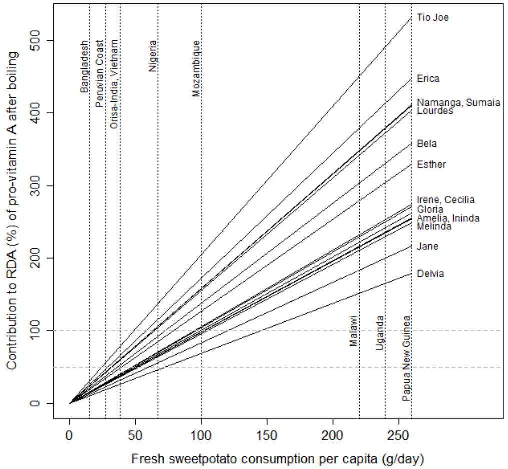
Biotic & Abiotic Stress / Pest & Diseases:

Resistance to sweetpotato virus disease (SPVD) - SP clorotic stunt virus (**SPCSV**) - the important component of SPVD (generally SP is very resistant to virus but …) – **VJ08.330** and offsprings (WG Robert & Wolfgang) – mol. markers might assist

Resistance to weevil damage - all drought prone regions - storage **roots morphology** (deep in the soil & clearly tapering at top - **latex compounds** / varieties like New Kawogo (Stevenson et al. 2009) Santo Amaro, PZ06.120 - complex trait – genetic gains possible recurrent selection (WG LaBonte)

Drought tolerance – sweetpotato is quite tolerant to drought but **vine survival** and **adequate response to rains** in genotypes adapted to drought prone areas more important as we imagined in the past – **stability of initiation of storage root development**

In most OFSP varieties a piece (40 g - after boiling) contributes >50% to the recommended daily allowance (RDA) of pro-vitamin A



Potential contribution of new OFSP varieties after boiling for drought prone areas to the RDA of pro-vitamin A (β-carotene) as a function of sweetpotato consumption per day.

Variance Components Yields – we have some information but need more studies independent in each country and across mega-environments

Information about variance components for yield traits in sweetpotato is still limited.

Table. Variance component ratios for storage root yield

Vg	**Vgxe**	**Verror**	**Country**	**Method**	**Referance**
1	: 1.27	: 1.93	Cameron	Anova	Ngeve and Boukamp (1993)
1	: 0.69	: 0.55	Peru	Anova	Manrique and Herman (2002)
1	: 0.78	: 0.21	Peru	Anova	Grüneberg et al. (2005)
1	: 6.12	: 10.62	Uganda	Anova	Tumwegamire (2011) PhD thesis
1	: 5.85	: 2.44	Peru	REML	5 location var. comp. study Peru 1174 germplasm clones

Vg	**Vgxl**	**Vgxs**	**Vgxlxs**	**Verror**			
1	: 0.32	: 0.06	: 0.50	: 1.33	Cameron	Anova	Ngeve (1993)
1	: -0.38	: -0.21	: 1.97	: 3.34	Cameron	Anova	Ngeve (1993)
1	: 1.46	: 0.96	: 1.83	: 2.62	Uganda/Kenya	REML	Grüneberg et al. (2004)
1	: 2.21	: -0.87	: 4.39	: 10.05	Uganda	Anova	Tumwegamire (2011) PhD thesis

Important is to note that storage root Vgxs is always or most often the smallest Vgxe

=> this means a breeder can test in less years and compensate the loss of precision by using more locations

Breeding Methods - Recombination

True seed from field trails and farmer fields are still attractive were NARS do not have breeding nurseries (i.e. Malawi gained 4 varieties with this method)

