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Biotechnology Research in the CGIAR: An Overview

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The CGIAR is a strategic alliance of members, partners, and 15 international agricultural research centers that mobilizes science to benefit the poor. Agricultural research at the CGIAR Centers entails various technologies, including biotechnology, and the extent to which modern biotechnology is part of the overall research activity differs greatly from center to center. The mode of collaboration between centers and their national counterparts on such research projects also vary. Drawing examples from two in-house surveys as well as from the outcomes of a recent workshop, the article provides a synopsis of current biotech-related activities conducted in the CGIAR Centers and considers what the CGIAR's role(s) might be in ensuring the safe and responsible use of biotechnology for conducting agricultural research that responds to the needs of developing countries.

Key words: biotechnology, biosafety, GM, developing countries, public sector.

Introduction

The Consultative Group on International Agricultural Research (CGIAR) was established in 1971 as a strategic partnership and has now grown to 64 members[1] supporting 15 international centers[2,3] (Figure 1), working in collaboration with governments and civil society organizations as well as the private sector. The CGIAR's mission is to "to achieve sustainable food security and reduce poverty in developing countries through scientific research and research-related activities in the fields of agriculture, forestry, fisheries, policy, and environment" (CGIAR, n.d.).

Today, the CGIAR Centers have more than 8,000 scientists conducting research in more than 100 countries (CGIAR, n.d.). The products and other outcomes are made available as international public goods (IPG),[4] to be utilized for sustainable agricultural development throughout the world. A major role played by scientists at the CGIAR is the collection, characterization, and conservation of plant genetic resources, and the maintenance of genebanks at eleven CGIAR Centers, where more than 650,000 samples of crop, forage, and agroforestry genetic resources are held "in trust" for the world community.

As a major public-sector body engaged in agricultural research for developing countries, the CGIAR has often been asked about its research activities involving the use of modern biotechnology at its centers. More specifically, the question seems to focus on whether GM crops are being developed by the CGIAR Centers; if so, the types of crops/traits under development. Questions have also been raised as to whether the CGIAR actively endorses/embraces or discourages GM crops in general. This article aims to provide a general overview of the CGIAR's policy on modern biotechnology and the current and past transgenic research conducted at the CGIAR Centers. Recent trends and developments in the Centers' research are highlighted, as well as the Centers' ongoing work on biosafety—scientific and policy practices used to ensure the safe use of living modified organisms (LMOs)[5] in research and in food, agriculture, and the environment (CGIAR Science Council, 2007).

1. *The members consist of 21 developing countries, 26 industrialized countries, four co-sponsors, and 13 international organizations.*
2. *The 15 CGIAR Centers are: Africa Rice Center (WARDA), Bioversity International, International Center on Tropical Agriculture (CIAT), Center for International Forestry Research (CIFOR), International Maize & What Improvement Center (CIMMYT), International Potato Center (CIP), International Center for Agricultural Research in the Dry Areas (ICARDA), International Crops Research Institute for Semi-Arid Tropics (ICRISAT), International Food Policy Research Institute (IFPRI), International Institute of Tropical Agriculture (IITA), International Livestock Research Institute (ILRI), International Rice Research Institute (IRRI), International Water Management Institute (IWMI), World Agroforestry Centre (ICRAF), and WorldFish Center.*
3. *The CGIAR was established in 1971 by incorporating existing centers and activities. Other centers were gradually added to the CGIAR. For details, see http://www.cgiar.org/who/history/origins.html.*
4. *For the definition of IPGs, see Ryan (2006).*

