

# FAO Technical Conference: ABDC-10



## Biotechnology in the CGIAR

**Thomas Lumpkin**

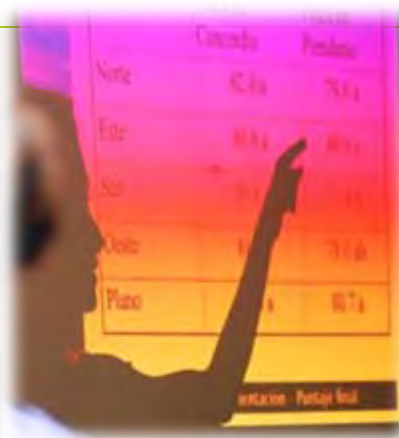
Director General (CIMMYT)

International Maize and Wheat Improvement Center



# Presentation Overview

- **Overview of the CGIAR.**
- **Biotechnology applications in CGIAR research.**
- **Issues, Constraints, and Opportunities.**



*Photo credits: CGIAR Centers and Programs*

# Dr. Norman E. Borlaug

## Father of the Green Revolution





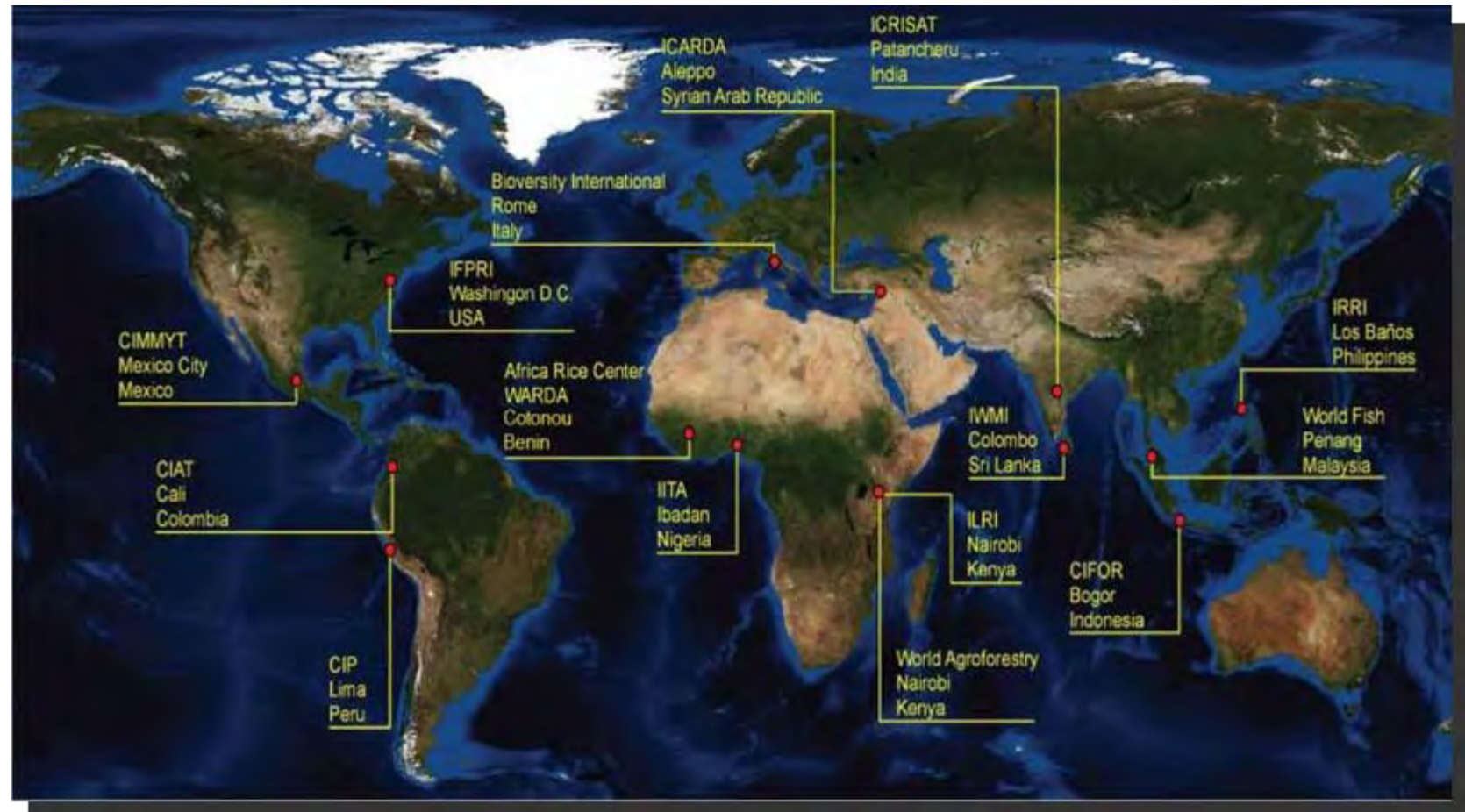
# Overview of the CGIAR

- Consultative Group on International Agricultural Research
- CGIAR has 64 public and private members including:
  - 21 developing and 26 industrialized countries,
  - 4 co-sponsors (World Bank, FAO, IFAD, UNDP)
  - 13 other international organizations
- Created in 1971 to support 15 international ag. centers
- Total funding in 2008: US\$ 531 million
- Centers conserve and produce ag. diversity and tech.



# CGIAR Around the Globe

A network of 15 agriculture research centers, 8,500 scientists and staff operating in over 100 countries



# International Research Centers of the CGIAR

- **Africa Rice Center**
- **Bioversity International**
- **CIAT** - Centro Internacional de Agricultura Tropical
- **CIFOR** - Center for International Forestry Research
- **CIMMYT** – International Maize and Wheat Improvement Center
- **CIP** - Centro Internacional de la Papa
- **ICARDA** - International Center for Agricultural Research in the Dry Areas
- **ICRISAT** - International Crops Research Institute for the Semi-Arid Tropics
- **IFPRI** - International Food Policy Research Institute
- **IITA** - International Institute of Tropical Agriculture
- **ILRI** - International Livestock Research Institute
- **IRRI** - International Rice Research Institute
- **IWMI** - International Water Management Institute
