Breeding CIP Headquaters

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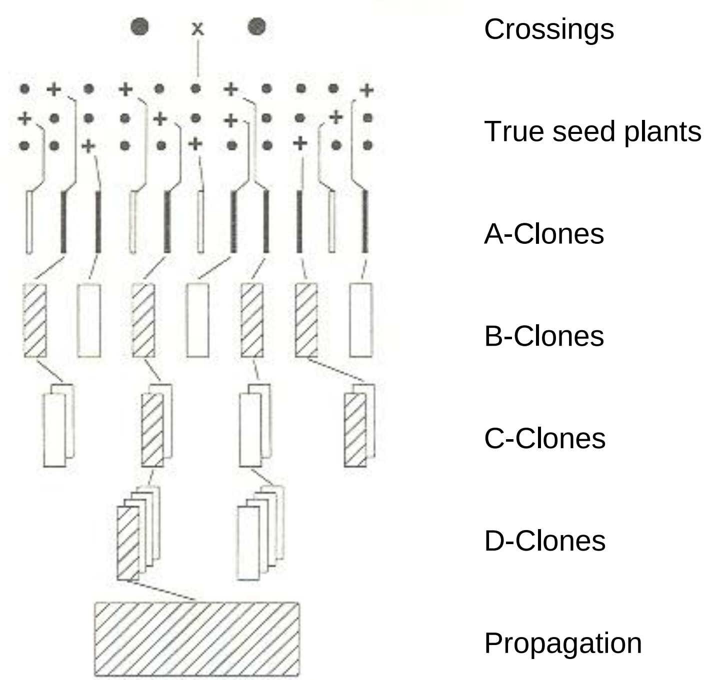
The general breeding scheme for clonally propagated crops

Selection

The long way to a new variety (???)

Benjamin in multiplication Nov. 2009 – ithe first sweetpotato variety launched with a breeding scheme that takes only four years (Jan. to April 2006 crossed - launched in March 2010)



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

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

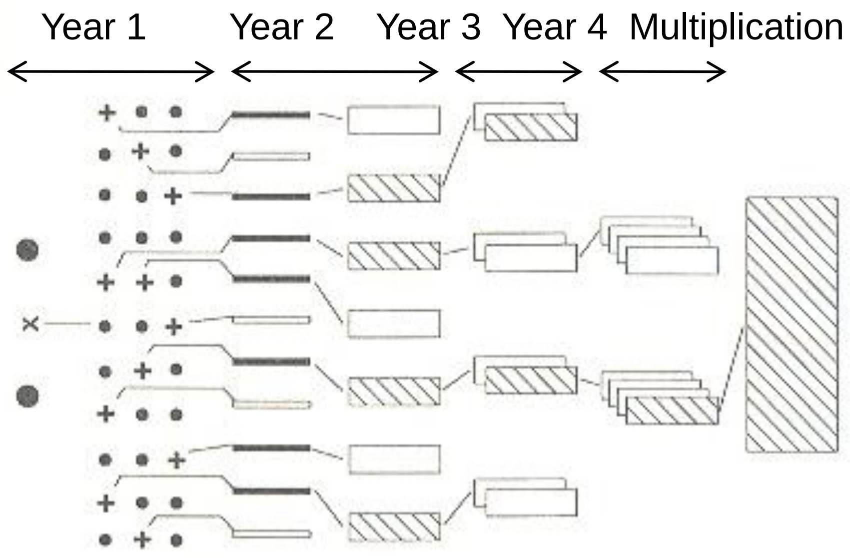
<u>This scheme is misleading:</u>

1) a breeder makes more than 1 cross (he makes hundreds of crosses)
2) different selection steps must not be in different years in clonally propagated crops – remember the finally selected D-clone is genetically absolutely identical with the true seed plant the D-clone is tracing back to

Modification of the general breeding scheme => the accelerated breeding scheme (ABS) for clonally propagated crops

Selection by ABS

Save time no one is waiting for you 7 to 10 years !!!