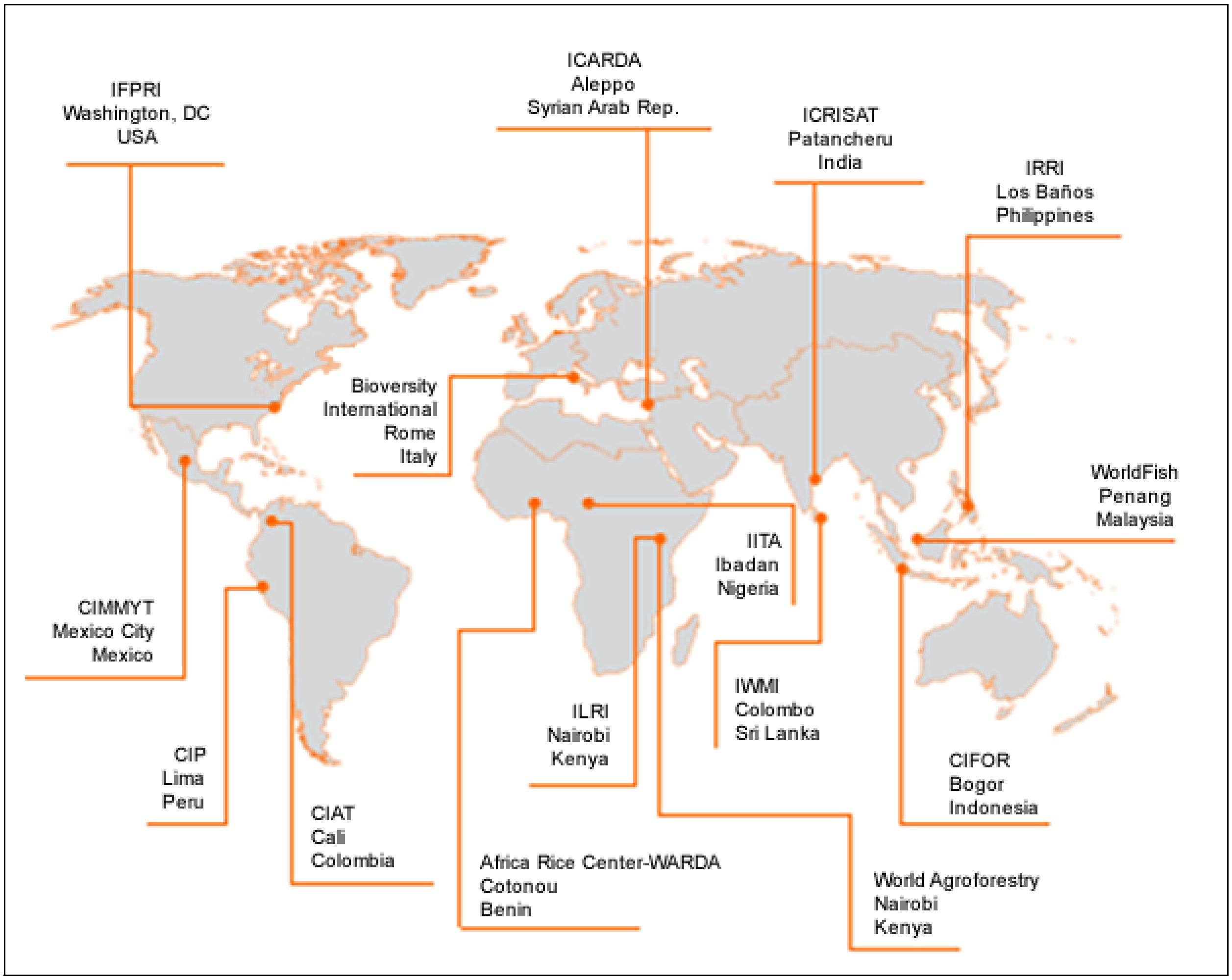

Figure 1. CGIAR Centers and their headquarters.
Source: http://www.cgiar.org.

CGIAR and Agricultural Biotechnology

The current research priorities of the CGIAR are described in five broad areas:

1. Sustaining agriculture biodiversity for future generation;
2. Producing more and better food at lower cost through genetic improvements;
3. Reducing rural poverty through agricultural diversification and emerging opportunities for high-value commodities and products;
4. Promoting poverty alleviation and sustainable management of water, land, and forest resources; and
5. Improving policies and facilitating institutional innovation to support sustainable reduction of poverty and hunger.

Within the context of the second research area above, as well as the ordinary progression of scientific research, various new biotechnological tools are developed and utilized in the CGIAR Centers. Modern biotechnology is one such tool that has been in use since the 1990s.[6] In response to the rapid development of applications of modern biotechnology, the CGIAR Centers have simultaneously considered the various policy and management issues surrounding the safe use of this new technology. With the facilitation of the Genetic

5. *Living Modified Organism (LMO) means any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology (Convention on Biological Diversity, 2000). LMO is a synonym of Genetically Modified Organism (GMO).*

Resources Policy Committee (GRPC) of the CGIAR, a "*common position statement on biotechnology*" was adopted in 1998 (CGIAR System-wide Genetic Resources Programme [SGRP], 2008):[7]