- **World Agroforestry Centre** (ICRAF)
- **WorldFish Center**



# Cost-Effective Impact

Due to public investment in international agricultural research through the CGIAR,

- World food production is 4-5 percent higher.
- Developing countries produce 7-8 percent more food.
- World food and feed grain prices are 18-21 percent lower.
- 13 to 15 million children do not suffer from malnourishment.

For every US\$1 invested in CGIAR research, \$9 worth of additional food is produced in developing countries.



# CGIAR Genebanks

- The CGIAR Centers safeguard 11 genebanks of seeds which are held in sacred trust and are a vital resource for crop improvement.
- Biotechnology is essential for making good use of these genebanks to develop new cultivars, especially through genetic characterization, gene discovery, and association mapping.



**Biodiversity:** Research on cryopreservation of **17** different plant species.



# Biotechnology for Crop Improvement


Crop improvement, the Green Revolution, has always been central to the CGIAR's research, which today employs the tremendous power of diverse biotechnologies to address the wide range of challenges facing global food security.

# Characterization of Genetic Resources

- AfricaRice: Profiling of New Rice for Africa (NERICA) varieties and fingerprinting of parental germplasm.
- CIMMYT: conservation and characterization of 145,000 accessions of wheat and 26,000 accession of maize.
- ICARDA: Genotyping of thousands of accessions of cereals and legumes.
- ICRISAT: Genotyping Service Laboratory for sorghum, millets, grain legumes and other crops.
- IITA: Characterization of molecular diversity in landraces and breeding materials (banana, cassava, cowpea, cocoa, maize, soybean and yam).
- IRRI: Analysis of the world collection of rice varieties for genetic variation.