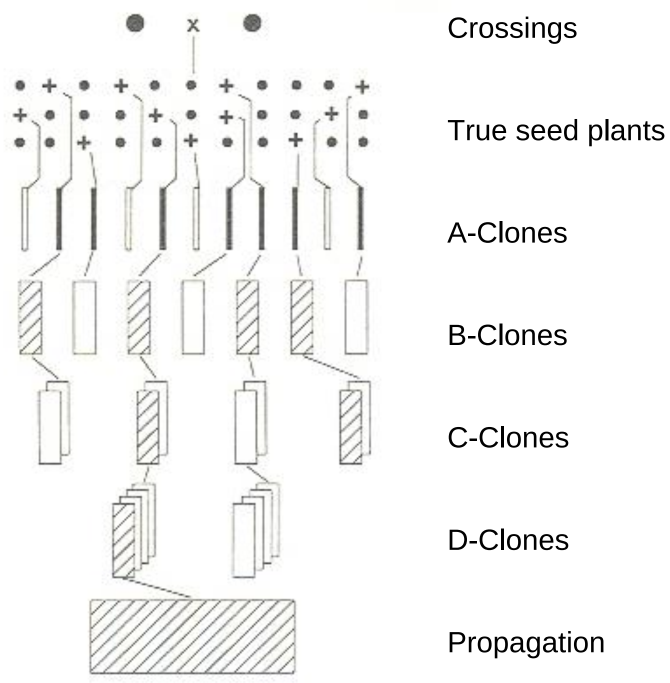
Polycross seed nurseries – most common recombination method in sweetpotato – produces huge amounts of seeds (40 to 100 thousand)

Controlled crosses – for theoretical reasons controlled crosses should be superior to polycrosses (currently under investigation – 3 of 4 environments harvested); require skilled technicians – there are technicians which can produce large amounts of controlled cross seeds)

Controlled crosses are required for heterosis exploitation (what is this we will see later)

Figures: You need true seed to become a breeder - Rubona 2008 (A), Namulonge 2011 (B), Xuzhou 2008 (C), Lima 2008 (D)

Breeding Methods – traditional breeding methods are too slow to achieve "good" progress, to make breeder happy & attract young scientists, **and donors**



This figure "**The general breeding scheme of clonally propagated crops**" is from Becker (1992)

Similar scheme can found in many other textbooks – unfortunately !!!

Two approaches to make things faster

1. **Accelerated breeding (ABS)** by less years and more locations on basis of variance component estimations incl. early breeding stages
2. **Genomic selection** – heavy use of SNP markers and prediction models

Note approach 1: **ABS resulted already in many accelerated variety releases for sweetpotato in SSA** within the period 2009 to 2012 (see our last slide) – of course approach 2 promised to be better

How to explain ABS in one slide?

Planting the ABS at San Ramon in 2005 (one of 3 locations) – with 1 year in controlled crossings / with 2 years in polycrosses you select the material for later breeding stages

Plot size: 1m row plot in early breeding stages not more not less and no plot replications !!!

Heterosis

Offspring is superior to the mid-parent performance (see figure)

F1 > (P1 + P2) /2 - where F1 is the family mean and P1 and P2 is the parental performance

What is the offspring in a clonally propagated crops such as sweetpotato? The family derived from a cross – note in a heterotic cross combinations / families you still can select for "the best" clone

<u>**Experiment I**</u> **- An experiment without genepool subdivision with so-called mega-clones** (important clones across regions) - 4 x 12 factorial designs **- we found positive heterosis in 14 out of 28 families with heterotic yield advantages** – (results in APA paper)

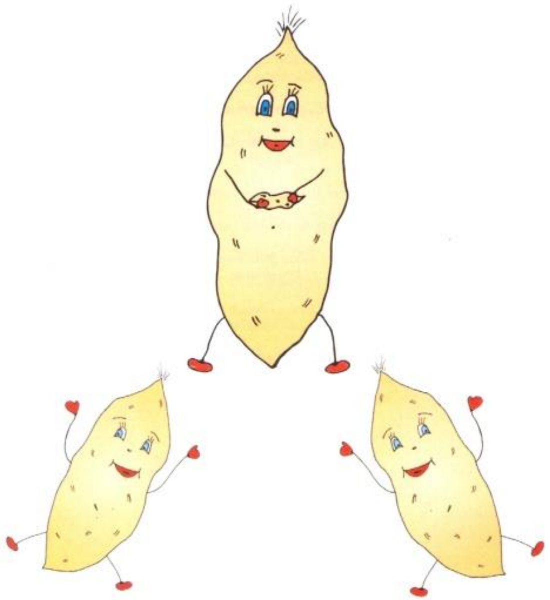


Fig. Illustration of Heterosis

Heterosis experiment II – HQ experiment in SASHA –

Heterosis experiments III Uganda and Mozambique currently carried out (seeds developed)

Heterosis is exploitable / stabilized by establishing two genetic divergent genepools

Genepools in Peru, Uganda, Mozambique estabished (in Ghana under development)