> "Given the immensity of the long-term food security and environmental conservation challenges confronting countries of the South, the Centres firmly believe in the following propositions:
>
> Biotechnology must be viewed as one of the critical tools for providing food security for the poor.
>
> The Centres advocate the prudent application of the full range of biotechnology tools to achieve substantial and sustainable growth in agricultural productivity in poor countries. These tools include, but are not limited to, molecular markers, genetic engineering, and recombinant vaccines.
>
> The Centres view biotechnology as an important means for ensuring environmental protection over the long term.
>
> The Centres have a clear comparative advantage in ensuring access by the countries of the South to the advanced tools of biotechnology. This advantage accrues by virtue of its present credible mass in biotechnology, its global network of partnerships within and among countries of the South, and its increasingly close linkages to advance research institutions of the north, both public and private.
>
> Given the extremely rapid pace of new developments in biotechnology, the Centres are committed to increasing their partnerships with ARIs, both public and private, north and south, to ensure ready access of Centre scientists and our partners in the south to advanced technologies.
>
> The Centres make adequate investments in the arena of biotechnology in order to: (1) maintain their own credible scientific mass, (2) be proactive in assisting countries of the South to establish effective biosafety regulations, and (3) contribute substantially to developing the human capital needed to ensure the judicious application of appropriate biotechnology tools to important food security and environmental problems.
>
> The Centres are firmly committed to the application of genomics (molecular genetics, molecular markers) for immediate use in better understanding and manipulating the genomes of plants, animals, and their pathogens and pests.
>
> The development and deployment of transgenics (via genetic engineering), is seen by the Centres to provide important options for meeting the food security and environmental challenges of the future.
>
> The Centres will carry out all of their activities in the arena of biotechnology under high standards of appropriate and approved biosafety regulatory frameworks, both within individual countries and institutions. The Centres will seek partnerships with institutes that have such frameworks in place (thus our commitment to policy and capacity building in this area)."

Two other CGIAR system-wide policy statements related to modern biotechnology exist. A common policy statement on Genetic Use Restriction Technologies (GURTs) (CGIAR SGRP, 2008) was also developed by the GRPC in 1998, and *Guiding Principles for the development of CGIAR Centres' policies to address the possibility of unintentional presence of transgenes in ex situ collections* was adopted in 2005 (CGIAR GRPC, 2005; FAO, 2007).

Past and Current Transgenic Research at the CGIAR Centers

The *Common Position Statement on Biotechnology* described above, forms the basis of the Centers' individual activities. The CGIAR Centers are committed "*to develop and release beneficial and safe LMOs that enjoy broad acceptance and wide adoption*" (CGIAR Science Council, 2007). A number of CGIAR Centers have developed their own internal guidelines on the use

6. *CGIAR Science Council (2007) notes that "[t]he CGIAR Centers have the potential to develop LMOs in a wide range of species of crops, microorganisms, trees, fish and livestock. However, only LMOs in crops and microorganisms are currently under investigation by some of the Centers."*
7. *A network of the key genetic resources scientists and programs at the CGIAR Centers (http://www.sgrp.cgiar.org/).*

of biotechnology.[8] Each center uses the technology according to its own needs as well as the needs of their national counterparts, while closely following local regulatory and administrative procedures. Some centers also provide assistance to the development of national biosafety framework for their host and collaborating countries and offer biosafety laboratory facilities and services.[9]

In addition to the individual center-based activities, two Challenge Programs[10] (new collaborative projects that encourage CGIAR Centers and partner institutions to work in consortia on issues of global importance) utilize new molecular biology techniques in their approaches to crop improvement. The Generation Challenge Program[11] combines genomics with molecular biology tools with the aim of developing improved crop varieties, with a focus on abiotic stress tolerance, particularly drought tolerance. The HarvestPlus Challenge Program[12] breeding technologies, including transformation, aims to breed staple foods biofortified in micronutrients, such as Vitamin A, zinc, and iron.

A general survey was conducted recently by the SGRP, which provides a comprehensive account of the current and past research and policy activities related to biotechnology and biosafety at the CGIAR Centers.[13] For the purpose of this article, the center responses on the current "LMO development activities" (CGIAR SGRP, 2008) were summarized by their crop type, target trait, and the latest stage of research in Table 1. There are nearly 15 different crops under research. Most of the research is still at the laboratory stage, and a few projects have progressed to the level of field trials. No transgenic products have yet been released.

