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

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ABCD-10 3 March 2010 Session Sponsors

IICA

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Red de Cooperación Técnica en Biotecnología Agropecuaria para América Latina y el Caribe

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

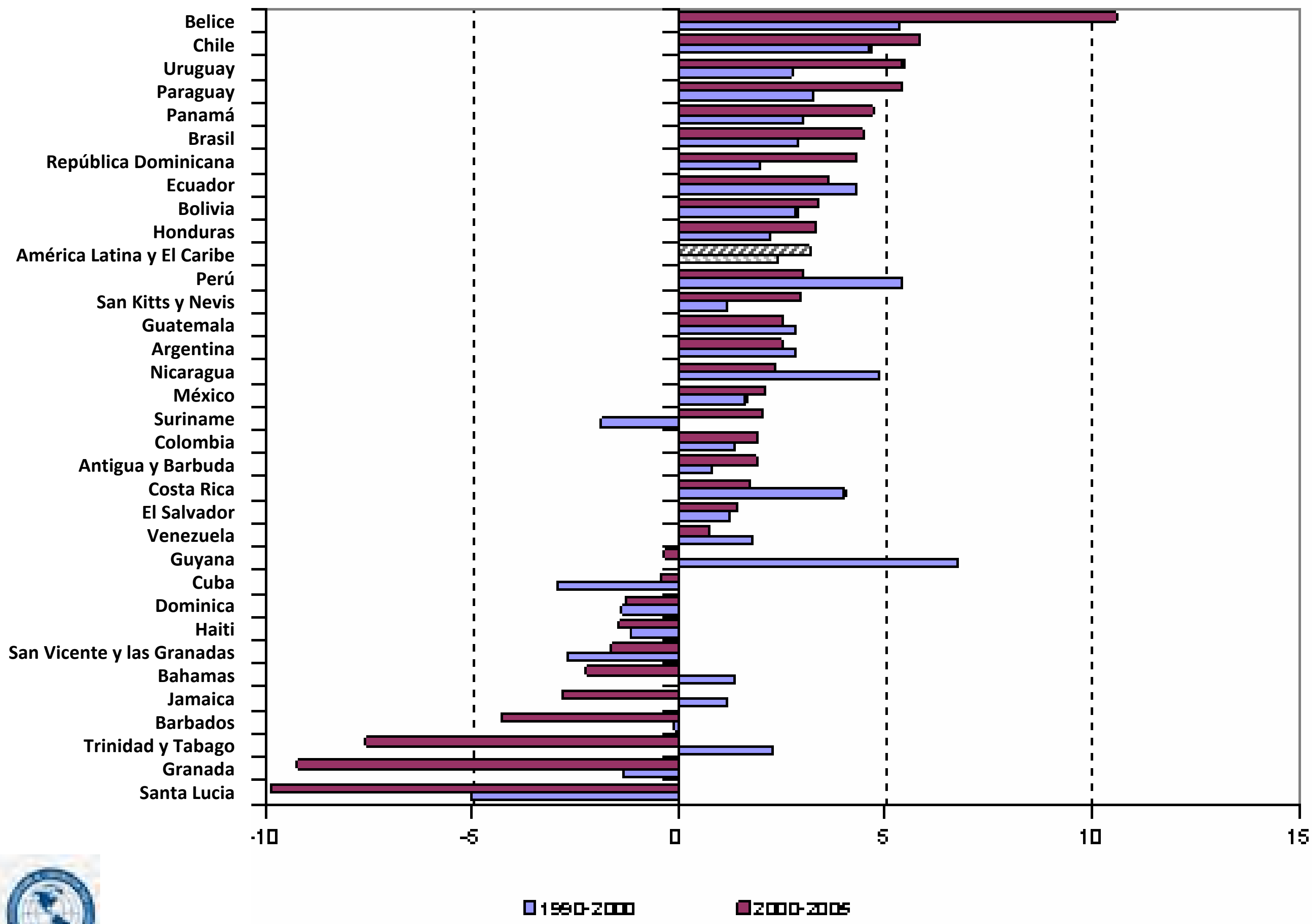
Agro-biotechnology and sustainable agriculture