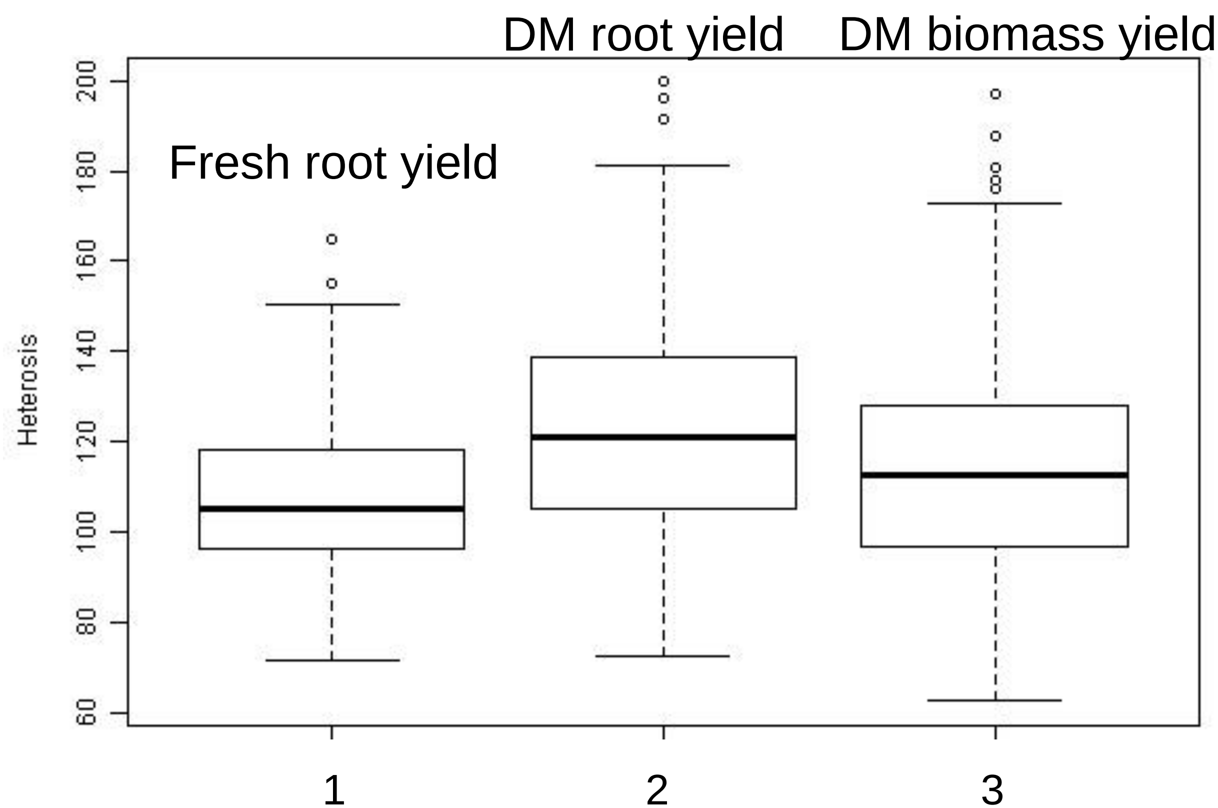
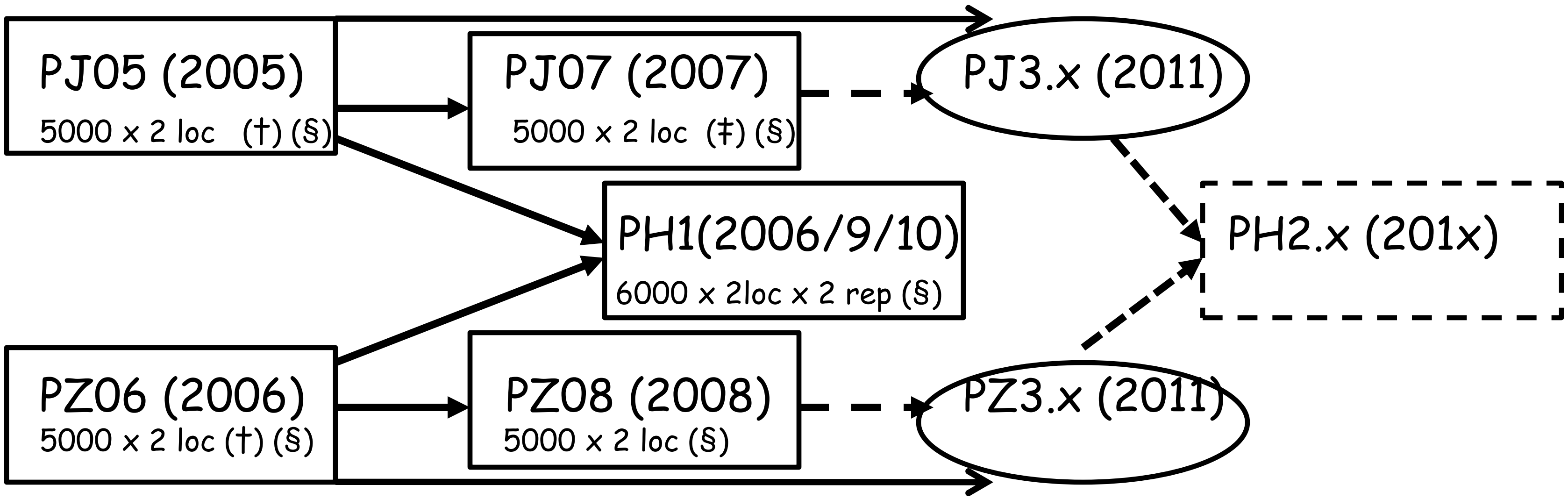