<u>Rules:</u>

1) the seed plant is already the final genotype = variety selection is relatively easy in lonally propagated crops
2) early breeding stages: 1m row plots (8000 – 12000 clones) - everything what   can be made simultaneously is made simultaneously – 2 to 4 locations no replications
3) later breeding stages: 4-5 row plots - 1st selection step: 300 clones, 3 locations, 2 replications - 2nd selection step: 40 clones, 6-12 locations, 2 replications)

Variance component and heritability estimates of observed traits (ratio σ^2_G : σ^2_{GL} in brackets) for ABS in the early breeding stage = year 1 of selection; no reps; small plots; several locations).

Traits	σ^2_G	σ^2_L	σ^2_{GxL}	N Obs	N Loc	Heritability
	Observations with Agronomic Scores 1 to 5					
RYLD (t^2/ha^2)	47.7 (1	23.2	98 2.05)	12093	3	0.59
FYLD (t2/ha2)	237 (1	52.1	349 1.47)	8066	2	0.58
DM ($\%^2$)	13.94 (1	8.18	6.22 0.45)	3875	2	0.82
TcDM (ppm^2)	33651 (1	3453	9539 0.28)	3865	2	0.88
FeDM (ppm^2)	7.41 (1	5.79	7.61 1.03)	3874	2	0.66
ZnDM (ppm^2)	3.1 (1	4.63	2.92 0.95)	3872	2	0.68
	Observations with Agronomic Scores 3 to 5					
RYLD (t^2/ha^2)	36.2 (1	23	110.4 3.05)	3655	3	0.5
FYLD (t2/ha2)	202 (1	16.6	265.2 1.31)	2718	2	0.6
DM ($\%^2$)	14.13 (1	11.28	5.01 0.36)	2040	2	0.85
TcDM (ppm^2)	31518 (1	5593	11896 0.38)	2038	2	0.84
FeDM (ppm^2)	7.39 (1	7.45	7.6 1.03)	2038	2	0.66
ZnDM (ppm^2)	3.07 (1	5.28	2.88 0.94)	2038	2	0.68

The new OFSP type – high dry matter, high starch & less sweet

Sweetpotato is propagated by cloning but true seed easily occur by out-crossing

Genetically sweetpotato is a hexaploid hyrbid => rapid development of genetic diversity with respect to adaptation and quality

New OFSP Type III
dry & starchy

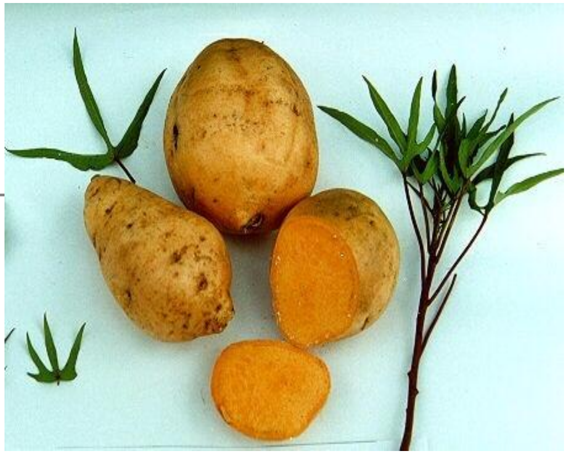
OFSP Type III (dry & starchy) - breed for:

1. **OFSP dry & starchy for high sweetpotato virus pressure zones of Uganda and other countries of East Africa**
2. **OFSP dry & starchy for drought prone areas of Mozambique and Southern Africa**

Breeding – accelerated breeding scheme (ABS) to release varieties in 4 years

Re: Grüneberg W.J., Mwanga R., Andrade M. and Espinoza J., 2009. Selection methods Part 5: Breeding clonally propagated crops. In: S. Ceccarelli, E.P. Guimarães, E. Weltzien (eds) Plant breeding and Farmer Participation, 275 – 322. FAO, Rome.

