Generation, adaptation and adoption of appropriate biotechnologies in the Latin America and the Caribbean Region: Concrete actions for the near future

Rodomiro Ortiz
Consultant, Lima, Perú

rodomiroortiz@gmail.com

ABCD-10 3 March 2010 Session Sponsors
Outline

• Sustainable crop production intensification by smallholders and family agriculture (focus)
• Agro-biotech assessment in the Region
• Molecular breeding that address abiotic and biotic stresses, genetic base narrowing and yield gap, nutritional enhancement, and sustainable and environmental friendly crop production
Agro-biotechnology and sustainable agriculture

• Conserving plant genetic resources by providing better insights into crop endowments

• Preserving the environment by reducing pesticide use or facilitating conservation agriculture practices

• Responding to social requirements by targeting improvement of traits to meet end user demands

• Being economically competitive and profitable as shown by the use of some agro-biotechnology products (including knowledge therein)
Agriculture and food in Latin America and the Caribbean (LAC) – a briefing

- 15 million farms and over 100,000 agricultural small-to-medium size plants that process food and agricultural products or produce inputs, contributing between 20 to 35% to the GDP
- One hectare of land should feed 1 person in 2050 whereas it fed 0.7 and 0.5 persons in 2000 and 1965
- Slight annual average grain yield growth of about 1.25 yr\(^{-1}\) and total cereal area may expand by 9% by 2050
- Sharp increase of net meat exports though the per capita demand for cereals will fall by 11 kg
Agric. production growth in Latin American but not in the Caribbean.
Challenges for agriculture in LAC

Inter-American Inst. Coop. in Agriculture (IICA)
• making agriculture more competitive
• achieving equity in agriculture + rural milieu
• adopting a more sustainable paradigm
• promoting governance in rural areas

FORAGRO
• Promoting a knowledge-led agriculture following an innovation systems perspective, which needs to consider innovating technology, policy and institutions
The challenge
Future challenges

- Anticipate abiotic and biotic stresses ensuing from global climate change
- Efficient use of crop biodiversity with the aid of new tools such as agro-biotechnology, GIS, bioinformatics ...
- Understand and respond to end-user demands for crops, their processing and other uses
- Potential use of biotech crops for increasing yields and food quality, preserving the environment and reducing production costs

Photo: CIMMYT
Agro-biotech in LAC

- Tissue culture in crops for mass propagation of pathogen-tested propagules, *in vitro* seed germination (often after inter-specific hybridization), haploidy, chromosome doubling, mutagenesis, somaclonal variation or DNA-recombinant technology for diagnostics of pathogens and pests
- Genetic engineering (transgenic crops)
- Genomics-led breeding (incl. genome sequencing)
Crop breeding methods

CONVENTIONAL BREEDING
Breeding based on the appearance of different plants.

- Plant 1
- Plant 2

The breeder looks for plants with certain characteristics such as 'many fruits' or 'round tomatoes'. Subsequently, he crossbreeds the plants. The genes of these plants will be mixed.

The new plant will have the characteristics of both parents. The characteristics of this new plant cannot be determined in advance. Afterwards, when the plant is grown, it can be determined if the plant has many tomatoes and round tomatoes, and then the selection of the plants can begin.

GENOMICS
Breeding based on the DNA of different plants.

- Plant 1
- Plant 2

The breeder looks for plants with certain characteristics such as 'many fruits' or 'round tomatoes'. He determines which genes are responsible for these characteristics.

The breeder then will crossbreed the plants with the desired characteristics. This is faster than with conventional breeding.

- DNA
- desired gene

Only the desired gene will be transferred instead of crossbreeding two plants.

GENETIC MODIFICATION
Breeding based on the DNA of different plants.

- DNA
- Plant 1

With genetic modification, one characteristic will be cut-out of the DNA. This characteristic will be added without changing the other characteristics.

