ISAAA
International Service for the Acquisition of Agri-biotech Applications

ISAAA Briefs

BRIEF 41

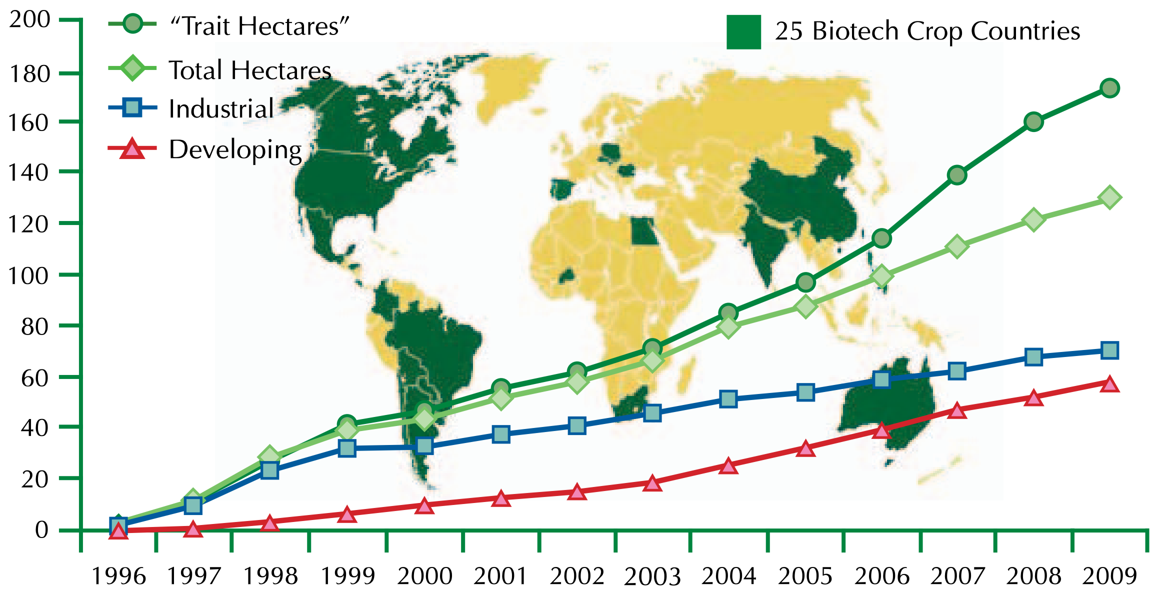
Global Status of Commercialized Biotech/GM Crops: 2009

by

Clive James
Founder and Chair, ISAAA Board of Directors

Dedicated by the author to the late Nobel Peace Laureate Norman Borlaug, First Founding Patron of ISAAA

GLOBAL AREA OF BIOTECH CROPS
Million Hectares (1996-2009)



A record 14 million farmers, in 25 countries, planted 134 million hectares (330 million acres) in 2009, a sustained increase of 7% or 9 million hectares (22 million acres) over 2008.

Source: Clive James, 2009.

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Highlights of "Global Status of Commercialized Biotech/GM Crops: 2009"

by Clive James, Founder and Chair, ISAAA Board of Directors

Dedicated to the late Nobel Peace Laureate, Norman Borlaug

ISAAA Brief 41 is the 14th consecutive annual review, by the author, of the global status of biotech crops since they were first commercialized in 1996. Brief 41 is dedicated, by the author, to the late Nobel Peace Laureate Norman Borlaug, first founding patron of ISAAA. The Highlights summarize the major developments in 2009, and more details can be found at http://www.isaaa.org.

As a result of consistent and substantial, crop productivity, economic, environmental and welfare benefits, a record 14 million small and large farmers in 25 countries planted 134 million hectares (330 million acres) in 2009, an increase of 7 percent or 9 million hectares (22 million acres) over 2008; the corresponding increase in "trait or virtual hectares" was 8 percent or 14 million "trait hectares" for a total of 180 million "trait hectares" compared with 166 million "trait hectares" in 2008. **The 80-fold increase in biotech crop hectares between 1996 and 2009, is unprecedented, and makes biotech crops the fastest adopted crop technology in the recent history of agriculture**; this reflects the confidence and trust of millions of farmers worldwide who have consistently continued to plant more biotech crops every single year since 1996, because of the multiple and significant benefits they offer.