- 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

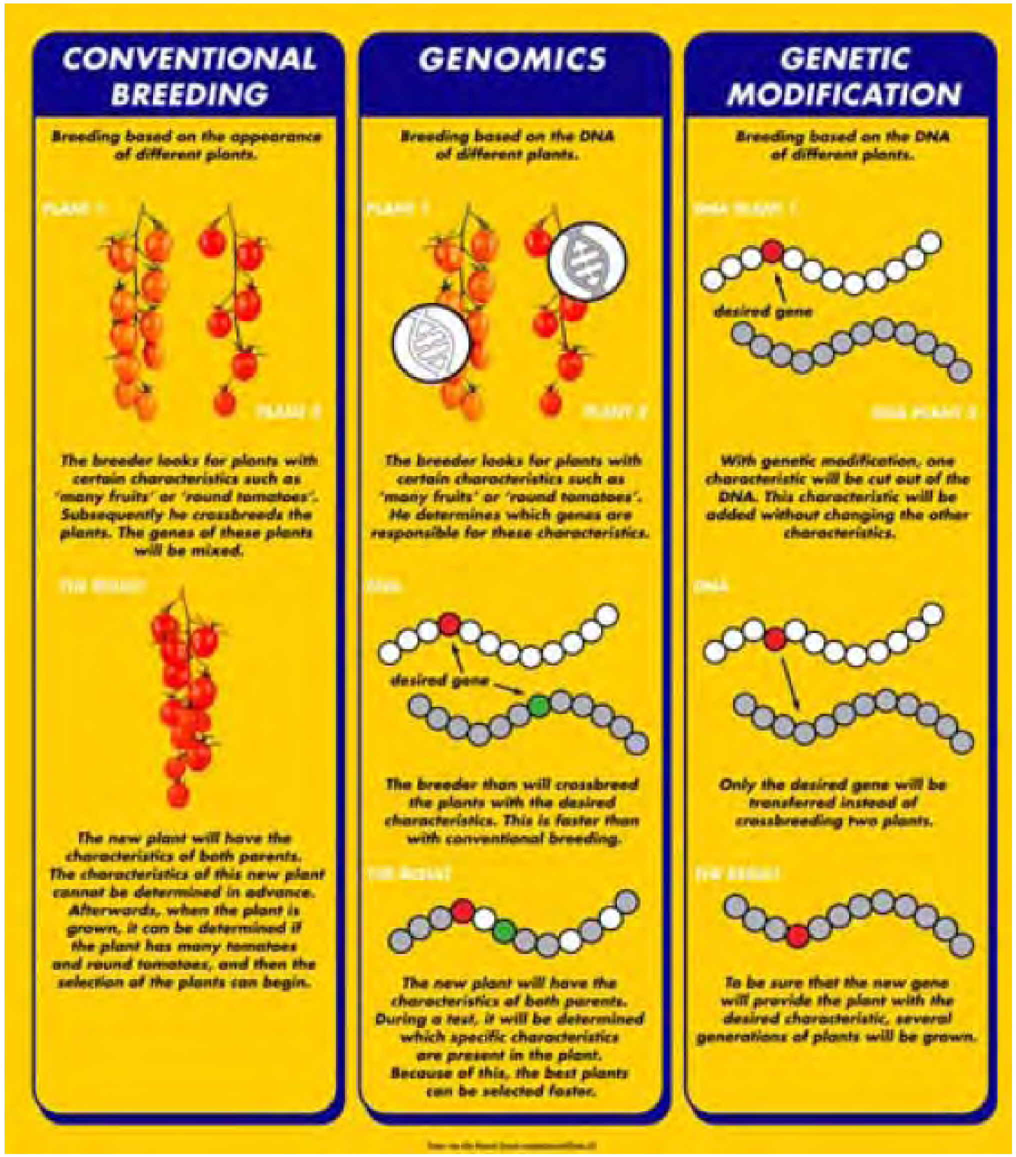
- Anticipate abiotic and biotic stresses ensuing from global climate change
- Efficient use of crop biodiversity with the aid of new tools such as agro-biotechnology, GIS, bioinformatics …
- Understand and respond to end-user demands for crops, their processing and other uses
- Potential use of biotech 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