8. CGIAR SGRP (2008) reports that the Centers that have established some form of internal policy documents are: Bioversity International, CIMMYT, ICRISAT, and IFPRI. Other Centers may also have some form of a guiding document or a code of conduct.

9. An example of such a service is the Biosciences eastern and central Africa (BecA) network, a joint initiative with NEPAD and based at the International Livestock Research Institute (ILRI) campus in Kenya.

10. A Challenge Program is defined as "a time-bound, independently-governed program of high-impact research, that targets the CGIAR goals in relation to complex issues of overwhelming global and/or regional significance, and requires partnerships among a wide range of institutions in order to deliver its products" (CGIAR, n.d.).

11. http://www.generationcp.org/index.php.

12. http://www.harvestplus.org/.

There has been a significant increase in the number of traits being researched for each crop, particularly compared to a similar survey of CGIAR Centers conducted in 2004 (CGIAR Science Council, 2007). Presumably, this reflects the scientific advancement and our increased capacity to address more traits than we were able to four years ago. The particular increase within the CGIAR can be traced in part to the increased contribution by the Generation and HarvestPlus Challenge Programs; more research is noted on nutritional enhancement and drought resistance compared to 2004. Although it does not appear in Table 1, there has also been significant progress in collaborative research with national partners.

The International Rice Research Institute's (IRRI) project to develop rice grains rich in provitamin A (Beta carotene), known as the Golden Rice project,[14] has been successful in multiple expressions of the event that would bring the carotenoid levels up to the target level thought to be necessary to effect nutritional improvement. The project has now moved to the breeding stage, where the ß-carotene loci are being crossed from American varieties into important Asian varieties from the Philippines, India, Vietnam, Bangladesh, and Indonesia, in close collaboration with the national partners in each of the countries. The first outdoor trials in Asia began earlier this year, with a goal to seek regulatory approval for release (for a variety improved by one event) in 2011. The Golden Rice project also aims to follow a fully integrated approach of regulatory review in each of the collaborating countries and to continue its communication/deployment approaches in order to increase awareness and demand among both consumers and producers.[15]

The International Potato Center (CIP) had been active in improving modern potato varieties using dif-

13. CIFOR, WARDA, and World Agroforestry Centre did not report any activities to the survey call by CGIAR SGRP (2008). As the center's contribution was voluntary, this may not necessarily indicate a lack of any biotechnology activities ongoing or being planned. WorldFish has reported that, although there are no current LMOs in development, research on quantitative genetic improvement program on Tilapia, African catfish, Giant freshwater prawns, is envisaged.

14. http://www.goldenrice.org.

15. The Golden Rice project was originally a product of the Rockefeller Foundation's Rice Biotech Program. After the initial breakthrough by Ingo Potrykus and Peter Beyer, the technology was transferred to Syngenta (then known as Zeneca) to advance the research (Potrykus, 2001). Syngenta has since asked IRRI to manage the project.

Table 1. Summary of transgenic research at CGIAR Centers (adapted from CGIAR SGRP, 2008).

		Trait (resistance)	Research
Bioversity[a]	Musa	Pests (weevils, nematodes), disease	Gene discovery & characterization; Transformation
CIAT	Beans	Agronomic	Transformation (particle bombardment & *Agrobacterium*); Backcrossing on wild species; Biosafety greenhouse
	Cassava	Insect	Transformation (*Agrobacterium*) of clones used by small farmers; Field trials
		Modified starch, early flowering, β-carotene	
	Rice	Virus, disease	Field trials
		Abiotic stress (flood, acid soils, high elevation)	Transformation (*Agrobacterium*) of recalcitrant cultivar into local cultivars with target trait
		Drought	Gene discovery (with CIMMYT, IRRI)
CIMMYT	Maize	Insect (Bt)	Gene characterization (target insect compatibility)
			Transformation and conventional backcrossing; Biosafety containment & confinement
	Wheat	Drought	Transcription factor/promoter characterization
			Genetic/molecular analysis for transmission & expression
		Agronomic	Transformation system development (*Agrobacterium*)
CIP	Potato	Insect (Bt)	Cultivar development; Field trials[b]
		Disease	Cultivar development
	Sweet potato	Virus	Cultivar development
		Insect	Gene discovery & characterization
		Modified starch	Cultivar development, Field trials
ICARDA	Chickpea	Disease, abiotic stress	Transformation (*Agrobacterium*)
	Lentil	Disease, abiotic stress	Transformation (*Agrobacterium*)
	Barley	Disease, abiotic stress	Transformation (*Agrobacterium*); Variety development
	Wheat	Abiotic stress (salt, drought)	Gene discovery & characterization; Transformation (*Agrobacterium*)
ICRISAT	Groundnut	Disease, virus	Tissue culture protocol; Small-scale field trials
	Pigeonpea	Insect (Bt)	Tissue culture protocol; Small-scale field trials
	Sorghum	Insect (Bt)	Tissue culture protocol
	Chickpea	Insect (Bt)	Tissue culture protocol; Small-scale field trials
	(non-crop specific)	Virus, insect, fungus, drought, nutrition	Searching genes for further use in cultivar development
IITA	Musa	Virus, bacteria, fungus	Transformation (*Agrobacterium*)
	Cassava	Virus	Transformation
	Cowpea	Insect (Bt)	Transformation
ILRI	NA		Diagnostic Processes for LMOs
	NA		Transformation of bacteria and virus to develop livestock vaccine against East Coast Fever
IRRI	Rice	Blight, insect (Bt)	Transformation
		ß-carotene	Cultivar development, Contained field trial