Record hectarages were reported for all four major biotech crops. For the first time, biotech soybean occupied more than three-quarters of the 90 million hectares of soybean globally, biotech cotton almost half of the 33 million hectares of global cotton, biotech maize over one-quarter of the 158 million hectares of global maize and biotech canola more than one-fifth of the 31 million hectares of global canola. Biotech crop hectares continued to grow in 2009 even when 2008 percent adoption rates were high for the major biotech crops in the principal countries. For example, adoption of Bt cotton in India increased from 80 percent in 2008 to 87 percent in 2009, and biotech canola in Canada increased from 87 percent in 2008 to 93 percent in 2009. Biotech soybean continued to be the most prevalent biotech crop occupying 52 percent of the 134 million hectares and herbicide tolerance the most prevalent trait (62 percent). Stacked genes are of growing importance occupying 21 percent of all biotech crops globally and deployed by 11 countries, 8 of them developing countries.

Of the 25 biotech crop countries (Germany discontinued in 2008 and Costa Rica joined in 2009), 16 were developing and nine industrial. Each of the following top eight countries grew more than 1 million hectares: USA (64.0 million hectares), Brazil (21.4), Argentina (21.3), India (8.4), Canada (8.2), China (3.7), Paraguay (2.2) and South Africa (2.1). The balance of 2.7 million hectares was grown by the following 17 countries, listed in decreasing order of hectarage; Uruguay, Bolivia, Philippines, Australia, Burkina Faso, Spain, Mexico, Chile, Colombia, Honduras, Czech Republic, Portugal, Romania, Poland, Costa Rica, Egypt, and Slovakia. **Accumulated hectarage of biotech crops for the period 1996 to 2009 reached almost 1 billion hectares (949.9 million hectares or 2.3 billion acres).**

Notably, almost half (46 percent) of the global hectarage was planted by developing countries, expected to take the lead from industrial countries before 2015, the Millennium Development Goal Year, when global society has pledged to cut hunger and poverty in half. **Biotech crops are already contributing to this goal, and the potential for the future is enormous**.

Remarkably, of the 14 million beneficiary farmers, 90 percent or 13 million were small resource-poor farmers. These farmers are already benefiting from biotech crops like Bt cotton, and have enormous future potential with crops such as biotech rice, to be commercialized in the near term.

The 2008 ISAAA Brief predicted that a new wave of biotech crops would become available, and this already started to materialize in 2009. In a landmark decision on 27 November 2009, China issued biosafety certificates for its nationally-developed proprietary Bt rice and phytase maize, clearing the way for crop registration, which will take 2 to 3 years before commercialization. The significance of this decision is that rice, the most important food crop in the world, has the potential to directly benefit 110 million rice households (440 million beneficiaries, assuming an average of four per family) in China alone, and 250 million rice households in Asia, equivalent to 1 billion potential beneficiaries. Rice farmers are some of the poorest people in the world surviving on an average of only one-third of a hectare of rice. Bt rice can contribute to increased productivity and the alleviation of their poverty and coincidentally reduce requirements for pesticides while contributing to a better and **more sustainable environment in the face of climate change. Whereas rice is the most important food crop, maize is the most important animal feed crop in the world. Biotech phytase maize will allow pigs to digest more phosphorous and coincidentally enhance their growth while reducing pollution from lower phosphate in animal waste. Given the increased demand for meat in a more prosperous China, phytase maize can provide improved animal feed for China's 500 million swine herd (half of the global swine population) and its 13 billion chickens, ducks and poultry. Phytase maize has the potential to directly benefit 100 million maize households (400 million beneficiaries) in China alone.** Given the importance of rice and maize globally, and China's growing influence, other developing countries in Asia and the rest of the world may seek to emulate the Chinese experience. China's lead in embracing biotech crops can serve as a role model for other developing countries and can **contribute to food self-sufficiency**, a more sustainable agriculture dependent on less pesticides and to the alleviation of hunger and poverty. **Given that rice and maize are the most important food and feed crops in the world respectively, these two new Chinese nationally-developed biotech crop products have momentous potential implications for China, Asia and the world**.

Brief 41 includes a fully referenced special feature on **"Biotech Rice – Present Status and Future Prospects" by Dr. John Bennett**, Honorary Professor, School of Biological Sciences, University of Sydney, Australia.