Figure: Mid parent – mid offspring heterosis. In total 6,898 offspring clones tracing back to 31 PZ and 49 PJ parents recombined in 231 cross combinations / families tested at two locations and two plot replications. Heterosis is by establishing two genepools so far without reciprocal recurrent selection (RRS) => there will more heterosis with RRS

Populations PJ & PZ and Hybrid Populations PH I-III (IV)

History of the Hybrid Populations: *Population **PJ05** formed on basis of selection for orange flesh color - generated by open pollination before 2004 (phenotypically and genotypically **more similar to North American varieties** such as Jewel and Resisto). Population **PZ06** formed by factorial controlled crosses conducted in 2005 (8 male parents, namely: **Jonathan, Zapallo, Huambachero, Tanzania, Yurimaguas, Wagabolige, Xushu18, Ninshu1) x 200 OFSP** female parents, which were selected visually for agronomic performance and orange flesh color – PZ06 clones resulted in several variety releases; PJ07 and PZ08 in the pipeline for release (4 clones)*

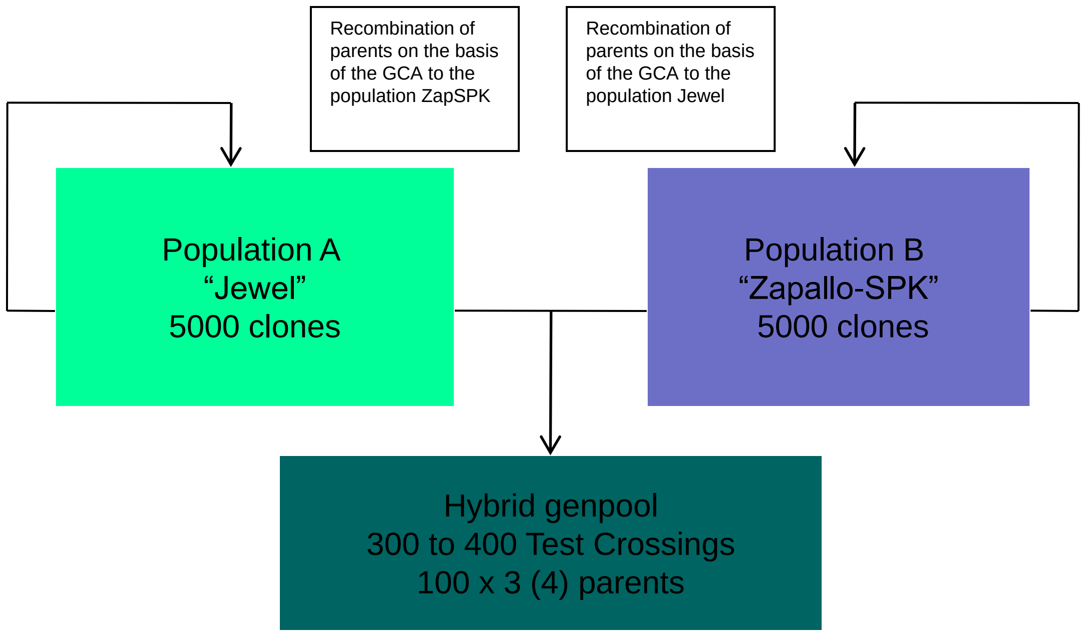


(†) *true seed of PJ05 and PZ06 (several thousands) were sent to Southern Africa and formed the **population Gurue** in Mozambique , (§) 142 families (non-sweet CIP x non-sweet IITA) sent to West Africa and formed population B in Ghana, and* (‡) *true seed of PJ07 (several thousands)send to **India***