[a] *Bioversity International did not report any activities to the survey call by CGIAR SGRP (2008), but information was obtained from its Medium Term Plan 2008-2010 (Bioversity International, 2007) and website (http://bananas.bioversityinternational.org/content/view/134/150/lang,sp/).*

[b] *Undertaken in 1994-1998; no current field trials undertaken since.*

ferent means, including transgenics. There are a number of research projects on GM potato (and sweet potato), but they have remained in the laboratory and no field trials have been undertaken at CIP since 1999. It was decided in 2006 that CIP would temporarily refrain from releasing any GM potato in the Andean countries, as there is "not yet an adequate understanding of potential environmental risks and cultural consequences associated with the introduction of transgenic potatoes in the center of diversity" (CIP, 2007). CIP recently published a set of official guiding principles for the development and deployment of GMOs (CIP Board of Trustees, 2008).

Biosafety Research at the CGIAR Centers

Research activities relevant to the assessment of potential impacts of LMOs have been conducted at CGIAR Centers to derive more information about the impact of LMOs on agriculture and the environment, as well as to elaborate on the management system required for the future release/deployment of GM crops. Table 2 summarizes the survey result of SGRP on research conducted by the centers (CGIAR SGRP, 2008).

Most of the centers conducting transgenic research have reported parallel biosafety studies, with stronger emphases on gene flow studies and studies on the effect of GM crops on non-target organisms. Socioeconomic (smallholder/consumer demand study, economic impacts) and human health studies (allergenicity, micronutrient uptake) are also conducted in some.

CGIAR's Role in Agricultural Biotechnology

The public's interest in the CGIAR's use of modern biotechnology is multi-faceted. There is often lack of public information, and uncertainty surrounding the safety of GM crops. In particular, uncertainties about food safety have significant implications for both consumer and farmer acceptance. It is imperative that the centers ensure rigorously tested and transparent use of the technology in order to address this issue. The rate of progress is also governed by the number of countries willing to disseminate GM crops and the development by each country of specific regulatory policy or law. A special consideration might be necessary when working in countries with center of origin or center of genetic diversity for certain crops. More research is needed on the interaction between GM crops and wild crops relatives, non-target organisms, and agricultural diversity.

Table 2. Summary of biosafety research at CGIAR Centers (adapted from CGIAR SGRP, 2008).

Center	Crop	Type of research
CIAT		Documentation of genetically compatible species and range of natural distribution
		Effect of transgenic crops on non-target associated biota
	Rice, beans, maize	Documentation of gene flow events (from transgenic and non-transgenic plants) to landraces and wild relatives
CIMMYT	Maize	Gene flow studies
		Effect on non-target anthropods
		Reference collection on anthropods
		Impact on the target insect development and on the bionomics of its key parasitoids
		Natural refugia and intercrops
CIP	Potato	Consumer demand study
		Environmental impact of transgenic varieties
		GM potato survivability and interaction with wild relatives
		Past occurrences of gene flow from modern (non-GM) potato varieties
		Identify presence of unintentional presence of transgenes in genebank
		Human health impact of potential products
		Allergenicity database searches
ICRISAT	Pigeonpea	Diversity in cultivars and landraces; Gene flow study
	Sorghum	Gene flow study (seed and pollen-mediated)
	Cotton, chickpea	Effect on non-target and beneficial insects
IFPRI		Environmental risk assessment; Interaction between transgenic crops and animals, agriculture, biodiversity
IITA	Cowpea	Gene flow studies
		Hybrid longevity studies
		Effect on non-target organisms (parasitoids of targets)
IRRI	Rice	Toxicological studies
		Food safety study
		Monitoring of risk assessment and cost-benefit studies
WorldFish	Tilapia	Ecological (environmental, biodiversity and economic) impacts of use of aquatic LMOs