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

Herbicide tolerance for conservation agriculture

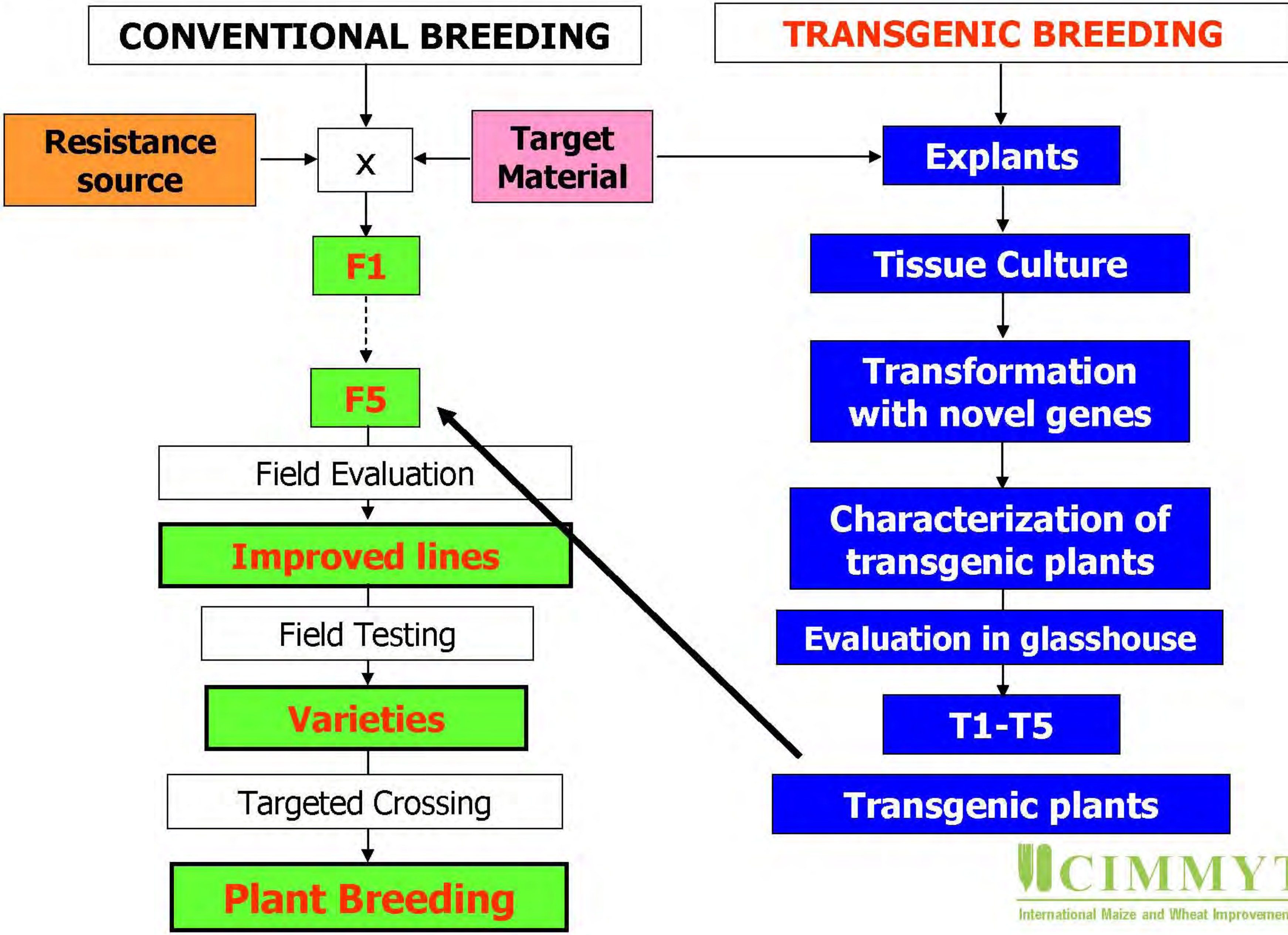
Nutritional quality of healthy food

Adaptation to abiotic stresses

Genetic yield potential

Norman E. Borlaug 2005

TRANSGENIC GENETIC ENHANCEMENT



CIMMYT MR
International Maize and Wheat Improvement Center

Global Status of Commercialized Biotech/GM Crops: 2008

Major Biotech Crops

Soybean

- 70% (65.8 million has.) of total global soybean planted is biotech
- US$4B increase in farmer income in 2007
- Countries growing biotech soybean: *Argentina, Bolivia, Brazil,* Canada, Chile, *Mexico, Paraguay, Uruguay, South Africa,* and the USA.

