The Role and Contribution of Plant Breeding and Plant Biotechnology to Sustainable Agriculture in Africa

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Outline

- Introduction
- Plant Breeding Concepts
- Status of Crop Improvement Programs in Africa
- Technology Challenges and Interventions in Breeding
- From Classical to Molecular Breeding
- Strengthening Sustainability into Agriculture
- Conclusion
Introduction
Background: Agriculture in Africa

- Africa’s economy is driven by agriculture – contributes about 32% GDP
- About 233 million people are either suffering hunger or undernourished. Of this 32 million are children under 5 years.
- Food importation is about $35 billion
- Agriculture is 95% rainfed
- Africa has 51 million farmers (80% are SHF) with 183 million ha.
- About 60% of unexplored land in Africa
- Agriculture is still largely subsistence and not strongly linked to industrial growth & increased markets
- SSA valued-added product accounts for only 3.4% of the developing world
Africa has lowest agricultural productivity and highest human malnutrition index

Increasing food by 50-70% in 2050 without destroying the environment is the biggest challenge
The Contextual Issues

- Food out of reach to millions of Africans
- Poor nutrition
- New biotic stresses
- Climate change
- Gender preferences
- Finding new niches (market specification)
- Inappropriately targeted breeding
- Science delivery (seed based technologies)

Does breeding and genetics have answers to all these issues?

Source: Monsanto 2016
Critical Gaps

- **African farmers** – lack of access and opportunities to *practical technology solutions to productivity challenges*

- **African Scientist** – Suboptimal environments for *access and application of new tools*

- **Technology Providers and Investors** – Absence of robust local models to facilitate *appropriate use of the technologies at scale with balance for expense, simplicity, and effectiveness.*

- **Private sector** – willing to share their significant technological resources under certain conditions *but lacking good policies for good regulatory framework; liability protection, agricultural commercialization and product standardization*

- **Public sector in SSA** – Largely the over-dominant player (highly protected) resulting in limited (broad and diversified) partnerships with the private sector thus **missing out on the synergy of complementation** in the agricultural sector
Value Chain Players in African Agriculture

International Systems
- IAR
- Development Agencies

National Systems
- Non-Research
- Research

Local
- Grassroot level

Farmers/ End-users

Technology Producers
- Agro-Dealers
- Processors
- Input suppliers
- Seed companies
- Multi-nationals
- Service providers
- Extension Organizations
- Financial Institutions
- NGOs
- CBOs
- FOs
- Marketers

Multi-nationals
Plant Breeding Concepts
Effective use of Genetic Resources/Diversity

- Defining heterotic groups – critical to hybridization
- Broadening germplasm base

Heterotic groups: Examples of application

<table>
<thead>
<tr>
<th>Crop</th>
<th>Heterotic Groups</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>US dent lines, European flint lines</td>
<td>Europe</td>
</tr>
<tr>
<td></td>
<td>Female group Stiff Stalk (SS) and the male group is designated Non – Stiff Stalk (NSS)</td>
<td>US Corn belt and Canada</td>
</tr>
<tr>
<td></td>
<td>Tang sipingtou and Luda honggu germplasm, Lancaster Sure Crop (LSC), Reid Yellow dent (RYD)</td>
<td>USA, China</td>
</tr>
<tr>
<td></td>
<td>Suwan, Reid, Non Reid</td>
<td>China</td>
</tr>
<tr>
<td></td>
<td>Tuxpano combines well with Cuban Flint, Coastal Tropical Flint (Carnbean Flint), Tuson, ETO, Perla and Chandelle</td>
<td>China</td>
</tr>
<tr>
<td>Rice</td>
<td>Early season <em>Indica</em> from Southern China and mid or late – season <em>Indica</em> from Southeastern Asia</td>
<td>China</td>
</tr>
<tr>
<td>Rye</td>
<td>The Petkus and Carsten</td>
<td>Europe</td>
</tr>
<tr>
<td>Faba bean</td>
<td>‘Minor’, ‘Major’ and ‘Mediterranean’</td>
<td>Europe, Germany</td>
</tr>
<tr>
<td>Rape seed</td>
<td>Asian, European winter type and Canadian and European Spring type</td>
<td>Canada, Europe</td>
</tr>
<tr>
<td>Millets</td>
<td>Tiouma, Souna3</td>
<td>Iran, India</td>
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</tbody>
</table>

Breeding Evolution

**Classical Breeding**
Mainly cross or mutagenesis to alter genome; often randomly undirected. Selection often by phenotype and pedigree information.

**Marker Aided- and Genomics Assisted- Breeding**
Selection based on molecular markers and genome based information paired with field evaluation.

**Genetic Engineering**
Specific genome alteration but undirected. Maybe by transgenesis or cisgenis. Selection involves use of molecular markers and phenotypic evaluation.