# Example: DNA Studies of Genetic Resources

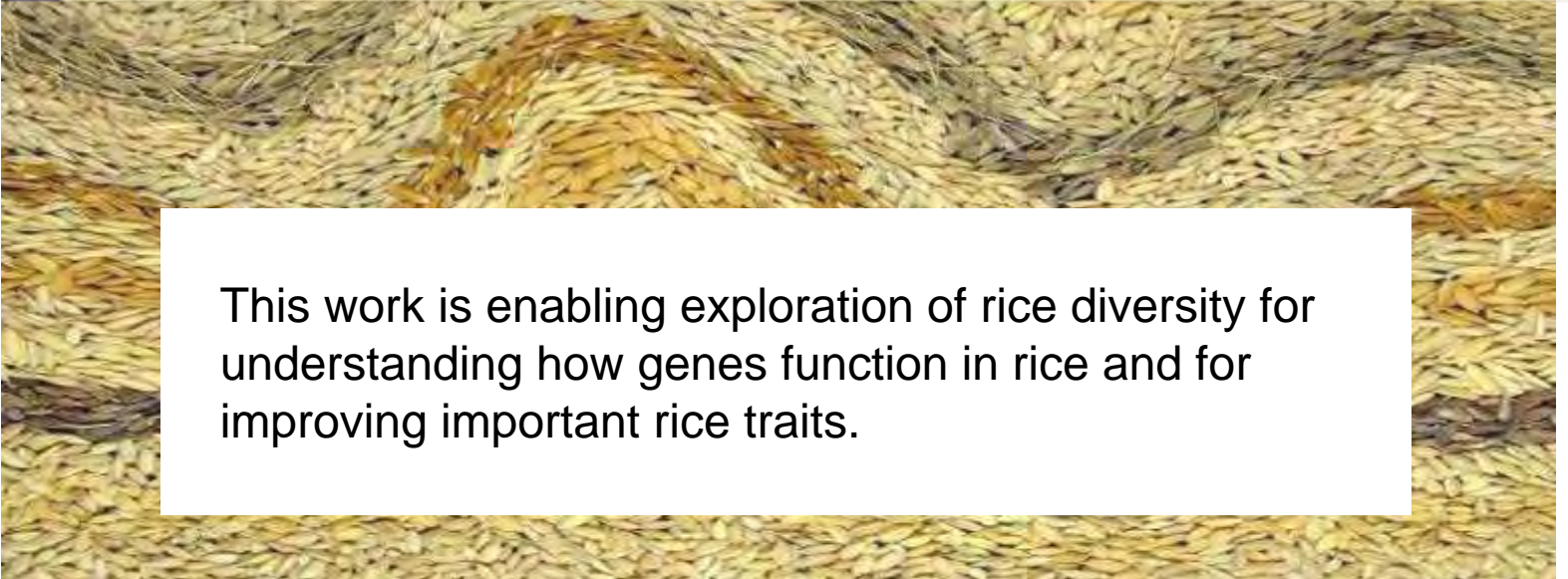
IRRI is analyzing 20 rice varieties for genetic variation to use in developing an association genetics platform



**Genomewide SNP variation reveals relationships among landraces and modern varieties of rice**

Kenneth L. McNally<sup>a,1</sup>, Kevin L. Childs<sup>b</sup>, Regina Bohnert<sup>c</sup>, Rebecca M. Davidson<sup>d</sup>, Keyan Zhao<sup>e</sup>, Victor J. Ulat<sup>a</sup>, Georg Zeller<sup>c,f</sup>, Richard M. Clark<sup>f</sup>, Douglas R. Hoen<sup>g</sup>, Thomas E. Bureau<sup>g</sup>, Renee Stokowski<sup>h</sup>, Dennis G. Ballinger<sup>h</sup>, Kelly A. Frazer<sup>h</sup>, David R. Cox<sup>h</sup>, Badri Padhukasahasram<sup>e</sup>, Carlos D. Bustamante<sup>e</sup>, Detlef Weigel<sup>f</sup>, David J. Mackill<sup>a</sup>, Richard M. Bruskiewich<sup>a</sup>, Gunnar Rättsch<sup>c</sup>, C. Robin Buell<sup>b</sup>, Hei Leung<sup>a</sup>, and Jan E. Leach<sup>d,1</sup>

[www.pnas.org/cgi/dol/10.1073/pnas.0900992106](http://www.pnas.org/cgi/dol/10.1073/pnas.0900992106) PNAS | July 28, 2009 | vol. 106 | no. 30 | 12273-12278



This work is enabling exploration of rice diversity for understanding how genes function in rice and for improving important rice traits.



