The Importance of Seed Technologies and Systems for Climate Smart Agriculture
Seed technologies and delivery systems represent an important investment area for Climate Smart Agriculture, offering farmers options to dynamically respond to climate change. Due to a number of constraints, however, delivery systems for seeds are currently underdeveloped in Africa, which limits the access of improved varieties to smallholder farmers.
Seed Industry and Farmers were ‘awkward guests’ in the Development Agenda

Credit: Lloyd Le Page
MAIZE SEED SYSTEM
SEED SYSTEM OVERVIEW

Variety R&D, Selection, and Breeding
Breeder Seed Production and Maintenance
Foundation Seed Production
Quality Seed Production
Marketing and Distribution Seed

Kelvin Kamfwe
Aline O’Conner
Policy Environment
Richard Jones
FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

www.feedthefuture.gov
Role of Plant Breeding in CLIMATE SMART AGRICULTURE

By

Kelvin Kamfwa, PhD
(University of Zambia)

Global Learning and Evidence Exchange Event on CLIMATE SMART AGRICULTURE
Lusaka, Zambia March 13-16, 2016
Climate-Smart Agriculture: What role is Plant Breeding Playing?

• Plant breeding: the art and science of changing genetics of plants for the benefit of humankind
  – Green revolution saved millions of people - Norman Borlaug

• Adapting to climate change for continued crop productivity will require climate robust crop varieties
  – Drought, flood and heat and pest tolerant varieties
Genetic Variation: Driver of Plant Breeding

• Plant breeding driven by genetic variation

• Most crop species have adequate genetic variation for major climatic stresses:
  – Drought, Heat, flooding

• Domestication and plant breeding has significantly reduced genetic variation
  – Selection for yield under highly managed environments
  – Crossing of elite by elite varieties

• Genetic variation in both primary, secondary and tertiary gene pools
  – Mining gene banks
Understanding of drought tolerance continues to develop

- Physiological studies: insights in plant response to drought, and traits conditioning drought tolerance
  - Deep rooting system/remarkable plasticity
  - Early flowering
  - Remobilization of water soluble CHO
  - Accumulation of molecular protectants

- Genetic and genomic studies have revealed genomic regions and genes for drought tolerance traits
  - Genetic mapping, QTL analysis, Genome wide association studies and genomic studies

- Drought tolerance is genetically complex
  - Many genes and mechanisms are involved
  - Contrast to the first generation GM traits

- Knowledge key to developing breeding strategies for drought and heat tolerance
Breeding strategies for drought tolerance in corn

- Traditional breeding:
  - Recurrent selection to accumulate favourable alleles for drought tolerance
  - Delayed silking: longer Anthesis-Silking Interval (ASI)
  - Reducing ASI has been a strategy – CIMMYT

- Genetic engineering
Using related species to breed for drought tolerance

- Interspecific crosses

- Widely used in common bean

- Tepary bean (*Phaseolus acutifolius*) and Common bean (*Phaseolus vulgaris*)

- Tepary native to the desert highlands of northwest Mexico and southwest of USA
  - Evolved in dry conditions
  - Tolerant to drought and heat stress
  - Deep root system, smaller leaves