Varieties

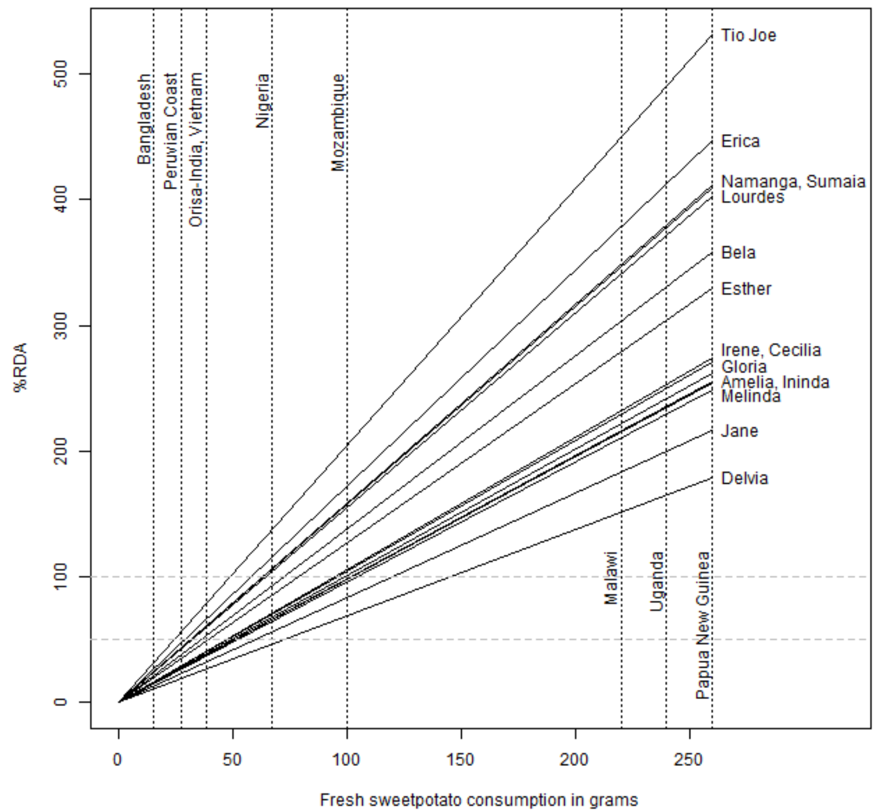


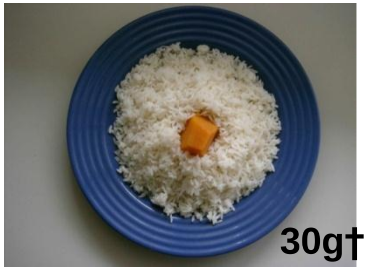
26 New OFSP varieties; Peru, Uganda, Mozambique

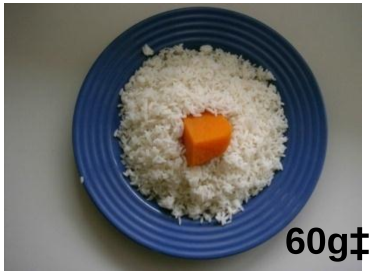
1. **2009/10 => 2 new OFSPs moist & sweet: Benjamin (MV), Arne (MV), Jewel (MV), & Xushu 18 (check MV) – trial series in Peru in 9 environments =>new OFSP releases (3-4 varieties) in 2013 for low land tropics including dry & starchy**
2. **OFSPs dry & starchy adapted to high SPVD pressure areas: Abuket 1 (FV), Carrot C (FV), Ejumula (FV), Kakamega (FV), KMI61 (FV), Zambezi (FV), SPK004/6 (MV), SPK004/6/6 (MV), Naspot 5/50 (MV) & Resisto (check MV) – trial series in Uganda in 9 environments**
3. **2011 => 15 new OFSP varieties dry & starchy adapted to drought prone areas: Amélia (MV), Bela (MV), Cecilia (MV), Delvia (MV), Erica (MV), Esther (MV), Glória (MV), Ininda (MV), Irene (MV), Jane (MV), Lourdes (MV), Melinda (MV), Namanga (MV), Sumaia (MV), & Tio Joe (MV) – trial series in Mozambique in 5 environments**

FV = Farmer varieties, MV = Breeding varieties

OFSP Type III Pro-vitamin A (RDA 4.8 mg β-carotene / day)







A piece of OFSP served to rice dominated dishes ….

Figure 1. Potential contribution of new OFSP varieties after boiling to the RDA of pro-vitamin A (β-carotene) as a function of flesh sweet potato consumption per day – variety releases Mozambique / drought prone areas).