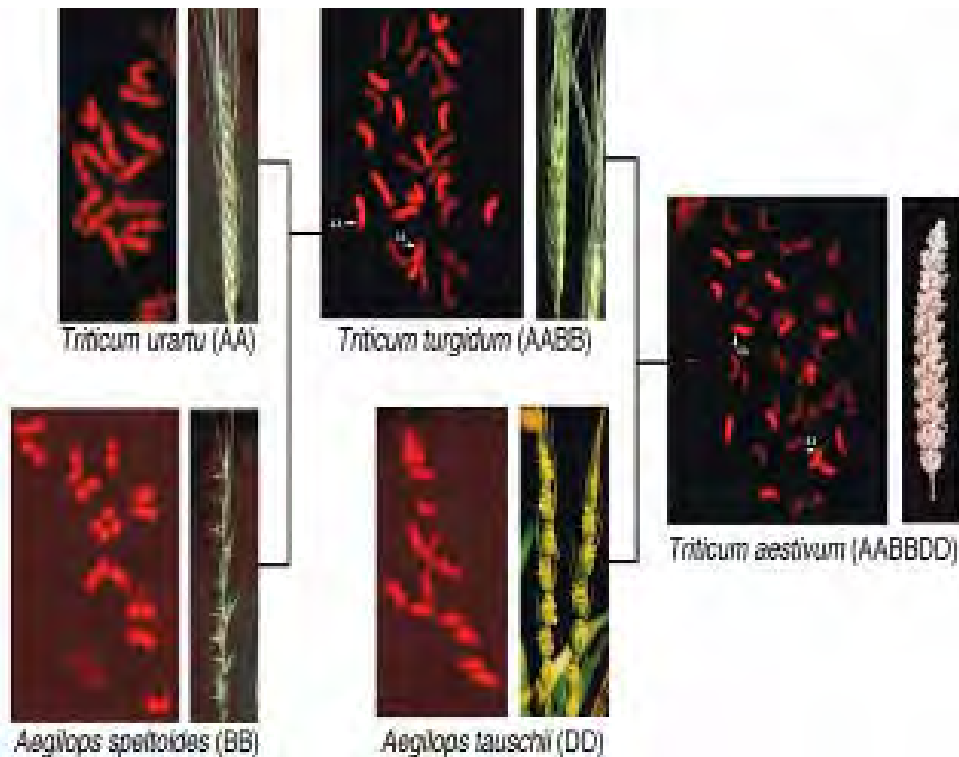
# Example: Genetic Identity Research

- CIP plays a crucial role in conservation of clonally-propagated crops like potato and sweet potato.
- The Center is developing microsatellite markers + genetic identification kits with standard DNA fragment size.



# Examples: Interspecific Hybridization

- AfricaRice, IRRI, CIAT: *O. sativa* x *O. glaberrima*.
  - Incorporating hardiness and other traits from African rice.
- CIMMYT: hexaploid wheat with *Aegilops tauschii* for adaptation to biotic and abiotic stresses.



# Molecular Marker Applications

- CIAT: Mapping QTLs in common bean; MAS for resistance to cassava mosaic disease.
- ICARDA: Allele mining; gene function studies, new marker development; saturated linkage maps; association mapping; MAS for disease resistance.
- ICRISAT: Trait mapping; marker verification; MAS for *Striga* resistance in sorghum and for drought tolerance and downy mildew resistance in pearl millet.
- IITA: Molecular breeding for nutritional quality and tolerance to biotic and abiotic stresses; development of markers for improvement of “orphan” crops.
- IRRI: MAS for submergence tolerance; discovery of QTLs for grain yield under drought.