CIAT, 2015
<table>
<thead>
<tr>
<th>Developer</th>
<th>Crop</th>
<th>Mechanism</th>
<th>Implementation location and status</th>
<th>Field trial results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monsanto</td>
<td>Corn</td>
<td>Expresses a cold-shock protein B from <em>B. subtilis</em>, which stabilizes RNA</td>
<td>Deregulated in US in December 2011; stewarded commercialization in US western Great Plains and Midwest</td>
<td>Average increase of five bushels of corn per acre during drought</td>
</tr>
<tr>
<td>PT Perkebunan Nusantara XI; Sugarcane University of Jember (East Java, Indonesia); Ajinomoto</td>
<td>Sugarcane</td>
<td>Expresses glycine betaine from <em>Rhizobium meliloti</em></td>
<td>Approved in Indonesia by the National Genetically Modified Product Biosafety Commission in May 2013</td>
<td>20–30% higher sugar production than conventional counterparts during drought</td>
</tr>
<tr>
<td>Performance Plants (Kingston, Ontario)</td>
<td>Canola, corn, petunia and rice</td>
<td>Uses RNAi driven by conditional promoters to suppress farnesyltransferase; shuts down stomata</td>
<td>Licensed to Scotts (Marysville, Ohio), Syngenta (Basel), Bayer CropScience (Monheim, Germany), DuPont Pioneer, Mahyco (Jalna, India), RiceTec (Houston) and DBN (Beijing)</td>
<td>Canola, 26% higher yield; petunia, double the number of flowers</td>
</tr>
<tr>
<td>DuPont Pioneer</td>
<td>Corn</td>
<td>Expresses an ACS6 RNA construct to downregulate ACC synthase and decrease biosynthesis of ethylene</td>
<td>Field trials in the US and Chile</td>
<td>2.7–9.3 bushel per acre advantage over nontransgenic varieties in drought conditions</td>
</tr>
<tr>
<td>Arcadia Biosciences</td>
<td>Rice and canola</td>
<td>Expresses isopentenyltransferase from Agrobacterium, which catalyzes the rate-limiting step in cytokinin synthesis; accompanied by SARK promoter from bean</td>
<td>Two years of US field trials in rice with combined water use efficiency, nitrogen use efficiency and salt tolerance; technology licensed to developers who have put the gene into their own varieties of soybean, wheat, rice, cotton, sugar beets, sugarcane and tree crops</td>
<td>13–18% under various nitrogen application rates; 12–17% under water stress conditions; 15% under combined stress</td>
</tr>
<tr>
<td>Verdea, a joint venture of Arcadia Biosciences and Bioceres</td>
<td>Soybean</td>
<td>Overexpresses Hahb-4, from sunflower thought to inhibit ethylene-induced senescence</td>
<td>Field trials in Argentina and the US</td>
<td>7–15% yield advantage over comparable varieties during drought and other stress</td>
</tr>
<tr>
<td>Japan International Research Center for Agricultural Sciences</td>
<td>Wheat, soybean and sugarcane</td>
<td>Expresses DREB1A transcription factor under the control of the rd29A promoter</td>
<td>Field trials via collaborations with International Maize and Wheat Improvement Center, International Rice Research Institute, International Center for Tropical Agriculture, Brazilian Enterprise for Agricultural Research</td>
<td>Varies</td>
</tr>
<tr>
<td>University of Tokyo and Japan International Research Center for Agricultural Sciences</td>
<td>Rice and peanut</td>
<td>Expresses DREB1A transcription factor under the control of the rd29A promoter</td>
<td>Field trials via collaborations with University of Calcutta (India, rice) and International Crops Research Institute for the Semi-Arid-Tropics (India, peanut)</td>
<td>Varies</td>
</tr>
<tr>
<td>Agricultural Genetic Engineering Research Institute (Giza, Egypt)</td>
<td>Wheat</td>
<td>Expresses HVA1 gene from barley, which confers osmotolerance</td>
<td>Conducting field trials and generating biosafety data required for approval by Egypt’s regulatory authorities</td>
<td>Not disclosed</td>
</tr>
<tr>
<td>Indian Agricultural Research Institute (New Delhi)</td>
<td>Tomato</td>
<td>Overexpressing osmotin-encoding genes under the control of the 35S CMV promoter</td>
<td>Greenhouse studies in India</td>
<td>Better survival and growth; yield data not yet available</td>
</tr>
</tbody>
</table>

*Emily Waltz, 2014 Nat. Biotech.*
Breeding for heat stress tolerance

- Heat stress during reproductive stage is a serious productivity constraint
  - Pollen viability, fertilization, seed set
  - Common bean lose yield when night temps are higher than 20°C

- Genetic variation exists for developing heat tolerant varieties

- Heat tolerance is genetically complex
  - Many genes and mechanisms involved
Strategies for breeding for heat tolerance

• Exploring gene banks for heat tolerance
  – Mexican landraces of wheat with grain yield advantage under heat stress