There might also be some public concern about the CGIAR's use of transgenic research because, currently, much of the proprietary information of modern biotechnology is closely associated with the private sector multinationals, leading to another type of skepticism as to whether CGIAR could continue to produce IPGs while "doing business" with the private sector. The CGIAR Science Council, the CGIAR advisory and partnership committees, the Genetic Resource Policy Committee, and the Private Sector Committee, together with Central Advisory Service on Intellectual Property,[16] are working to seek ways in which third-party IPRs can be effectively utilized by the CGIAR Centers and their national partners. There are a number of public sector IP management groups that are gaining practical experience in this area.

Second, there is a sense of hope and expectation that the CGIAR, in collaboration with the National Agricultural Research Systems (NARS) and other organizations such as the African Agricultural Technology Foundation (AATF)[17] might prove that modern biotechnology can be harnessed in a way that is truly beneficial to the poor farmers in developing countries. One of the criticisms of modern biotechnology is that it has produced products that are beneficial only for the private sector and large-scale farmers in the north and not to the small farmers in developing countries. The stakes are high for the public sector, as for the CGIAR, to succeed in using the transgenic technology "right." Demonstration of good practice through transparency and a prudent application of safety arrangements would be vital. It is also important to show that "scientific and economic concerns are not the only issue that the CGIAR Centers address; ethical and developmental issues are also important factors that determine CGIAR research" (CGIAR, n.d.).

The CGIAR Centers' goal is to breed strategic crop/tree/aquatic germplasm using conventional and biotech approaches and provide such advanced (or improved) germplasm—as an end product or as segregating lines—to private and public national partners in the developing world (and for some crops even in the developed world). The national partners may use such materials as sources of alleles for their breeding programs, or continue with their regional or local testing. Thereafter they may select most promising materials that may be included in national trials to identify the best for further cultivar registration and release to their farmers.

A recent workshop co-organized by IRRI, Bioversity International, and the Science Council considered how best this can be done on a CGIAR system-wide basis.[18] The workshop aimed, among others, to identify means of collaboration with various stakeholders in the centers' projects that will lead to research outcomes that meet the needs of partner NARS. It was generally agreed among the workshop participants that although there was good research capacity in the CGIAR Centers, there was an evident gap in the product development and delivery to end-users (CGIAR Science Council, 2008). More attention is needed on biosafety research, regulatory issues, and intellectual property rights to be able to drive the research outputs towards commercialization. A network of centers and NARS that are engaged in transgenic research might fill such a gap by facilitating the sharing of experiences and ideas, as well as identifying tasks for each stakeholder group in the product development process.

Conclusion

The current issues and changes in the agriculture and food security debate are rapidly changing the landscape of research opportunities for the CGIAR. Challenges of rising food prices, climate change, and bioenergy demands and land degradation all require an increase in agricultural production. Overcoming biotic and abiotic stresses in reasonable time frames is becoming part and parcel of a modern approach to tackle a continuing human problem. Those most negatively affected by the current food crisis would be smallholder farmers in developing countries, who must increase productivity and integrate with local, regional and international markets. Through their search to accelerate the process of research in the development of IPGs, the CGIAR Centers are committed to developing and releasing safe and beneficial products of agriculture, making use of all available knowledge and technologies, including modern biotechnology.

16. *One of the System Office units of the CGIAR.*
17. *AATF is a "not-for-profit organization is designed to facilitate and promote public/private partnerships for the access and delivery of appropriate proprietary agricultural technologies for use by resource-poor smallholder farmers in Sub-Saharan Africa" (AATF, n.d.).*
18. *CGIAR, Biotechnology, Biosafety: Promoting best practice in science and policy, was held at IRRI headquarters, Los Baños, Laguna, Philippines, on 22-24 April 2008. Participants to the meeting consisted of Center scientists who are involved in transgenic research, representatives of selected NARS (some of which work closely with centers on transgenic projects), other R&D partners, and Civil Society representatives.*

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