Yield & Quality milestones in populations

Mozambique:
Milestone Population improvement SA year 3 month 12: Drought adapted population dissemination (I) as true seed to NARS breeding programs in Southern Africa (Population means of > 8 t /ha, > 26% dry matter, > 59% starch, >100 ppm beta-carotene, >1000 ppm calcium, >18 ppm iron, >9 ppm zinc, and medium variety ability in the traits vine survival and weevil avoidance)
Milestone Population improvement SA year 5 month 12: Drought adapted population dissemination (I) as true seed to NARS breeding programs in Southern Africa (Population means of > 9 t /ha, > 27% dry matter, > 62% starch, >120 ppm beta-carotene, >1200 ppm calcium, >20 ppm iron >11 ppm, zinc and high variety ability in the traits vine survival and weevil avoidance)

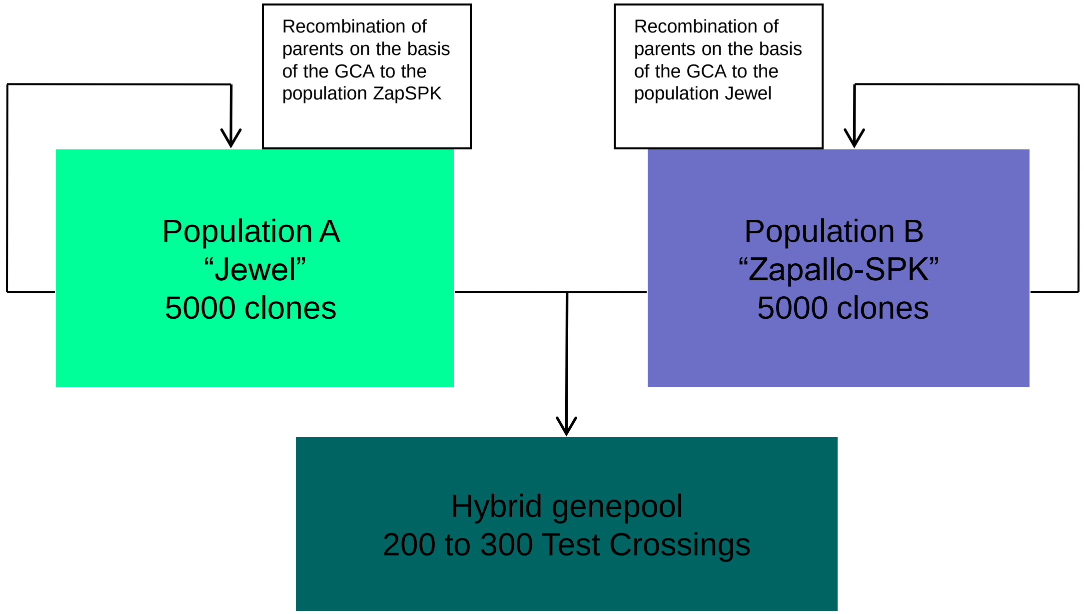
Uganda:
Milestone Population improvement EA year 3 month 6: First humid high SPVD pressure adapted population dissemination as true seed to NARS breeding programs in East Africa (Population means of > 10 t /ha, > 28% dry matter, > 62% starch, >100 ppm beta-carotene, >1000 ppm calcium, >18 ppm iron ,>9 ppm zinc and low to medium variety ability in the trait SPVD resistance)
Milestone Population improvement EA year 5 month 12: Second humid high SPVD pressure adapted population dissemination as true seed to NARS breeding programs in East Africa (Population means of > 11 t /ha, > 28% dry matter, > 62% starch, >120 ppm beta-carotene, >1200 ppm calcium, >20 ppm iron >11 ppm, zinc and medium to high variety ability in the trait SPVD resistance

Ghana:
Milestone Population improvement WA year 4 month 9: First non-sweet breeding population disseminated as true seed to NARS breeding programs in West Africa – non-sweet population A in Ghana (Population means of > 9 t /ha, > 28% dry matter, > 60% starch, total sugar <12%, <9% sucrose, >50 ppm beta-carotene and medium variety ability in the traits vine survival and weevil avoidance)
Milestone Population improvement WA year 5 month 6: Second recurrent selection cycle completed for non-sweet population B in Ghana (Population means of > 12 t /ha, > 28% dry matter, > 60% starch, total sugar <10%, <8 sucrose, >50 ppm beta-carotene and medium variety ability in the traits vine survival and weevil avoidance)
Milestone Population improvement WA year 5 month 6: Second non-sweet breeding population disseminated as true seed to NARS breeding programs in West Africa – non-sweet population A in Ghana (Population means of > 14 t /ha, > 28% dry matter, > 60% starch, total sugar <10%, <8% sucrose, >50 ppm beta-carotene and medium variety ability in the traits vine survival and weevil avoidance)

Note: Underlined, milestones appear to be reached! – Milestones which are not underlined are critical or still can not be estimated

Selection of Parents and Heterosis Exploitation

Selection for new crosses / parents – best family makes



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

Note 1: Population A and B and the hybrid genepool can be used to select clonally propagated varieties.