• Interspecific crosses
  – Tepary x Common bean
  – Tepary more tolerant to heat stress than common bean

• Selection strategies for heat tolerance
  – High temperature hot spot
  – selections based on pod fill, grain yield and pollen viability
Breeding for flood tolerance

- Flooding or submergence: production constraints of several crops especially in low-lying countries
  - Reduction of oxygen to roots

- Genetic variability for flooding tolerance exists in several crops

- Conventional breeding: tolerant varieties in rice, wheat, soybean

- Genetic studies identified genomic regions/genes for submergence tolerance in rice:
  - Sub1 QTL ($R^2=70\%$) confers protection of 3-18 days of complete flooding
  - Tolerant types identified in the 70s
  - Mapped in the 90s
  - Cloned in 2006, Marker-assisted backcrossing
  - Varieties with Sub1 QTL released in 2009
    - Swarna-Sub1
Take Away Messages

• Plant breeding will play a critical role in developing adaptation strategies to climate change

• Genetic variation for tolerance to drought, heat and flood stress exists in many crops: within germplasm, their wild relatives and related species
  – Mining gene banks

• Genetic and physiological studies have provided valuable insights in genetic variation and traits conditioning tolerance to drought, heat and flood stresses

• Drought and tolerance are genetically complex traits with no quick breeding fix

• Through conventional and marker-assisted breeding incremental gains are being made to develop tolerant varieties

• More investment into drought and heat tolerance research is needed to sustain these gains

• Need for effective seed systems to get improved varieties into farmers fields
Liberalizing Seed Regulations to Increase Crop and Varietal Choice

Richard Jones
Chief of Party, Scaling Seeds and Technologies Partnership (SSTP) in Africa

March 15, 2016
Mitigating Climate Variability

• Improvements in grain yield and crop water productivity arise from:
  – Breeding for superior varieties
  – From better agronomic and water management practices
  – The synergy between breeding and agronomy
  – Matching crops and varieties to the environment
    • Drought tolerant crops and varieties
    • Short duration varieties
Policies, Laws and Regulations
Preliminary Results

• Liberalization of seed sector in 1990’s
  – Emergence of more commercial seed companies
  – Increased choice of seed to farmers
  – Development of agro dealer networks
  – Rise in counterfeit seed and other inputs
What is the Problem?

• Regulatory systems designed pre-liberalization impede the flow of new crops and varieties
  – Three years of testing
  – Inappropriate criteria for release
• Impose unnecessary costs on seed businesses
• Not addressing counterfeit seed
• Failing to incentivize commercial seed business through effective and appropriate intellectual property management
Dominant Models

• Government authority
  – All field inspections carried out by government inspectors
  – Seed laboratories government operated
  – Resource limitations, inefficiencies, and lack of innovation

• Delegation of authority e.g. SANSOR
Need for Effective Seed Policy Reform

- Small national seed markets
- Different agro-ecologies within countries
- Similar agro-ecologies between countries
- Different regulations between countries
  - Variety release
  - Phyto-sanitary standards
  - Very limited plant variety protection laws
Organization of formal seed sector

• Vertically integrated
  – Larger seed companies including multinationals
  – Private capital

• Vertically coordinated
  – Smaller seed companies
  – Mix of public and private investment
Lack of Early Generation Seed (EGS)

- Publicly developed varieties
  - No clear institutional arrangements for supply and maintenance of EGS
  - Licensing systems poorly developed
    - Limits commercial incentive to invest in seed production and marketing
      - Different systems needed for different crops/varieties
        - Performance based contracts (non hybrid crops)
        - Commercial production (hybrid crops)
- Particularly damaging for smaller seed companies
Seed Trade Harmonization

• COMESA
  – COMESA Seed Trade Harmonization Regulations that are in the COMESA Gazette Volume 19 No. 1 of February 2014, Annex VII.

• SADC
  – Memorandum of Understanding on the Harmonization of Seed Regulations in the Southern African Development Community Region that entered into force on July 7, 2013.