**New Plant Breeding Techniques**
New Plant-Breeding Techniques (NPBTs) facilitates genome alterations which are specifically directed- specific mutagenesis and selection by molecular marks.

Genome editing is one of these techniques with fast development and great potential for novel trait correction.
Plant Breeders use any combination of these technologies to develop enhanced products for customers, and continue to explore technologies to enhance this process.
Status of Crop Improvement in Africa
Research and Breeding Capacity

- In Africa the number of researchers is low: 198 researchers per million people, compared with 428 in Chile and over 4,000 in the UK and US. (UNESCO, 2005)
- Africa’s share of global agricultural research expenditure is 6.5%
- Low enrolment for Agricultural courses in universities and much further compounded for “breeding and genetics” discipline
- Low adoption due to inappropriateness of technologies or varieties
- No transgenic food crop yet released in SSA excluding RSA

Only few crops (mostly staple) get more attention. A lot of orphan crops are under-researched yet very critical for nutrition.

Varieties spend about 20 years before being replaced.

Africa has acute shortage of world class breeders. The continent has 500 active breeders - just a tenth of breeders needed.

The time of initiating breeding to adoption on farmers field is about 18 years.

Poor succession plans between scientists in breeding institutions.

Development of varieties is mostly done by International Agricultural research Centers IAC then tested by NARs (downstream in the breeding pipeline).

Sub optimal breeding labs; and few regional advanced laboratories.
Technology Challenges and Interventions in Breeding
Areas of Crop Improvement Requiring Technology Interventions

1. Genetic resource conservation
   - Facilitate clean genetic stocks for diseases

2. Defining heterotic groups

3. Pre-breeding
   - Identification of new generation traits of interest for target markets
   - Knock off genetic load

4. Rapid multiplication
   - Vegetatively propagated seed

5. Trait introgression

6. Gene mining

7. Genetic gain (rapid yield and quality improvement)

8. Shortening breeding cycle

9. Genetic stock generation/development (DH)

10. Novel trait creation
## Biotech Techniques in Crop Improvement

<table>
<thead>
<tr>
<th>Area</th>
<th>Techniques</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetic resources</td>
<td>Tissue culture / cryopreservation</td>
<td>Conservation and management</td>
</tr>
<tr>
<td>Pre-breeding</td>
<td>Embryo rescue</td>
<td>Interspecific crosses</td>
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<tr>
<td>Rapid multiplication</td>
<td>In vitro (e.g. semi autotrophic hydroponic)</td>
<td>Rapid ramping of seeds (clonally propagated materials)</td>
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<tr>
<td>Trait introgression</td>
<td>MABC</td>
<td>Fast track transfer of traits to elite lines</td>
</tr>
<tr>
<td>Gene mining</td>
<td>MABC</td>
<td>Exploring useful traits from the wild species</td>
</tr>
<tr>
<td>Genetic gain</td>
<td>MARS, genomic selection</td>
<td>To efficiently combine best alleles</td>
</tr>
<tr>
<td>Genetic stock generation</td>
<td>DH</td>
<td>Rapidly develop parental lines (e.g. inbred lines)</td>
</tr>
<tr>
<td>Hybrid development</td>
<td>Genotyping and crosses</td>
<td>Assigning accessions and parental lines into heterotic groups</td>
</tr>
<tr>
<td>Genetic diversity</td>
<td>Genotyping</td>
<td>Clustering to identify genetic relatedness or not</td>
</tr>
<tr>
<td>Novel traits</td>
<td>Genome editing, GE (transgenics)</td>
<td>Transferring traits across species</td>
</tr>
</tbody>
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AATF’s Focus Areas

1. Productivity
2. Climate change
3. Pest Management
4. Soil Management
5. Nutrient enhancement in foods
6. Improved breeding Methods; speed, cost and efficiency of product development
7. Mechanization; Geometric impact
8. Enabling environment
## Appropriateness of Technologies/Innovations

