Biofortification of Sweet Potato

Pro-vitamin A (β-carotene), Iron and Zinc

What has been achieved and what is within reach?

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International Potato Center

Introduction

Annual Sweetpotato Production (FAO 2005):
about 130 million tons
- **11 M -Africa**
- 2 M- South & Central America
- 1 - India
- **107 - China**

Vit. A, Fe & Zn deficiency AND BIOFORTIFICATION

125,000,000 children Vitamin A deficiency (VAD)
33 to 66% of the world population Fe & Zn deficiency

A child 0 - 5 years needs **5 mg pro-vitamin A / day**
A child 0 - 5 years needs **7 -11 mg Fe & 5 mg Zn / day**

OFSP extreme high pro-vitamin A concentrations

⇔ 30mg - 70mg/100g DM

A child needs 5 mg per day
⇔ 35 to 70 g fresh OFSP

!!! A piece per day meets the need per day !!!

Introduction

Major Sweetpotato Breeding Programs at CIP

1. **OFSP Breeding = for Better Nutrition (yield, DM, β-carotene, Fe & Zn)**
   - about 30,000 seeds from controlled crossings
   - 90% of resources

   Objectives: Where is the base line (β-carotene, Fe & Zn)?
   Where is the maximum (yield, protein, β-carotene, Fe & Zn)?
   What are the genetic variance/covariances = expected improvement?
   ULTIMATE GOAL!!!! More and better OFSP varieties!

2. **Breeding for non-sweet sweetpotato (high extractable dry matter = starch)**
   < 5% of resources

3. **Breeding for purple flesh sweetpotatoes (high anti-oxidants)**
   < 2% for resources

=> About 90% of resources in OFSP Breeding = better nutrition

Materials & Methods

Three different trials

1. **Elite Demonstration Clones (2 locations 2006)**
   - 26 Mega Clones (> 50% of production in the world)
   - La Molina, San Ramon (Indonesia, Vietnam, India, Mozambique etc.)

2. **Germplasm Clones (1 location 2006)**
   - 1209 clones
   - La Molina, (San Ramon-with/without fertilization)
3. **Breeding Population "Jewel" (3 locations 2005)**
   - 5000 clones
   - La Molina, San Ramon-WF, San Ramon-NF, (Canete High SPVD spot)

Evaluation and Estimation of Genetic Parameters

1. **NIRS (protein, β-carotene (2nd calibration), Fe & Zn (2nd calibration)**
2. **Mean, Min., Max, genetic variances & covariances, h^2 (PLABSTAT, SAS)**

Assumption & Targets by Harvest Plus (2005)

Assumption of Targets and Base Lines for ProVitamin A (β-carotene), Fe and Zn in OFSP Breeding / Biofortification = Quality Breeding

	Targets	Assumption Base Line	Target Achieved
β-carotene	100 ppm (75ppm)	>200ppm	>200%
Fe	60 ppm	15 ppm	25.0%
Zn	20 ppm	7.5 ppm	37.5%

Iron and zinc in sweetpotato are not high but there is promise with zinc

Results I
Mega Clone or Elite Demonstration & G x E Clones

Table 1 Yield, dry matter, β-carotene, Fe and Zn in 26 Mega Clones

	YLD (t ha $^{-1}$)	DM (%)	PRO (% in DM)	ppm in DM β-carot.	Fe	Zn
Mean	23.3	30.9	8.8	90.6	**24.4**	**14.2**
Min - Max	2.2 – 50.6	23.2 – 39.8	6.6 – 10.8	0 – **566.1**	18.6 – **29.9**	10.3 – **18.4**

Genetic Variances:

YLD: σ^2_G = 93.1 t^2 ha^{-2} (**), DM: σ^2_G = 16.9 %^{2} (**), β-carot.: σ^2_G = 29316 (**),

Fe: σ^2_G = 2.07(*), Zn: σ^2_G = 0.94(*) ppm^2

Genetic Covariances / Correlations:

DM - β-carot.: r_G = – 0.56** (a negative genetic correlation which makes breeding difficult)

β-carot. – Fe: r_G = 0.75**, β-carot. – Zn: r_G = 0.78**, Fe – Zn: r_G = 0.76** (positive genetic correlations or OFSP have more Fe and Zn)