PJ07	100g fresh storage root mean:	β-carotene: 10.2 mg,	iron: 0.64 mg,	zinc: 0.38 mg
PZ08	100g fresh storage root mean:	β-carotene: 7.9 mg,	iron: 0.56 mg,	zinc: 0.34 mg
Child 1 – 3 years needs per day:		β-carotene: 4.8 mg,	iron: 5 mg,	zinc: 4 mg

Enhance degree of heterozygousity for yield and yield stability **AND** Inbreeding within genepools for resistances (SPVD) and quality

Hybrid breeding schemes for selection for better crosses better parents better families



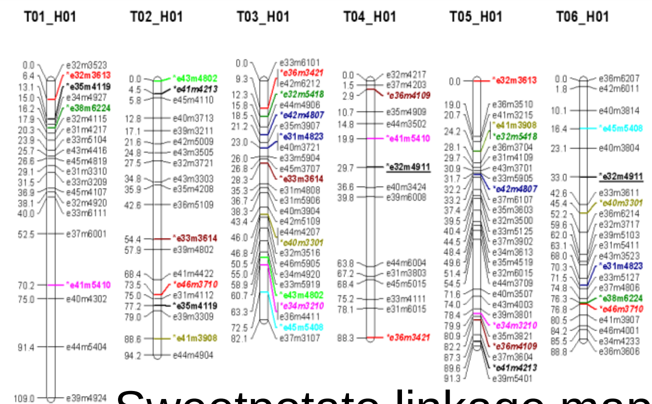
A potential reciprocal recurrent selection scheme for sweetpotato to exploit and improve heterosis with two breeding populations (! inbreeding by selfings not required !).

Note 1: Each population and the hybrid genepool can be used to select clonally propagated varieties.

Note 2: Population improvement and variety development are have several selection stages in common

Such a scheme was already suggested by Hull for clonally propagated crops using sugercane as an example – (Hull, F.H. 1945 Recurrent selection for specific combining ability in corn. J. Am.Soc. Agron. 37: 134-145)

Breeding Methods – next generation tools (will they improve yields?)



Sweetpotato linkage map

- Developing a **SNP (single nucleotide polymorphism) platform for sweetpotato** and GbS (genotyping by sequencing) – established through the platform at Cornell.

- **Training population / Calibration population for GBS** to assess breeding values - about 300-500 varieties and advanced breeding lines for phenotypying important traits in different locations (e.g. 3 in Africa, 1 in Asia, and 1 in USA).

- To accelerate sweetpotato breeding with superior genomic tools (might need **complete SP genome sequence**)

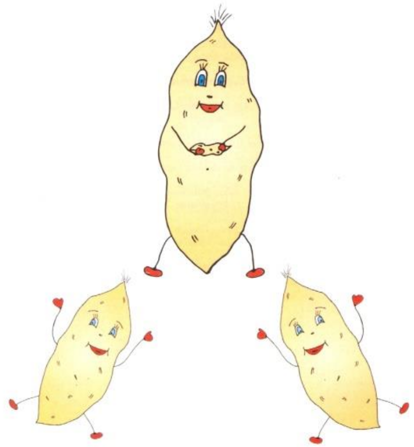
- **Two mapping populations** (NCSU, Uganda/CIP, CIP) – linkage maps
  Tag genes for starch, dry matter, beta-carotene, virus resistance

- Genome sequence of the **diploid ancestor of SP** but ancestry among the Batatas section would be needed by sequencing homologous loci

Varieties released 1992 to 2012 – restricted to SSA more information across regions in the paper for this presentation

Country	No. of varieties released		
	1999 to 2008	2009 to 2012*	**Total**
Ethiopia	10	0	**10**
Ghana	0	4	**4**
Kenya	5	4	**9**
Malawi	6	10	**16**
Mozambique	12	20	**32**
Nigeria	3	5	**8**
Rwanda	8	11	**19**
S. Africa	12	18	**30**
Tanzania	6	7	**13**
Uganda	19	1	**20**
Zambia	7	0	**7**
Total	**88**	**80**	**168**

*2012 Application for variety release done



Thank-you for your Attention