• ECOWAS
  – ECOWAS Seed Trade Harmonization Agreement that was adopted by the ECOWAS Council of Ministers on 18 May 2008 in Abuja, Nigeria.
COMESA

• Objectives
  – Harmonize phytosanitary measures for seed in the region in order to facilitate the safe movement of seed within Member States, in a transparent manner and without dissemination of any pest of quarantine importance
  – Ensure that varieties listed in the COMESA Variety Catalogue and traded among Member States are of high and known quality and that movement of seed is more efficient
  – Encourage investment in seed business in the Member States
  – Increase access to existing varieties in the Member States; and
  – Stimulate the breeding and availability of improved seed varieties resulting in increased variety choices for all farmers
Welcome to the COMESA Plant Variety Catalogue

The objective of the COMESA Variety Release System is to encourage investment in seed business in the COMESA Member States, to enhance access to new and existing varieties in the COMESA Member States, and to stimulate the breeding and availability of seed varieties resulting in increased variety choices for all farmers.

This website allows plant breeders/seed developers to register varieties in the COMESA Catalogue and seed users to find varieties which can be legally commercialized among the 19 COMESA countries.

Seed users can select varieties adapted to their Agro-Ecological Zones, with short technical descriptions. For more detailed descriptions or orders, they will find commercial contact references associated to each variety.

Plant breeders who want to apply for regional registration of a variety fulfilling the COMESA Variety Release System requirements have to create a breeder’s account in the restricted access area.

National Seed authorities will also have access to the varieties database through the restricted area.
What Next?

• Use of ICT for traceability
• Labeling and packaging to reduce fraud
• Improved laboratory techniques for varietal identification – e.g. DNA finger printing
• Improved farmer education and compensation
• Training and licensing of seed inspectors, seed samplers, and seed laboratories
• Abolition of VCU testing and greater urgency in moving new crops/varieties into the system
  – Let farmers decide!
Conclusions

• Seed delivery is the domain of commercial companies not public sector
• Greater collaboration needed between public and private sectors
• Enabling regulatory environment needed to improve seed quality and to increase choice
• Regulatory agencies should devote more attention to building capacity, licensing etc.
Acknowledgements

• AGRA, with support from Feed the Future through USAID, is conducting this work as a contribution to the New Alliance for Food Security and Nutrition. A shared commitment of G7 partners, African leaders, and private sector partners, the New Alliance aims to lift 50 million people in sub-Saharan Africa out of poverty by 2022
Seed Technologies and Systems: Thoughts on Commercialization

Aline O’Connor
USAID CSA GLEE
March 14, 2016
For farmers, climate change can mean:

- Drought and/or floods
- Earlier, or later, rains
- Earlier, or later, cessation of rains
- New diseases
- New weeds
- New insects, change in populations
- Post harvest storage challenges
- Soil changes, including salinity
- Changes in livestock feed and health
But...

- Solutions already exist, in many instances!
- Climate change brings opportunities, not just problems
- Businesses love challenges
- African ingenuity is a huge strength
- Youth + technology + information
- Seed is a big part of the solution
Is seed just “seed”? 

✓ Basic genetics for **yield** 
✓ **Disease** tolerance/resistance 
✓ **Fertilizer** responsiveness 
✓ Maturity, including ‘**drought escaping**’ 
✓ **Water and nutrient use** efficiency 
✓ Seed **treatment** (pests, diseases) 
✓ Information/extension (packaging text) 
✓ Genetics for **fodder** qualities 
✓ Customer **feedback** mechanism 
✓ **Soil improvement** via root systems, refuge 
✓ **Nitrogen** fixation 
✓ Heat **sheltering** canopies 
✓ **GMO trait** vehicle
But, there’s a catch:

Seed systems in SSA often don’t work at all, or are very sub-optimal
The science is far ahead of our ability to deliver it
The science is far ahead of our ability to deliver it.