# Example: CIAT's mapping genes/QTLs of agronomic importance in bean

## Yield

### Adaptation - Morphology

### Biotic Constraints

#### Diseases

Root rots\*  
ALS\*  
Anthracnose\*  
BCMV  
BGMV\*

#### Insects

Apion\*  
Bean Fly  
Empoasca  
Thrips\*  
Whitefly

### Abiotic Constraints

P use efficiency\*  
Al tolerance\*  
Drought tolerance\*  
Sym. Nitrogen Fix.

### Nutrition / Quality

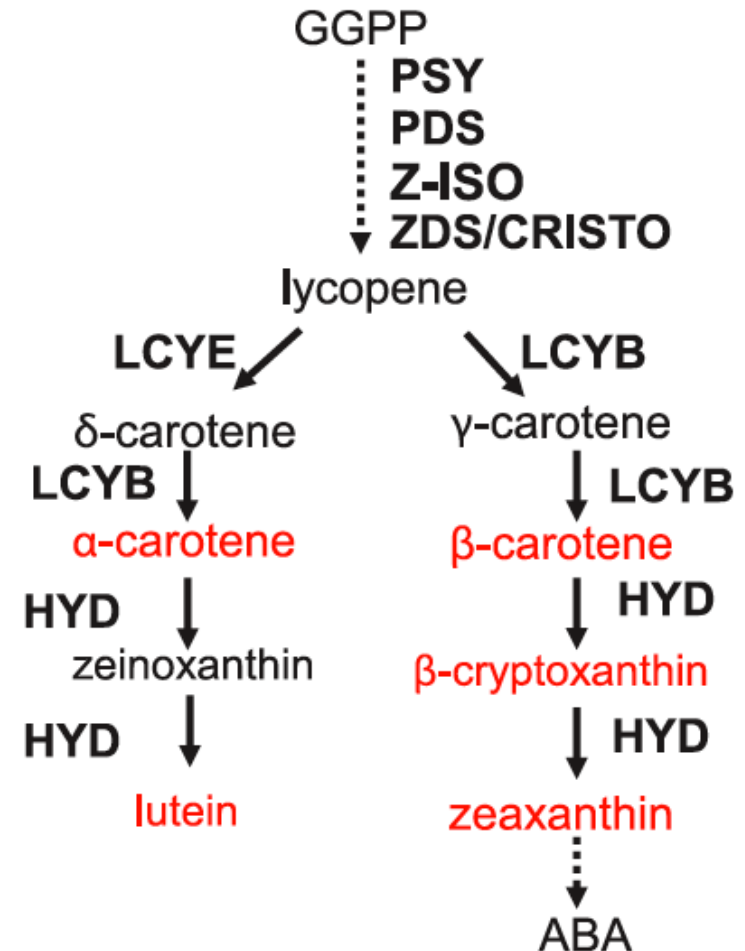
iron - zinc content\*  
protein content



\* linked markers for marker assisted selection

# Example: From Gene Discovery to Breeding CIMMYT and HarvestPlus CP

- Major breakthroughs on carotenoid pathways involved in flux and degradation (Beyer, Dellapena, Rocheford).
- Promoters and target genes identified for maize transformation.
- PCR markers developed for Lycopene Epsilon Cyclase and HYDB1 in temperate maize.
- Identification of the best alleles for LYCe and HYDB1 in tropical maize.



# Biotechnology for Livestock Research (ILRI)

- A platform for pathogen discovery.
- A platform for reverse vaccinology.
- Bovine haplotypes: Linking livestock genetics with value chains.





# Biotechnology for Agroforestry (ICRAF)

- Micropropagation, seed of indigenous species.
- Molecular characterization of medicinal, timber, fruit, soil enriching, and fodder trees.
  - Assess reproductive biology, gene flow.
  - Determine relationships between taxa.
  - Detect hybridization.
  - Study human impacts.