Notably, in 2009, Brazil narrowly displaced Argentina to become the second largest grower of biotech crops globally – the increase of 5.6 million hectares of biotech crops was the highest absolute growth in hectares for any country in the world, equivalent to a 35 percent year-over-year growth between 2008 and 2009. It is evident that Brazil is a world leader in biotech crops and an engine of growth for the future. India, the largest cotton grower in the world, has benefited from 8 years (2002 to 2009) of spectacular success with Bt cotton, which reached a record 87 percent adoption in 2009. Bt cotton has literally revolutionized cotton production in the country. **The accumulated economic benefit to Bt cotton farmers in India for the period 2002 to 2008 was an impressive US$5.1 billion. Bt cotton also cut insecticide requirements in half, contributed to a doubling of yield and transformed India from an importer to a major cotton exporter. Bt brinjal (eggplant), expected to be India's first biotech food crop, was recommended for commercialization by the Indian Regulatory authorities.** Final endorsement by Government is pending. **Continued progress was witnessed in all three countries in Africa – South Africa with a significant 17% growth in 2009, Burkina Faso and Egypt. Bt cotton hectares in Burkina Faso increased 14-fold from 8,500 hectares in 2008 to 115,000 hectares in 2009, a 1,353 percent increase which was by far the highest proportional increase globally in 2009**. Six EU countries planted 94,750 hectares in 2009, 9 percent to 12 percent less than 2008. Spain grew 80 percent of all EU Bt maize and maintained the same adoption rate as 2008, at 22 percent. **RR®sugarbeet achieved a remarkable 95 percent adoption in the USA and Canada in 2009 in only its third year of commercialization, making it the fastest adopted biotech crop globally, to-date.**

2009 saw substitution of first generation products with second generation products, which, for the first time, increased yield *per se*. RReady2Yield™ soybean, the first example of a new class of biotech crops being researched by many technology developers, was planted by over 15,000 farmers on more than 0.5 million hectares in the United States and Canada in 2009.

Updated global impact assessments for biotech crops indicate that for the period 1996 to 2008 economic gains of US$51.9 billion were generated from two sources, firstly, reduced production costs (50%), and secondly, substantial yield gains (50%) of 167 million tons; the latter would have required 62.6 million additional hectares had biotech crops not been deployed, hence biotech crops are an important land saving technology. During the same period, 1996 to 2008, pesticide reduction was estimated at 268 million kg of active ingredient (a.i.), a saving of 6.9% in pesticides. In 2008 alone, the CO_2 savings from biotech crops through sequestration was 14.4 billion kg of CO_2 equivalent to removing 7 million cars from the road (Brookes and Barfoot, 2010, forthcoming).

In 2009, more than half (54 percent or 3.6 billion) of the world's population lived in the 25 countries that planted 134 million hectares of biotech crops, equivalent to 9 percent of the 1.5 billion hectares total global cropland.

Global value of the biotech seed market alone was valued at US$10.5 billion in 2009. The global value for the **corresponding commercial biotech maize, soybean grain and cotton was**

valued at US$130 billion for 2008, and projected to grow at up to 10 percent to 15 percent annually.

While 25 countries planted commercialized biotech crops in 2009, an additional 32 countries, totaling 57, have granted regulatory approvals for biotech crops for import for food and feed use and release into the environment since 1996. **A total of 762 approvals have been granted for 155 events in 24 crops; this includes a biotech blue rose grown in Japan in 2009.**

Future prospects of a new wave of biotech crops between 2010 to 2015 are encouraging: top priority must be assigned to operation of **appropriate and responsible, and cost-effective and timely regulatory systems;** there is **growing political will, financial and scientific support** for the development, approval and adoption of biotech crops; there is cautious optimism that **global adoption of biotech crops, by country, number of farmers, and hectarage will all double** in the second decade of commercialization between 2006 and 2015, as predicted by ISAAA in 2005 (**by 2015, ISAAA predicts 40 biotech countries, 20 million biotech crop farmers and 200 million hectares of biotech crops**); there will be a continuing and expanding supply of appropriate new biotech crops to meet the priority needs of global society, particularly the developing countries of Asia, Latin America and Africa. **The following partial selection of new biotech crops/traits are expected to become available from 2010 to 2015: SmartStax™ maize in the USA and Canada in 2010, involving eight genes which code for three traits; Bt brinjal (eggplant) in India in 2010, subject to government endorsement; Golden Rice in the Philippines in 2012, followed by Bangladesh and India and eventually Indonesia and Vietnam; biotech rice and phytase maize in China within 2 to 3 years; drought-tolerant maize in the USA in 2012 and in Sub-Saharan Africa in 2017; possibly a Nitrogen Use Efficiency (NUE) trait and biotech wheat in five years, or more.**