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

Such a scheme was already proposed 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)

Dry Matter Storage Root Yield – Heterosis Experiment

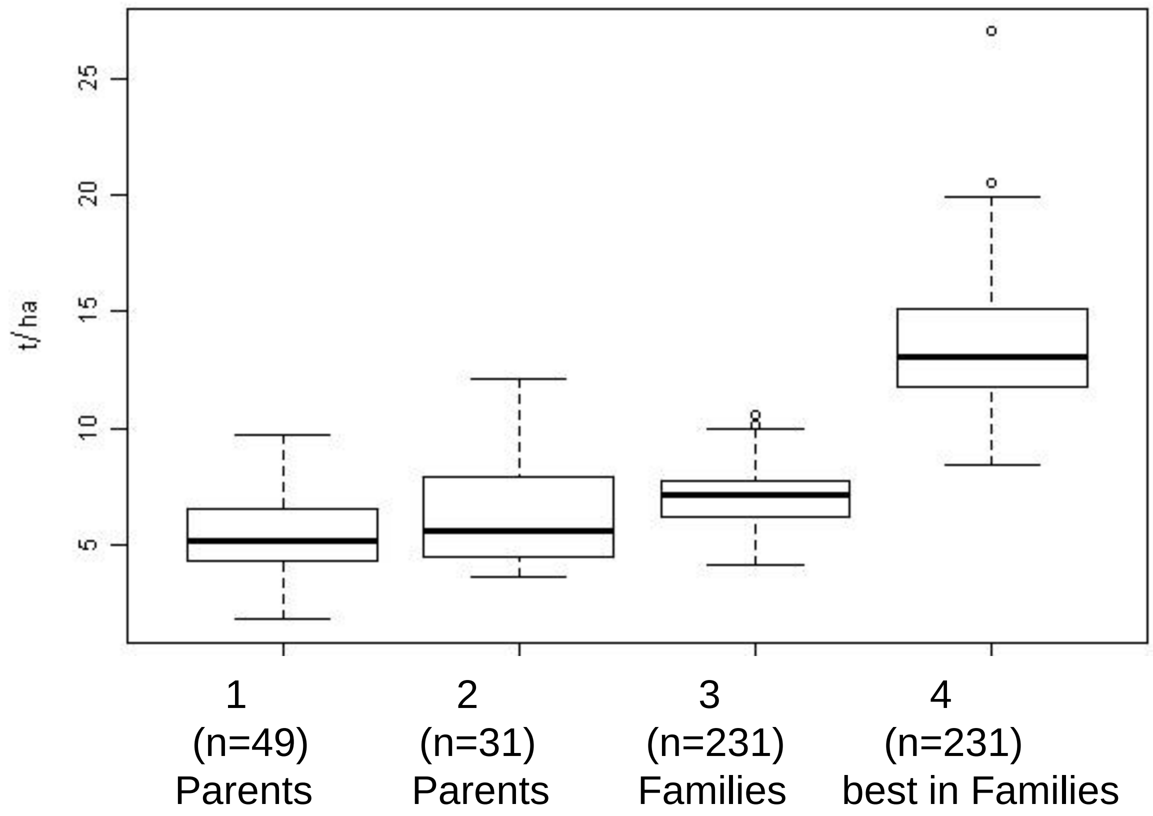
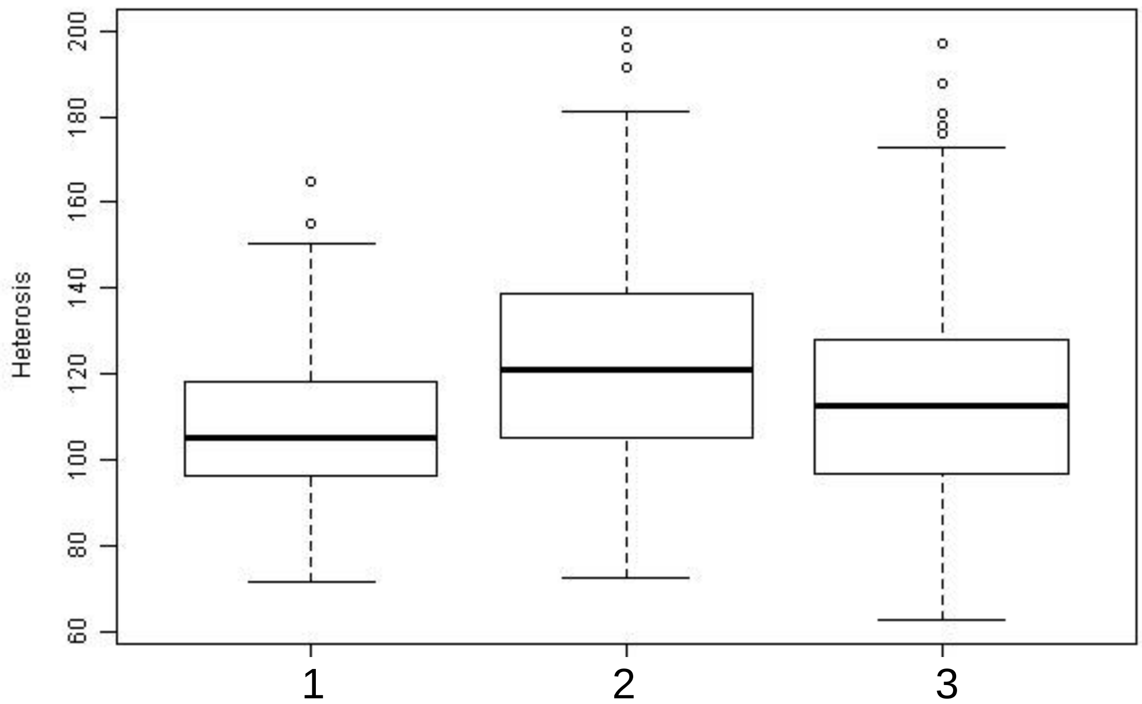