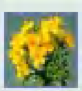
Cotton

- 46% (15.5 million has.) of total global cotton planted is biotech
- US$3.3B increase in farmer income in 2007
- Countries growing biotech cotton: *Argentina,* Australia, *Brazil, Burkina Faso, China, Colombia, India, Mexico, South Africa,* and the USA.

Maize

- 24% (37.3 million has.) of total global maize planted is biotech
- US$2.4B increase in farmer income in 2007
- Countries growing biotech maize: *Argentina, Brazil,* Canada, Chile, Czech Republic, *Egypt,* Germany, *Honduras, Philippines,* Poland, Portugal, Romania, Slovakia, *South Africa,* Spain, *Uruguay,* and the USA.

Canola



- 20% (5.9 million has.) of total global canola planted is biotech
- US$0.4B increase in farmer income in 2007
- Countries growing biotech canola: Canada, *Chile,* and the USA.

#21 Portugal
<0.05 Million Has.
Maize

#14 Spain*
0.1 Million Has.
Maize

#22 Germany
<0.05 Million Has.
Maize

#19 Czech Republic
<0.05 Million Has.
Maize

#23 Poland
<0.05 Million Has.
Maize

#24 Slovakia
<0.05 Million Has.
Maize

#20 Romania
<0.05 Million Has.
Maize

#25 Egypt
<0.05 Million Has.
Maize

#5 Canada*
7.6 Million Has.
Canola, Maize, Soybean, Sugar beet

#1 USA*
62.5 Million Hectares
Soybean, Maize, Cotton, Canola, Squash, Papaya, Alfalfa, Sugar beet

#13 Mexico*
0.1 Million Hectares
Cotton, Soybean

#17 Honduras
<0.05 Million Hectares
Maize

#16 Colombia
<0.05 Million Hectares
Cotton, Carnation

#6 China*
3.8 Million Has.
Cotton, Tomato, Poplar, Petunia, Papaya, Sweet Pepper

#4 India*
7.6 Million Has.
Cotton

#10 Philippines*
0.4 Million Has.
Maize

#18 Burkina Faso
<0.05 Million Has.
Cotton

#11 Australia*
0.2 Million Has.
Cotton, Canola, Carnation

#10 Bolivia*
0.6 Million Hectares
Soybean

#15 Chile
<0.05 Million Hectares
Maize, Soybean, Canola

#2 Argentina*
21.0 Million Hectares
Soybean, Maize, Cotton

#9 Uruguay*
0.7 Million Hectares
Soybean, Maize

#7 Paraguay*
2.7 Million Hectares
Soybean

#3 Brazil*
15.8 Million Has.
Soybean, Maize, Cotton

#8 South Africa*
1.8 Million Has.
Maize, Soybean, Cotton

* 14 biotech mega-countries growing 50,000 hectares, or more, of biotech crops.

Global Area of Biotech Crops in 2008: by Country (Million Hectares)

Country	Area	Biotech crops
USA*	62.5	Soybean, maize, cotton, canola, squash, papaya, alfalfa, sugar beet
*Argentina**	21.0	Soybean, maize, cotton
*Brazil**	15.8	Soybean, maize, cotton
*India**	7.6	Cotton
Canada*	7.6	Canola, maize, soybean, sugar beet
*China**	3.8	Cotton, tomato, poplar, petunia, papaya, sweet pepper
*Paraguay**	2.7	Soybean
*South Africa**	1.8	Maize, soybean, cotton
*Uruguay**	0.7	Soybean, maize
*Bolivia**	0.6	Soybean
*Philippines**	0.4	Maize
Australia*	0.2	Cotton, canola, carnation
*Mexico**	0.1	Cotton, soybean
Spain*	0.1	Maize
Chile	<0.1	Maize, soybean, canola
Colombia	<0.1	Cotton, carnation
Honduras	<0.1	Maize
Burkina Faso	<0.1	Cotton
Czech Rep.	<0.1	Maize
Romania	<0.1	Maize
Portugal	<0.1	Maize
Germany	<0.1	Maize
Poland	<0.1	Maize
Slovakia	<0.1	Maize
Egypt	<0.1	Maize

