An Overview of Root and Tuber Crops
Genomics

• General Context

• Need for a genomics assisted global surveillance strategy for pest and diseases

• Opportunity for scaling up phenotyping

• New frontiers in genome editing
Next Generation Sequencing
New opportunities

Cost per Raw Megabase of DNA Sequence

Moore's Law

National Human Genome Research Institute

http://www.genome.gov/sequencingcosts
What breeders expect?

- Greater uses of the germplasm banks
- Better selection of parents
- Knowledge of traits genetics and gene-trait associations
- Speed and more efficient markers assisted selection programs for biotic and abiotic stresses
- Ability to implement novel breeding strategies
- Understanding of genes function and epigenetics variations

Breeders already manage successfully many, many traits for multiple environments
Accelerated uses of genomics tools since the release of the cassava and potato reference genomes

- Global engagement on whole genome sequencing of cassava and potato genotypes
- Sequencing of sweet potato initiated
- Pan genome of different taxa of cassava and cultivated potato and related wild species initiated
- Rad Seq of 1000 cassava accessions from Latin America and Africa completed
- Sequencing of Pan-African sweet potato viromes, cassava viruses, cassava bacterial blight and whiteflies, potato *Phytophthora infestans*
Accelerated uses of genomics tools since the release of the cassava and potato reference genomes

- High density SNP maps for cassava and potato
- Genomic selection cassava project well advanced
- GBS (genotyping by sequencing) of germplasm accessions and mapping populations
- Marker assisted selection programs for a range of pest and diseases for cassava, potato and sweet potato
- GWAS projects initiated CBB, CMD, CBSD, beta carotene.....
- Open access databases developed
Tracking crop varieties using genotyping-by-sequencing markers: a case study using cassava (Manihot esculenta Crantz)

Cassava
A Global Crop in a Globalized World

Global shares of cassava production

Asia is the largest global cassava trader
~ 94% of world’s import
97% of world’s export

*88 mil tons

World’s top producers

Nigeria 19%
Indonesia 9%
Brasil 8%
Thailand 11%
Congo 6%
Ghana 6%
Angola 6%
Mozamb. 4%
Vietnam 4%
India 3%
China 2%
Other 22%

Ignazio Graziosi (CIAT)
Cassava mealybug: a global invasion

Cassava mealybug world distribution

Cassava mealybug infestations

Ignazio Graziosi (CIAT)
Pests and diseases invading SE Asia cassava fields

(% fields affected in each country, survey 2014 of 430 fields)

*CWV: cassava witches’ broom disease
Visualizing Cassava Witches Broom (CWB) Impact
Determining the Pan-African sweet potato virome: understanding virus diversity, distribution and evolution and their impacts on sweet potato production in Africa

Cassava: a disease surveillance network in Africa

04/08/2014 - Article

Twenty-eight international organizations recently joined forces to fight cassava diseases in Africa. The network, PACSUN (Pan-African Cassava Surveillance Network) created is setting out to prevent a possible food catastrophe, since cassava is playing an increasingly vital role in the subsistence of people in Africa.
A must: Speed & Low cost

Impressive post PCR cheap diagnostics tools available now or coming into commercialization in the next 3-5 years

Will Real Time- Cheap detection tools become a reality?

Biomeme one of many start up in the field of diagnostics

Oxford Nanopore one of many sequencing companies working on miniaturization

CIAT field portable detection systems - Isothermal DNA amplification
What a genomics assisted pest & diseases GLOBAL surveillance strategy bring for root and tuber crops?

• Accurate and fast classification system using rapid deep sequencing with advanced computational techniques and algorithms

• Surveillance and alert network system

• Assist in rapid responses

• Search for resistance and accelerate breeding
Next Generation Sequencing
New opportunities

CHALLENGE:
Phenotyping at a Scale

http://www.genome.gov/sequencingcosts
How far are we from the 100$ Phenome?

Recent Progress
Average Progress
Fast Progress
Moore’s Law

Posted on 4 January 2016 in by Stefan Schwartz
Opportunity for scaling at field level
Off the shelf sensors micro processors: Arduino & Raspberry Pi

Raspberry Pi with infra red camera
~ 30-50 US $

Use at the Danforth Center for cassava disease screening
Root biomass estimation in Root and Tubers

Ground-penetrating Radar Technology
CIAT-Texas A&M Collaboration on cassava

Pi Michael Selvaraj

Older Version

Improved Version
Ground Penetrating Radar

- GPR transmits pulses of EM electromagnetic energy from a transmitting antenna
- Energy reflected by discontinuities is captured by a receiving antenna
- Information is captured as amplitude response at a given travel time
Radargram collected on (6 month) cassava at CIAT

GPR-Radargram

Depth Slices

Ground root samples collected from field
Remote sensing of biomass root and tuber crops is achievable

Linear regression of GPR return pixel counts versus corrected dry weight of M-NGA11 cassava suggest remote sensing of biomass of root and tuber crops are feasible.

$R^2 = 0.71$, $\alpha < .01$
New RTB initiative in 2016: High throughput phenotyping early stage root bulking in cassava using ground penetrating radar

Funding: NSF- BMGF BREAD
CRISPR – CAS 9

A revolutionary genome editing tool with the capability of modifying genome regions with targeted high precision.
Jenifer Dudana and Emmanuelle Charpentier, two researchers expected to win the Chemistry Nobel in the coming years.
CRISPR (Clustered Regularly Interspaced Short Palindromic Repeat) is an RNA guided gene editing platform that makes use of a bacterially derived protein (CAS 9) and a synthetic guide RNA to introduce a double strand break at a specific location within the genome.
Areas of interest:

– Human health
– Personalized medicine
– Agriculture
– Bioenergy - develop efficient metabolic pathway
Potential Uses:

- Deleting a gene or genes
- Site-specific insertion of a trait gene
- Activating genes
- Possibly controlling gene activity level
Simultaneous editing of three homoeoalleles in hexaploid bread wheat confers heritable resistance to powdery mildew

Yanpeng Wang¹,³, Xi Cheng²,³, Qiwei Shan¹, Yi Zhang¹, Jinxing Liu¹, Caixia Gao¹ & Jin-Long Qiu²
Potential traits for gene editing in Root and Tuber Crops

- Nutrition
- Starch pathway
- Post-harvest deterioration pathway
- Biotic constraint resistance
- Herbicide resistance
- Plant architecture genes
NIAS-CIAT Collaborations on CRISPR
Initiated October 2014 with Seiichi Toki and Masaki Endo

Multigene Knockout Utilizing Off-Target Mutations of the CRISPR/Cas9 System in Rice
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Parameters affecting frequency of CRISPR/Cas9 mediated targeted mutagenesis in rice
Masafumi Mikami¹,² · Seiichi Toki¹,²,³ · Masaki Endo² ©
Potato genome editing using CRISPR–CAS 9

RESEARCH ARTICLE

Generation and Inheritance of Targeted Mutations in Potato (Solanum tuberosum L.) Using the CRISPR/Cas System

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FOCUS

Efficient targeted mutagenesis in potato by the CRISPR/Cas9 system

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Genomics, phenotyping and genome editing platforms

- Major role for accelerating breeding and genetic gain through rapid traits discovery & validation
- Access to engineering capacity for phenotyping platforms is a must
- Defining target genes-trait for CRISPR requires careful consideration
- Genomics, phenotyping and CRISPR, diagnostics-monitoring platforms generate Big Data and will require access to high computing clusters
Impressive Root and Tuber Crops genomics advances must be translated to improve livelihoods for sustainable development