### AATF Accessed Technologies:

<table>
<thead>
<tr>
<th>Priority Area</th>
<th>Project</th>
<th>Product/Genes</th>
<th>Trait</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate change</td>
<td>WEMA</td>
<td>• <em>Bt</em></td>
<td>• Stem Borer resistance</td>
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<tr>
<td></td>
<td></td>
<td>• CSPs</td>
<td>• Drought tolerance</td>
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<td></td>
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<tr>
<td>Pest Management</td>
<td>Striga, Cowpea, Banana, Casava, Potato</td>
<td>• Imazapyr Resistance gene</td>
<td>• Herbicide resistance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• <em>Cry1Ab</em></td>
<td>• <em>Maruca vitrata</em> resistance</td>
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<tr>
<td></td>
<td></td>
<td>• <em>Hrap, Pflp</em> genes</td>
<td>• Bacterial Wilt resistance</td>
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<tr>
<td></td>
<td></td>
<td>• <em>Hrap, Pflp</em> genes</td>
<td>• Bacterial Blight resistance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• <em>Pflp, EFR</em> genes</td>
<td></td>
</tr>
<tr>
<td>Soil Management</td>
<td>NEWEST Rice</td>
<td>• <em>HvAlaAT</em></td>
<td>• Nitrogen Use Efficient (NUE)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• <em>AtuIPT</em></td>
<td>• Water Use Efficient (WUE)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• <em>OsNHX1</em></td>
<td>• Salt Tolerance (ST)</td>
</tr>
<tr>
<td>Improved breeding</td>
<td>Hybrid Rice</td>
<td>• Parental lines (S and P)</td>
<td>• High yields</td>
</tr>
<tr>
<td>methods</td>
<td></td>
<td></td>
<td>• Quality</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Aroma</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Milling value</td>
</tr>
<tr>
<td>Mechanization</td>
<td>CAMAP</td>
<td>• Specialized cassava machinery for Planting, Harrowing, weeding, harvesting etc.</td>
<td></td>
</tr>
<tr>
<td>Enabling Environment</td>
<td>COMPROII, OFAB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food Quality and Safety</td>
<td>USDA-FAS</td>
<td>• <em>Aflasafe</em></td>
<td>• Atoxigenic strains of <em>Aspergillus flavus</em></td>
</tr>
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From Classical Breeding to Molecular Breeding

Plant Biotech innovation
Example 1: Doubled Haploid (DH) Technology

- This technology generates pure lines in 1 or 2 generations, saving time in inbred line and hybrid development.

- A DH facility is established and operational in Kiboko, Kenya through the WEMA project, which AATF is leading (Odiyo et al. 2014; Ougo et al. 2014; Sserumaga et al. 2015).
Example 2: MARS/GS Application in WEMA for Drought Tolerant Maize

Drought conditions

Optimum conditions
Strengthening Sustainability into Agriculture
Enhancement of Agricultural Sustainability through Plant Breeding and Biotech

Plant breeding and biotech advancement for precision development of product has huge potential to strengthen sustainability of food & nutrition security in Africa:

- **Stewardship** – Genetic purity of products, efficient use of technology with better results/outputs on a long term basis, QA/QC

- **Science based regulatory systems** - supports evidence –based product development

- **Fast tracking release of new demand-responsive varieties on time**

- **Improved confidence of the Private sector investment in better products**

- **Commercially amenable product** – hybrid technology (seed purchase)

- **Pyramiding of genes creates long term product stability and impact e.g. horizontal Resistance using Cry1Ab and Cry2Ab**

- **Improved value for money at production, processing and marketing levels with overall value chain development**

However, sustainability is not driven by genetics-based technologies alone
Systems Approach to Sustainability

- Service Provision
- IT Solutions & Farmer Aggregation Platform
- Inputs & Extension Capacity Building
- Finance and Insurance
- Markets
Trials established using minimum fertilizer input for proof of concept

At farmer’s input level, hybrid rice is profitable (extra profit of US$365 – 1747)

Increasing the input might economically increase the yield or not

Trials on the effect of increased fertilizer input on performance of the hybrids will be investigated in next phase of project

The mean yield of the 15 hybrids > Best commercial check

8 hybrids yielded better than the mean of the 15 hybrids
Maximizing Productivity Benefits from Genetic Gain

Synergistic interaction of breeding and agronomy was used during “Green Revolution”

AATF is leading CAMAP initiative for cassava as a first crop with intent to cover other crops as well through AgriDrive
Tackling Infrastructural Challenges for Phenotyping

1200m² of plant production space

Plant Phenomics Platform

AATF facilitated facilities for CRI, Ghana and NCRI, Nigeria under NEWEST rice Project
Enabling Environment: Current Status of Regulatory Terrain in Africa

The best technologies will not see light of day if the environment is not right

- Advocacy
- Regulatory & Policies

Countries with GM Project Activities
1. South Africa
2. Burkina Faso
3. Nigeria
4. Cameroun
5. Ghana
6. Ethiopia
7. Kenya
8. Tanzania
9. Mozambique
10. Malawi
11. Sudan
12. Egypt
13. Swaziland
Conclusion

- Classical breeding and plant biotechnology are inalienable and complementary
- Africa’s food and nutrition security cannot be solved without the best of science
- Transforming Africa from subsistence farming to commercial agriculture for agribusiness driven demand for best technologies
- Crop improvement must transform to commercial breeding to explore and create new market niches
- Apt policies to develop an enabling environment are crucial to drive the agricultural sector for sustainability
- Integrated system built on strong partnerships of players in the public and private sectors of value chain is critical to sustainability
- We need every tool in the box
Thank You!

Map shows the areas AATF is working in and the crops