Following the food crisis of 2008, (which led to riots in over 30 developing countries and overthrow of governments in two countries – Haiti and Madagascar), there was a realization by global society of the grave risk to food and public security. As a result, **there has been a marked increase in the political will and support for biotech crops** in the donor group, the international development and scientific community and from leaders of developing countries. More generally, there has been a renaissance and recognition of the life sustaining essential role of agriculture by global society, and importantly, its vital role in ensuring a more just and peaceful global society. More specifically, there has been a clarion call to achieve **"a substantial and sustainable intensification of crop productivity, to ensure food self-sufficiency and security, using both conventional and crop biotechnology applications."**

Norman Borlaug's success with the wheat green revolution hinged on his ability, tenacity and single-minded focus on one issue – **increasing the productivity of wheat per hectare** – by intent, he also assumed full responsibility for gauging his success or failure by measuring productivity at the farm level (not at the experimental field station level), and production at the national level, and most importantly, evaluating its contribution to peace and humanity. He titled his acceptance speech for the Nobel Peace Prize on 11 December 1970, 40 years ago – **The Green Revolution, Peace and Humanity.** Remarkably, what Borlaug crusaded for 40 years ago – **increasing crop productivity, is identical to our goal of today** except that the challenge has become even greater because **we also need to <u>double productivity sustainably, using less resources</u>, particularly water, fossil fuel and nitrogen,** in the face of **new climate change challenges.** The most appropriate and noble way to honor Norman Borlaug's rich and unique legacy is for the global community involved with biotech crops to come together in a "**Grand Challenge".** North, south, east and west, involving both public and private sectors should engage collectively in a supreme and noble effort to optimize the contribution of biotech crops to productivity using less resources. **Importantly, the principal goal should be to contribute to the alleviation of poverty, hunger and malnutrition**, as we have pledged in the Millennium Development Goals of 2015, which coincidentally marks the end of the second decade of the commercialization of biotech crops, 2006 to 2015.

The closing words are those of Norman Borlaug, who having saved one billion from hunger, was the world's most ardent and credible advocate of biotech crops because of their capacity to increase crop productivity, alleviate poverty, hunger and malnutrition and contribute to peace and humanity. Borlaug opined that "***Over the past decade, we have been witnessing the success of plant biotechnology. This technology is helping farmers throughout the world produce higher yield, while reducing pesticide use and soil erosion. The benefits and safety of biotechnology has been proven over the past decade in countries with more than half of the world's population. What we need is <u>courage</u> by the leaders of those countries where farmers still have no choice but to use older and less effective methods. The Green Revolution and now plant biotechnology are helping meet the growing demand for food production, while preserving our environment for future generations.***

Detailed information is provided in Brief 41 Global Status of Commercialized Biotech/GM Crops: 2009 by Clive James. For further information, please visit http://www.isaaa.org or contact ISAAA *SEAsia*Center at +63 49 536 7216, or email to info@isaaa.org.

Global Status of Commercialized Biotech/GM Crops: 2009

by

Clive James
Chair, ISAAA Board of Directors

Introduction

This Brief focuses on the global biotech crop highlights in 2009, and is dedicated to the late Nobel Peace Laureate, Norman Borlaug who passed away on 12 September, 2009. Norman Borlaug, was the First Founding Patron of ISAAA – a commemorative brochure describing his immense contributions to humanity is included in Brief 41. Having been awarded the Nobel Peace Prize in 1970 for implementing the green revolution, which saved up to 1 billion people from hunger in the 1960s, Norman Borlaug was the world's most ardent and credible advocate of biotech crops and their vital contribution to the alleviation of poverty, hunger and malnutrition.

This Brief also includes a fully referenced special feature on "Biotech Rice – Present Status and Future Prospects" by Dr. John Bennett, Honorary Professor, School of Biological Sciences, University of Sydney, Australia, and former senior molecular biologist of the Plant Molecular Biology Laboratory at the International Rice Research Institute in the Philippines, which hosts the ISAAA South East Asia Center.