Variety Names of the Mega-Clones: Tanzania, Wagabolige, Kemb37, Blesbok, SPK004, Brondal, Resisto, Beauregard, Cemsa74-228, SantoAmaro, Jonathan, Zapallo, Humbachero, Yanshu1, Xushu18, Ningshu1, FengShouBai, Jewel, Mohc, NCSU1560, Naveto, 101048.1, 101074.1, 101091.3, 187003.1, 192033.5

Results I
Mega Clones or Elite Demonstration & G x E Clones

Table 2 The current OFSP "Stars" among the 26 Mega Clones

	YLD (t ha $^{-1}$)	DM (%)	PRO (% in DM)	ppm in DM β-carot.	Fe	Zn
Resisto	23.9	27.3	9.7	566	29.9	**18.4**
Beauregard	32.9	23.2	10.3	376	29.8	**16.4**
Jewel	35.6	27.7	8.0	295	23.7	13.1
Jonathan	19.7	29.2	10.1	253	28.2	**16.2**

Results II Germplasm at CIP
OFSP is strong in Zinc

Table 3 Evaluation of 1209 Germplasm Clones for Yield, dry matter, protein, β-carotene, Fe and Zn

	YLD (t ha $^{-1}$)	DM (%)	PRO (% in DM)	ppm in DM β-carot.	Fe	Zn
Mean	17.3	31.5	8.6	62.0	**21.7**	**14.6**
Min - Max	0 – 63.9	13.4 – 44.2	3.3 – 14.3	0 – **883.2**	12.2 – **36.2**	7.0 – **24.0**

Table 4 The Top 55 OFSP Clones in Germplasm (>200 ppm β-carotene, >15 ppm Zn) evaluated for Yield, dry matter, protein, β-carotene, Fe, Zn (Ca and Mg) in storage roots

	YLD (t ha $^{-1}$)	DM (%)	PRO (% in DM)	ppm in DM β-carot.	Fe	Zn
Mean	20.8	26.5	9.8	**384.5**	**24.9**	**17.3**
Min - Max	3.4 – 40.1	18.8 - 32.9	7.8 – 14.3	203 - 883	19.7 –32.7	15.1 – 21.0
CHECK Resisto CIP Code 440001	10.3	25.3	8.5	712	24.3	17.9

Note: The top 55 OFSP together with yield, quality and passport data will be listed on the CIP webpage

Results III

Table 4a Yield, dry matter, β-carotene, Fe and Zn for 63 Selected Promising Clones out of 5000 clones in 2005 (SPVD Tested)

	YLD (kg 0.9m^{-2})	DM (%)	ppm DM β-carot.	Fe	Zn
Mean	2.4	29.3	424	25	18.6
Min - Max	1.2– 9.4	22.8 - 43.6	76.4 – 895	20.1 – 37	12.2 –22

Table 4b Health Status 2 for 24 Selected Promising Clones in August 2006 (SPVD Tested)

	YLD (kg 0.9m^{-2})	DM (%)	ppm DM β-carot.	Fe	Zn
Mean	2.4	30.4	414	24.6	18.4
Min - Max	1.3– 6.0	24.3 - 43.6	76.4 – 699	20.1 – 35	13.3 –21

189121.14, 189150.1, 190094.52, 189123.68,189123.25, 189135.9, 189140.32, 189141.40, 189198.18, 189148.21, 189165.37, 190083.9, 190094.28, 194515.15,194519.28, 194521.2, 194539.36, 194555.7, 194569.1, 194573.9, 194541.45, 194549.6, 189148.65, 189151.38

Results Targets (CIP 2006)

Targets and Base Line Estimations for ProVitamin A (β-carotene), Fe and Zn in OFSP Breeding and 55 OFSP Germplasm Clones

	Targets	Base Line (Mega Clones)	Top55 OFSPs	Achieved Mega Clones	55 OFSPs
β-carotene	100 ppm (75ppm)	253 ppm	348 ppm	253%	348%
Fe	60 ppm	24.4 ppm	24.9 – 32.7 ppm	40%	42 - 54%
Zn	20 ppm	14.2 ppm	18.8 –21.0 ppm	71%	85 -105%

Conclusions:

- OFSP is extremely strong in pro-vitamin A (easy to meet recommended daily intake requirements)
- OFSP is not too far away to be biofortified for Zinc (Biofortification OFSP for zinc is possible and within reach -> 2 to 3 ppm more)
- OFSP and Iron -- Breeding has still a long way to go! (but we should remember also sweetpotato leaves are eaten -> about 3 – 4 times more iron than in storage roots)

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Thank-you for your Attention