Figure 4. Dry matter storage root yield for parents PJ (1), PZ (2), hybrid family means (3), and best clone with each family (4) determined across two locations and two plot replications (in total 6898 offspring clones tracing back to 31 PZ and 49 PJ parents)

Heterosis observations in sweetpotato – two genepools

Fix Heterosis exploitation by establishing two genepools



Mid parent – mid offspring heterosis for fresh storage root yield (1), dry matter storage root yield (2), and dry matter biomass yield (3) – Note each boxplot shows the distribution of 231 family means.

In total 6898 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 of observed traits – estimated from heterosis experiment

Heterosis by working with two genepools / genepool subdivision

!!! so far without selection for recombining ability = best family makes !!!

Table 4. Significance tests and confidence limits for mid parent – mid offspring heterosis **on population basis** for all observed traits.

Mid parent – mid offspring heterosis

Variable	**Mean (%)**	**t-value**	**P**	**95% CL**
Fresh root yield	115.3	9.36	<0.0001	112.1 – 118.5
Dry root yield	122.9	14.16	<0.0001	119.7 – 126.1
Dry biomass yield	107.8	6.90	0.0061	105.6 – 110.0
Dry matter	101.4	3.56	0.0002	100.6 – 102.2
Protein	100.6	1.31	0.0961	99.7 – 101.6
Fe	100.9	1.99	0.0240	100.0 – 101.7
Zn	98.8	-2.62	0.9954	97.9 – 99.7
Ca	105.8	5.23	<0.0000	103.6 – 108.0
Mg	99.8	-0.44	0.6715	98.7 – 100.8
BC	99.7	-0.18	0.5694	96.4 – 103.0
Starch	101.8	5.05	<0.0000	101.1 – 102.5
Fructose	97.4	-1.96	0.9744	94.8 – 100.0
Glucose	96.1	-3.87	0.9999	94.1 – 98.1
Sucrose	97.6	-3.04	0.9987	96.0 – 99.1

1 2 3

Parent offspring correlations – estimated from heterosis experiment

The heterosis experiment allowed us also to get "good" information of parent – offspring correlations in sweetpotato

Expected (from smaller previous experiments) r = 0.5 to 0.6 in sweetpotato; in wheat (a diploid) it is r ~ 0.8

Table 5. Parent offspring correlations for storage root yield (correlation means calculated across locations and replications) – spearman correlations are given in brackets.