And this has huge implications for CSA.
Major commercialization challenges

- Enabling policy and regulatory environment – the road
- Early generation seed – the fuel
- Working capital – the engine
- Demanding, knowledgeable customers – the rules of the road
- Direct government involvement with delivery – the uphill climb?
On the ground reality: Kenya

Local Seed Production Volumes Certified by KEPHIS 2014

Source: KEPHIS Annual Report
Local Seed Production Volumes Certified by KEPHIS 2014

Source: KEPHIS Annual Report
Success will be as dependent upon what countries STOP doing as what they START doing.
Reasons for hope

• Good varieties, potential farmer choices
• Local seed companies, but they need smart help
• Agrodealer interest and competition
• Farmer feedback loops, farmer empowerment
• Youth and technology
• Transparent information (E.g., TASAI, Seed Sector Platform KENYA)
Hub agrodealers at an over-subscribed convening focused on crop seed and food security in Kenya
Because Our Farmers Deserve To Know
<table>
<thead>
<tr>
<th>Crop</th>
<th>Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>CASSAVA</td>
<td>MAIZE – OPV</td>
</tr>
<tr>
<td>CHICKPEA</td>
<td>MUNG BEANS/GREENGGRAMS</td>
</tr>
<tr>
<td>CLIMBING BEAN</td>
<td>PEARL MILLET</td>
</tr>
<tr>
<td>COMMON BEAN</td>
<td>PIGEON PEA</td>
</tr>
<tr>
<td>COWPEA</td>
<td>RICE – PADDY</td>
</tr>
<tr>
<td>DOLICHOS BEAN</td>
<td>RICE – UPLAND</td>
</tr>
<tr>
<td>FINGER MILLET</td>
<td>SORGHUM</td>
</tr>
<tr>
<td>FOXTAIL MILLET</td>
<td>SOYA BEANS</td>
</tr>
<tr>
<td>IRISH POTATO</td>
<td>SWEET POTATO</td>
</tr>
<tr>
<td>MAIZE – HYBRID</td>
<td>WHEAT</td>
</tr>
</tbody>
</table>

Because Our Farmers Deserve To Know!
<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which maturity of the crop are you interested in?</td>
<td>Extra Early, Early, Medium, Late</td>
</tr>
<tr>
<td>(Check all that apply)</td>
<td></td>
</tr>
<tr>
<td>Which special characteristics of the crop are you interested in?</td>
<td>Drought Tolerant, Disease Tolerant / Resistant, Storage and Field Pest Resistant, Consumer Preferences</td>
</tr>
<tr>
<td>(Check all that apply)</td>
<td></td>
</tr>
<tr>
<td>Are you looking for a variety for long or short rains?</td>
<td>SHORT, LONG, BOTH</td>
</tr>
</tbody>
</table>
Low quality certified maize seed reported through the Kajiado County farmer feedback loop. The farmer desperately tried to gap plant...
FARMERS | DON'T just plant FAKE or POOR QUALITY SEED and keep quiet.

STAND UP! SPEAK OUT! HOW?

SMS Your Complaint to: 20767  SMS Cost is FREE

1. SMS your County "KAJIADO" to 20767.
2. Wait for an AUTO-REPLY confirming your message was received.
3. Give your FEEDBACK or COMPLAINT on SEED.

Always keep your seed package and receipt.
Is seed just “seed”?

- Basic genetics for yield
- **Disease** tolerance/resistance
- **Fertilizer** responsiveness
- Maturity, including ‘drought escaping’
- Water and nutrient use efficiency
- Seed **treatment** (pests, diseases)
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- Genetics for **fodder** qualities
- Customer feedback mechanism
- Soil improvement via root systems, refuge
- **Nitrogen** fixation
- Heat **sheltering** canopies
- GMO **trait** vehicle
Take Aways

- Seed delivery systems need to catch up with the science
- Ground-level truths must be checked, information triangulated
- There are LOTS of reasons for hope
- Local private sector solutions can offer real sustainability
- Smart agriculture is already climate smart but is often, tragically, missing
Useful Links

www.seedsectorplatformkenya.com
Example of information provision for decision-making. See YouTube video. Coming soon in Uganda

www.mbeguchoice.com
Example of information driving farmer awareness and choice. See YouTube video.

www.tasai.org
Very good, new index on creating enabling environments for seed systems
Asante sana
Thank you