# Program for Biosafety Systems (PBS)

- Managed by IFPRI.
- Critical support to the passage of the Biosafety Bill, Kenya, December 2008.
- Instrumental in the approval of confined field trials for GM banana and cotton in Uganda, GM cotton in Malawi and Kenya, GM cowpea in Nigeria.
- The Common Market for East and Southern Africa (COMESA) Ministerial Council endorsed PBS work to foster harmonized regulatory scheme for region.

# Strengthening National Capacity

- AfricaRice: Short-term training for 60 scientists from Burkina Faso, Gambia, Guinea and Mali.
- Bioversity International: Centers of excellence for short-term training in China, India and Korea; sponsoring research fellowships.
- CIAT: Building biosafety capacity in Brazil, Colombia, Costa Rica and Peru.
- CIMMYT: The Asian Maize Biotechnology Network (AMBIONET).
- ICRISAT: Courses on molecular plant breeding for crop improvement.



# Generation Challenge Program (GCP)

- Launched in August 2003.
- 10-year framework (2004-2008; 2009-2013).
- About US\$15M annual budget.
- Target areas: Harsh, drought-prone environments.
- Mandate CGIAR crops.



**Mission:** *To increase food security and improve livelihoods in developing countries by enhancing the use of public **genetic resources** in plant breeding and providing access to **biotechnology tools** and supported services to conduct **modern breeding in developing countries.***