To be sure that the new gene will provide the plant with the desired characteristic, several generations of plants will be grown.
Molecular breeding in LAC

- Capacity to perform transgenic crop improvement: Argentina, Brazil, and Mexico
- Ability to use conventional and modern breeding techniques: Chile, Colombia, Costa Rica, Perú and Uruguay
- Low capacity for conventional breeding + lacking ability for modern agro-biotechnology applications: Central America as well as Bolivia, Dominican Republic and Paraguay
21st Century Crops

- Host plant resistance to pathogens and pests
- Nutritional quality of healthy food
- Genetic yield potential
- Herbicide tolerance for conservation agriculture
- Adaptation to abiotic stresses

Norman E. Borlaug 2005
Impacts of *Bt*-maize in Argentina

• Grown in **41.9%** of the 23.5 million ha (2006)
• **4.8 million t** of additional grain after introducing in 1998 this gene technology
• Production could fall **3.1%** without *Bt*-maize
• Accumulated benefits of *Bt*-maize: **US$ 481.7 million** (1998-2005), of which farmers get 43.19%, seed suppliers 41.14% and the National Government 15.67%

*Sources:* Brookes *et al.*, 2010; Trigo and Cap, 2006
Annual growth rates of maize grain yield (kg ha\(^{-1}\))

Source: Mezzalama et al. 2010
Roundup Ready® soybean impact

• **Argentina**: US$ 19.7 billion (1996-2006), of which 77.5% went to farmers, 3.9% to seed suppliers, 5.2% to herbicide suppliers and 13.4% to the National Government (export tax)

• **Argentina and Paraguay**: facilitated the adoption of no-tillage, thereby shortening the crop cycle and allowing a second crop that added 53.1 t of soybeans

**Sources**: Brookes *et al.*, 2010; Trigo and Cap, 2006
Bt-cotton

• **Argentina**: US$ 20.8 million; of which 86.19% to farmers, 8.94% to seed suppliers and 4.87% to the National Government (1998-2005) (initial adoption low because of seed costs, but black market ...)

• **Mexico**: Annual benefits of US$ 2.7 million after introducing in 1996. Adopting farmer — with an average holding of 14 ha — spent below US$ 100 on pest control and their net revenue was US$ 295 ha$^{-1}$ than non-adopting farmers

**Sources**: Traxler and Godoy Avila, Trigo and Cap, 2006
Gene flow hits the headlines: The Mexican maize controversy

Transgenes in Mexican maize: Desirability or inevitability?

Peter H. Raven*
Missouri Botanical Garden, P.O. Box 299, St. Louis, MO 63166

Absence of detectable transgenes in local landraces of maize in Oaxaca, Mexico (2003–2004)

S. Ortiz-Garcia†, E. Ezcurre‡, B. Schöel§, F. Acevedo∥, J. Soberón¶, and A. A. Snow∆

*Instituto Nacional de Ecología, Secretaría del Medio Ambiente y Recursos Naturales, Avenue Periférico Sur 5000, Colonia Insurgentes Cuauhtémoc, Delegación Coyocacán, 04300 México D.F., Mexico; ‡Genetic ID North America, Inc., Fairfield, IA 52556; ¶Comisión Nacional para el Conocimiento y Uso de la Biodiversidad en México, Avenida Línea Periférico-Insurgentes Sur 4800, Colonia Frayces del Pedregal, Delegación Tlalpan, 14010 México, D.F., México; and ∆Department of Evolution, Ethology, and Organismal Biology, Ohio State University, Columbus, OH 43210


Editorial

No Credible Scientific Evidence is Presented to Support Claims that Transgenic DNA was Introgressed into Traditional Maize Landraces in Oaxaca, Mexico

Paul Christou (on behalf of the Editorial Board)
Lessons from the case in Mexico

Traditional Mexican agricultural systems and the potential impacts of transgenic varieties on maize diversity

Mauricio R. Bellon¹ and Julien Berthaud²
¹International Maize and Wheat Improvement Center (CIMMYT), Mexico DF, Mexico; ²Institut de Recherche pour le Développement (IRD), Montpellier, France

- **Farmers’ behavior** is expected to have a significant influence on causing transgenes to diffuse, to be expressed differently, and to accumulate within landraces
- **Farmers’ or consumers’ perceptions** that transgenes are “contaminants” and that landraces containing transgenes are “contaminated” could cause these landraces to be rejected and trigger a direct loss of diversity
Environmental biosafety and transgenic potato in a centre of diversity for this crop

Carolina Celis\textsuperscript{1,*}, Maria Scurrah\textsuperscript{2,*}, Sue Cowgill\textsuperscript{3,*}, Susana Chumbiauca\textsuperscript{2,*}, Jayne Green\textsuperscript{4,*}, Javier Franco\textsuperscript{5,*}, Gladys Main\textsuperscript{6,*}, Daan Kleeba\textsuperscript{7,*}, Richard G. F. Visser\textsuperscript{1} & Howard J. Atkinson\textsuperscript{1}