* 14 biotech mega-countries growing 50,000 hectares, or more, of biotech crops.
Developing countries in italics

Biotech Crop Traits:

- Herbicide tolerance (HT)
- Insect resistance (IR)
- Virus resistance (VR)
- Delayed ripening (DR)
- Stacked traits (IR/HT, IR/IR, IR/IR/HT)

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Or visit: http://www.isaaa.org

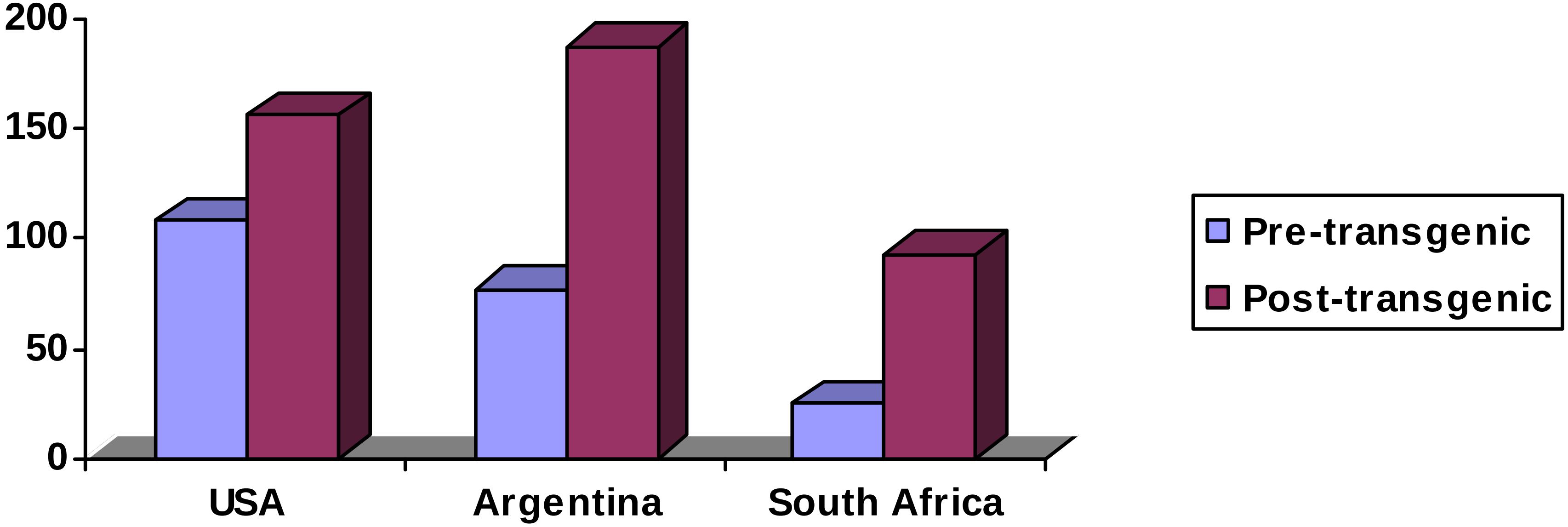
Source: Clive James, 2008. Global Status of Commercialized Biotech/GM Crops: 2008. ISAAA Briefs No. 39-2008.

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 which77.5% 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-García[*], E. Ezcurra[*†], B. Schoel[‡], F. Acevedo[§], J. Soberón[§¶], and A. A. Snow[‖**]

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Transgenic Research **11:** iii–v, 2002.