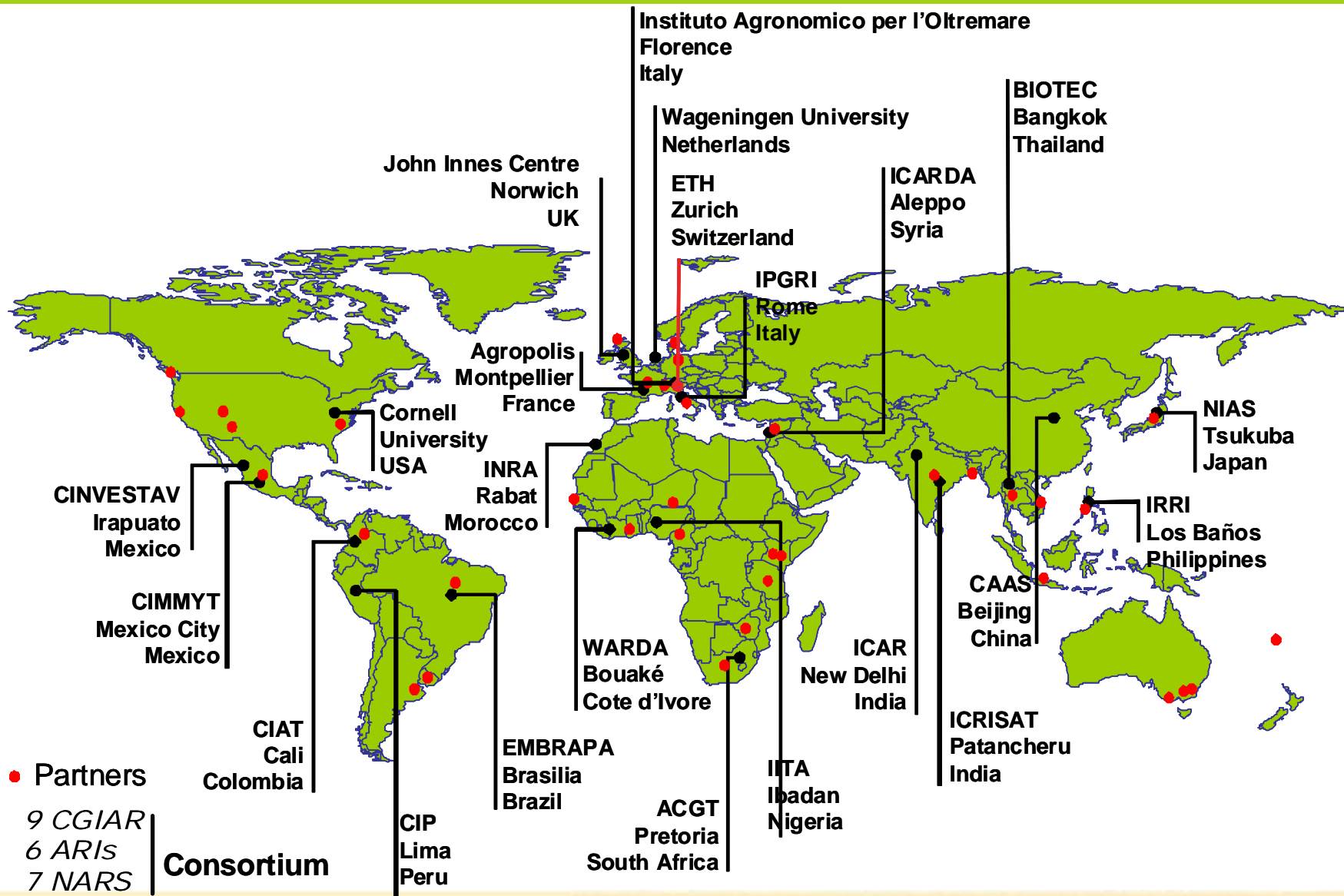


# Selected GCP Outputs (phase 1)

- Genotyping for 21 reference sets of CGIAR mandated crops.
- Mutant collections (rice, potato, bean).
- Genomics resources for orphan crops (e.g. legumes, tubers).
- Validated markers for resistance to downy mildew in maize, diverse pests and diseases in potato, tolerance to Al toxicity in sorghum, salinity and phosphorus deficiency in rice, and drought mainly in chickpea, cowpea, maize, rice, wheat.



# GCP Network



# CGIAR Partnerships for Biotechnology

- **Advanced research institutes** (just a few examples):
  - Asia: CSIRO, ACPFG, Australia; JIRCAS, Japan.
  - Europe: Max Plank Institute, University of Hohenheim, Germany; CIRAD, INRA, France; NIAB, United Kingdom.
  - North America: Cornell University, Washington State University, USA; University of Saskatchewan, Canada.
- **Strong national programs**
  - Chinese Agricultural Academy of Sciences (CAAS).
  - Department of Biotechnology, Government of India.
  - Biosciences eastern and central Africa (BecA) initiative.
- **Large private seed companies**
  - Pioneer Hi-Bred, Syngenta, Monsanto, Limagrain, others.

# Issues, Constraints, and Opportunities (2)

- Diverse capacity of developing country partners.
- Effective public-private partnerships.
- Negotiating access to proprietary intellectual property and advanced technology.
- Cost effective, high-throughput genotyping with rapid cycling technologies for MAS.
- Effective data management / bio-informatics systems.
- Deploying transgenics in the developing world.





# Genetic Transformation Research

- Banana
  - Platform for banana genetic engineering; transformation for resistance to bacterial wilt (Bioversity International; IITA).
- Rice
  - Transformation for tolerance to abiotic stresses (CIAT).
- Maize
  - Drought tolerance, insect resistance and nitrogen use efficiency (CIMMYT).
- Potato / sweet potato
  - Bt, virus resistance, R genes for late blight resistance (CIP).
- Legumes
  - *Integration of BI-GST/GPX, DREB1A, LeTpx1, vst-1 and chitinase genes in the target species, in addition to plant marker genes *bar* and *nptII*. (ICARDA)*



Drought tolerant groundnut containing *DREB1A* gene (ICRISAT).

# CGIAR & the Dilemma of GMO Crops

- Countries-of-origin
- Poverty handicap
- CGIAR donors
- Time and money
- Intellectual property
- Risks:
  - Biosafety
  - Biodiversity
  - Reputation
  - Financial



# Summary: Biotechnology in the CGIAR

- Diverse
- Rapid
- Cost effective
- Transformational
- Controversial
- Essential