\textsuperscript{1}Laboratory of Plant Breeding, Wageningen University, PO Box 386, 6700 AJ, Wageningen, The Netherlands
\textsuperscript{2}SENASA, Pedro de Pasaje Fransisco de Zela No. 150 piso 10, Ministerio de Agricultura, Lima 11, Lima, Peru
\textsuperscript{3}Centre for Plant Sciences, University of Leeds, Leeds LS2 9JT, UK
\textsuperscript{4}Fundación PROINPA, Av. Blanco Galindo km 121/2, PO Box 4285, Cochabamba, Bolivia

\begin{itemize}
  \item Research on \textbf{GM-potato} clones that provide \textbf{resistance to nematodes}, principal pests of Andean potato crops
  \item \textbf{No harm to many non-target organisms}, but gene flow occurs to wild relatives growing near potato crops
  \item If stable introgression were to result, the \textbf{fitness} of these wild species could be altered
  \item \textbf{GM-male sterile cultivar} provides an option for producing GM-nematode-resistant potato to assess benefits until the possibility of stable introgression to wild relatives is determined
  \item \textbf{Scientific progress} is therefore possible without compromise to the \textbf{precautionary principle}
\end{itemize}
Post-release GM-crop monitoring

Key steps or actions

• Set monitoring program goals and immediate objectives
• Identify potential barriers
• Identify potential risks and benefits
• Develop a testing hypothesis to guide actions and decisions
• Identify a limited number of potential indicators
• Determine appropriate trigger values for decision making and action
• Cultivate a transparent and effective process
Genomics to unlock crop diversity in LAC

• Molecular markers are descriptors that offer reproducible results for characterizing genotypes
• DNA markers can be also used for identifying duplicate genebank accessions, determining out-crossing rates and effective population sizes, and revealing population structure of the crop and its wild species, or elucidating crop domestication
Marker-aided selection for smart crop breeding in Latin America

Choose Germplasm

Create 3 data sets from the germplasm set

- Phenotype Traits in Multi-location Trials (T)
- Measure population structure using neutral markers (Q matrix) or Coefficient of Parentage (K Matrix) (or both, Q+K)
- Find SNP polymorphisms in candidate gene(s) (C) or high density markers (within LD)

Association Analysis:

\[ T = C + (Q+K) + E \]
• Mapped **DArT markers** to find associations with trait variation in CIMMYT wheat international **multi-environment trials**

• Two **linear mixed models** were used to assess marker‐trait associations incorporating information on **population structure** and **covariance between relatives**

• **Integrated map**: 813 DArT and 831 other markers

• Several linkage disequilibrium **clusters bearing multiple host plant resistance genes**

• **Modeling** genotype x environment interaction, and **identifying markers** contributing to both additive and additive x additive interaction
The Palomero Genome Suggests Metal Effects on Domestication


Fig. 1. (A) Cob of Palomero Toluqueño EMX-2233; scale bar indicates 1 cm. (B) Colocalization of SMS1 and SMS33 (each containing a heavy-metal–detoxification gene) with the predicted location of a major QTL for domestication (blue asterisk) in the short arm of chromosome 5 (2). SMS18 (also containing a heavy-metal–detoxification gene) maps within the range of the centromere.
The role of public-private agro-biotechnology partnerships in LAC

- **PPP**: multi-stakeholder, participative, research collaboration between the public and private sectors in which each sector contributes to the planning, resources, and activities needed to accomplish a mutual objective.

- Partnerships between technology providers and the productive sector pool scarce resources for innovation that provide solutions to the needs of farmers, consumers, and agro-industry.
PPP for developing and deploying agro-biotechnology for smallholders in LAC

• “Honest broker” contributes its leadership, unique experience in public-private partnership management, technology stewardship and project management expertise
• Public sector provides locally adapted crop germplasm and expertise in plant breeding and its field testing network
• Private sector brings proprietary germplasm, advanced breeding tools and expertise, and desired transgenes
Agro-biotechnology regional networking and platforms

SNIA in LAC, Univs. In LAC, ARIs elsewhere ...
Agro-biotechnology for development ...

- Health
- Livelihoods
- Dreams