N = 231 families (80 parents)

	Family	Male	Female	P1+P2
Family	1.000	0.358	0.332	0.512
	(1.000)	(0.248)	(0.309)	(0.443)

N = 6898 clones (80 parents)

	Clone	Male	Female	P1+P2
Clone	1.000	0.145	0.134	0.204
	(1.000)	(0.115)	(0.120)	(0.184)

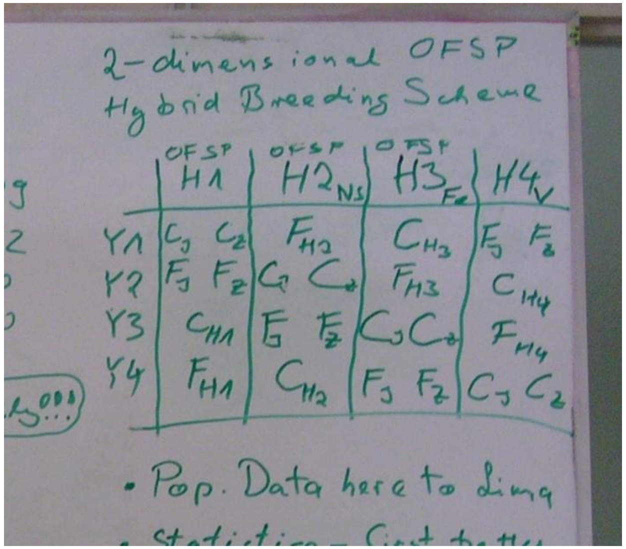
⇒ In sweetpotato you do not know the value of a cross before you have made it

⇒ The only change to enhance the chances of making good crosses is by reciprocal recurrent selection – the same story as in maize (perhaps more needed) to get population means up in sweetpotato

⇒ food for thoughts for genomic selection … are models predicting genotypic marker association with phenotypic clone performance enough to achieve gains of 2 to 3% per year in population improvement ? Or predicting offspring performance by G1+G2 ?!

Current steps in heterosis research

1. **Uganda: Seed generation from 8 parents in genepool A with 8 parents of genepool B in a diallel (inter-genepool crossing) and corresponding intra-genepool crosses => comparing means of intra-genepool versus inter-genepool crosses in Uganda (2 locations & 2 reps – design similar to heterosis experiment in Peru (SASHA)**
2. **Mozambique: Obtains seeds from Uganda (8x8) and conducts similar experiment as Uganda under drought stress (SASHA)**
3. ***Peru: Selection of parents on basis of offspring performance in heterosis experiment (16 PZ and 20 PJ parents) & intra-genepool crosses to select parents for the next heterosis experiment to determine response to selection after genepool sub-division and one step of reciprocal recurrent selection => new OFSP hybrid population H1 wide adaptation + new OFSP hybrid (H2) non-sweet + new OFSP hybrid population (H2) high Fe & Zn (CRP-RTB)***
4. ***Peru: Genepool subdivision of East Asian Germplasm (CRP-RTB)***



Polycross versus controlled cross breeding

Many breeder do polycross breeding – few breeders do controlled cross breeding

Why? Because it is so easy to create very large amounts of seed in sweetpotato polycrosses and controlled crosses requires skilled technicians

Remind Table 5. Parent offspring correlations for storage root yield

N = 231 families (80 parents)

	Family	Male	Female	P1+P2
Family	1.000	0.358	0.332	0.512
	(1.000)	(0.248)	(0.309)	(0.443)

What is more efficient – polycross breeding or controlled cross breeding?

The answers is not as straight forward as it looks like on basis of the number of the parent – offspring correlations!