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

Agriculture and Human Values (2006) 23: 3–14
DOI 10.1007/s10460-004-5861-z

Traditional Mexican agricultural systems and the potential impacts of transgenic varieties on maize diversity[1]

Mauricio R. Bellon[1] and Julien Berthaud[2]
[1]International Maize and Wheat Improvement Center (CIMMYT), Mexico DF, Mexico; [2]Institut de Recherche pour le Développ ement (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[1*], Maria Scurrah[2*], Sue Cowgill[3*], Susana Chumbiauca[2*], Jayne Green[3*], Javier Franco[4], Gladys Main[4], Daan Kiezebrink[3], Richard G. F. Visser[1] & Howard J. Atkinson[3]

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

NATURE | VOL 432 | 11 NOVEMBER 2004 | www.nature.com/nature

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

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

GENETICALLY MODIFIED ORGANISMS IN CROP PRODUCTION AND THEIR EFFECTS ON THE ENVIRONMENT: METHODOLOGIES FOR MONITORING AND THE WAY AHEAD

EXPERT CONSULTATION
18–20 January 2005

Food and Agriculture Organization
Rome, Italy

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:

$$T=C+(Q+K)+E$$

Association Analysis of Historical Bread Wheat Germplasm Using Additive Genetic Covariance of Relatives and Population Structure

José Crossa,*,[1] Juan Burgueño,* Susanne Dreisigacker,* Mateo Vargas,*
Sybil A. Herrera-Foessel,* Morten Lillemo,[†] Ravi P. Singh,* Richard Trethowan,[‡]
Marilyn Warburton,* Jorge Franco,[§] Matthew Reynolds,*
Jonathan H. Crouch* and Rodomiro Ortiz*

Genetics 177: 1889–1913 (November 2007)

- 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

Genome-sequencing in Latin America

The Palomero Genome Suggests Metal Effects on Domestication

Jean-Philippe Vielle-Calzada,* Octavio Martínez de la Vega,* Gustavo Hernández-Guzmán, Enrique Ibarra-Laclette, Cesar Alvarez-Mejía, Julio C. Vega-Arreguín,† Beatriz Jiménez-Moraila, Araceli Fernández-Cortés, Guillermo Corona-Armenta, Luis Herrera-Estrella,‡ Alfredo Herrera-Estrella

Cinvestav
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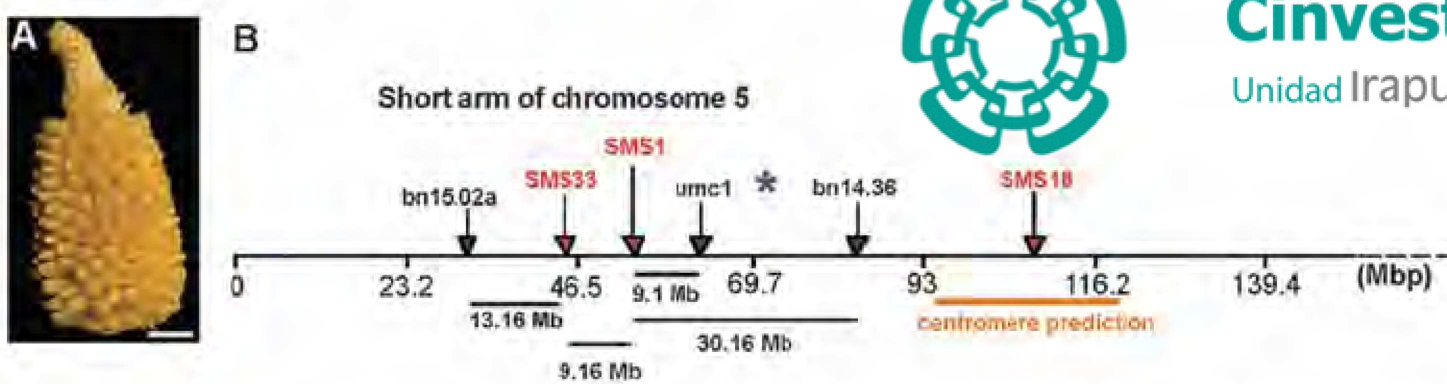

Fig. 1. (**A**) Cob of *Palomero Toluqueño EMX-2233*; scale bar indicates 1 cm. (**B**) Colocalization of SMS1 and SMS33 (each containing a heavy-metal–detoxification gene) with the predicted location of a major QTL for domestication (blue asterisk) in the short arm of chromosome 5 (*2*). SMS18 (also 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

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SNIAs in LAC, Univs. In LAC, ARIs elsewhere …

Agro-biotechnology for development …

- Health
- Livelihoods
- Dreams