1. **Selection intensities are much higher in polycross breeding than in controlled cross breeding**
2. **There are different design in controlled cross breeding which cannot be "simulated" by model calculations (i.e factorial cross designs, partial diallels ….**
3. **Unbalances pollination in polycross breeding – some parents in polycrosses nearly do not contribute as male parent, whereas others contribute in many many cross combinations**

Polycross versus controlled cross breeding study

Compare polycross & controlled cross breeding by observed responses to selection & model calculations

Similar to the study early selection in segregating generations of wheat Peters et al. 1991 in Plant Breeding

A set of Mega-clones (22 clones) has been recombined in a polycross nursery (P1 and P4) and in two controlled crossing designs: A partial diallel (P2) and a factorial crossing design (P3)

Multiplication and first selection in polycross population P1 "simulating" applied polycross breeding has been completed (year 1 see next slide)

Year 2 field trials has been completed in Satipo and in the field in La Molina (see P1,P2, P3, and P4 in year 2 next slide)

Year 3 field trials (P1,P2, P3, and P4) will be planted in June 2013 in Satipo and November 2013 in La Molina

Overview of the polycross versus controlled cross breeding trials

Year I (Satipo)		Year II (Satipo, La Molina)		Year III (Satipo, La Molina)
Pob. "I" (Polycross 6500 clones Single Plants)	selection →	Pob. "I" (Polycross with selection, 1000 clones, 2 repl.)	→	Pob. "I" (Polycross with selection, 1000 clones, 2 repl.)
		Pob. "II" (1000 clones, 2 rep., controlled cross design I)	→	Pob. "II" (1000 clones, 2 rep., controlled cross design I)
		Pob. "III" (1000 clones, 2 rep., controlled cross design II)	→	Pob. "III" (1000 clones, 2 rep., controlled cross design II)
		Pob. "IV" (Polycross without selection, 1000 clones, 2 repl.)	→	Pob. "IV" (Polycross without selection, 1000 clones, 2 repl.)

Pop. I will serve the determination of observed response to selection, Pop. II and Pop. III will serve parameter estimations and the determination of observed response to selection, Pop. IV will serve parameter estimations

(Parameters to be determined are: the variance components V_G, V_{GxL}, V_{GxY}, V_{GxLxY}, and $V_{Plot\ error}$.

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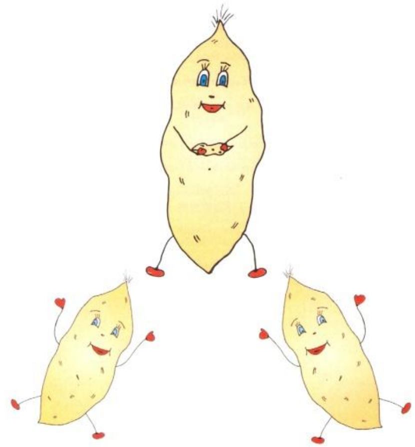
Note: Check clones included in each population are Tanzania, Jonathan, and Resisto.

SPVD work

Testing the offspring of VJ08.330 supposed to be resistant to SPCSV

Table. Testing VJ08.330 and 11 offspring clones from VJ08.330 derived from self-fertilization for SPCSV (graphing, 3 plant replications and 3 repeated measurements)

Genotype	N	TAS ELISA SPCSV	95% confidence limits	
VJ08.330	3	0.053	-0.02024	0.126244
CIP_110025.1	3	0.070333	-0.00291	0.143578
CIP_110025.10	3	0.056333	-0.01691	0.129578
CIP_110025.11	3	0.0735	-0.01621	0.163206
CIP_110025.2	3	0.073333	0.000089	0.146578
CIP_110025.3	3	0.059667	-0.01358	0.132911
CIP_110025.4	3	0.066	-0.00724	0.139244
CIP_110025.5	3	0.114667	0.041422	0.187911
CIP_110025.6	3	0.099	0.025756	0.172244
CIP_110025.7	3	0.062667	-0.01058	0.135911
CIP_110025.8	3	0.073333	0.000089	0.146578
CIP_110025.9	3	0.059667	-0.01358	0.132911
DLP3163	3	0.442	0.352294	0.531706
PZ06.077	3	0.115667	0.042422	0.188911
PZ06.085	3	0.053333	-0.01991	0.126578
Paramong Virus free check clone	24	0.056542	0.030646	0.082437



Thank-you for your Attention