Shortly before this Brief went to press, biotech Bt rice and biotech phytase maize were approved by China on 27 November 2009 when three biosafety certificates were issued. **These approvals are momentous and have enormous implications for biotech crop adoption not only for China and Asia, but for the whole world.** There are several aspects that make them unique:

- Both nationally-developed proprietary products were produced in China entirely with public sector resources from the Government;

- Rice is the most important food crop in the world. Bt rice can deliver estimated benefits of US$4 billion per year to up to 110 million rice households in China alone (440 million beneficiaries, assuming 4 per family) who grow 30 million hectares of rice – on average they farm one-third of a hectare of rice. Increased yield and farmer income from Bt rice can contribute to a better quality of life and a safer and more sustainable environment due to less dependency on insecticides. Nationally, it can be a very significant and critical contribution to China's goal of food and feed "self-sufficiency" (optimizing the nations' home-grown food and feed crops) and to "food security" (enough food and feed for all) – the distinction is important and the two goals are not mutually exclusive.

- Maize is the major animal feed crop in the world. In China, maize occupies 30 million hectares and farmed by 100 million maize households (400 million beneficiaries) with an average maize holding per farm of one third of one hectare. Potential benefits of phytase maize include more efficient pork production, China has the largest swine herd in the world, 500 million equivalent to 50% of global. Pork production with phytase maize will be more efficient because pigs can more easily digest phosphorus, thereby coincidentally enhancing growth and reducing pollution from lower phosphate animal waste. Farmers will no longer be required to purchase and mix phosphate supplement resulting in savings in supplements, equipment and labor. Nationally, increased efficiency of meat production is critical at a time when prosperity is driving increased meat consumption in China which has to import maize for feed. Maize is also used to feed China's 13 billion chickens, ducks and poultry.

- China's approval of biotech rice and maize will probably facilitate and expedite the decision making process regarding acceptance and approval of biotech rice maize and other biotech crops in developing countries. This will be particularly so in Asia, which is facing the same challenges as China in relation to food self-sufficiency and the 2015 MDG goals to alleviate poverty, hunger and malnutrition and increase small farmer prosperity.

- The approvals of vital, nationally-developed Chinese biotech rice and maize staples could also shift the dynamics of global food, feed and fiber trade, the role of developing countries in food security, and could stimulate other countries to emulate China and/or engage in technology transfer/sharing programs with China.

The Chinese Government's assignment of high priority to crop biotechnology, championed by Premier Wen Jiabao, is paying off handsome returns to China, both in terms of Bt cotton and strategically important new crops like biotech rice and maize and also reflects academic excellence of China in biotech crop development. Agricultural science is China's fastest-growing research field with China's share of global publications in agricultural science growing from 1.5% in 1999 to 5% in 2008. In 1999, China spent only 0.23% of its agricultural GDP on agricultural R & D but this increased to 0.8% in 2008 and is now close to the 1% recommended by the World Bank for developing countries. The new target for the Chinese Government is to increase total grain production to 540 million tons by 2020 and to double Chinese farmers' 2008 income by 2020 and biotech crops can make a significant contribution to this goal (Xinhua, 2009a).

Unfortunately, time constraints associated with the printing and publication of this Brief allowed only an initial cursory discussion of the enormous global significance and implications of the approval of biotech rice and maize in China, both of which will have to satisfy and complete 2 to 3 years of the standard field registration trials prior to full scale commercialization in farmers field. The approvals are also discussed later in this Brief.

2009 marks the fourteenth year of the commercialization, 1996-2009, of biotech crops, also known as genetically modified (GM) or transgenic crops, now more often called “biotech crops” as referred to in this Brief. The experience of the first thirteen years of commercialization, 1996 to 2008, has confirmed that the early promise of crop biotechnology has been fulfilled. Biotech crops have delivered substantial agronomic, environmental, economic, health and social benefits to farmers and, increasingly, to society at large. The rapid adoption of biotech crops, during the initial thirteen years of commercialization, 1996 to 2008, reflects the substantial multiple benefits realized by both large and small farmers in industrial and developing countries, which have grown biotech crops commercially. Between 1996 and 2008, developing and industrial countries contributed to a 74-fold increase in the global area of biotech crops from 1.7 million hectares in 1996 to 125 million hectares in 2008. Adoption rates for biotech crops during the period 1996 to 2008 are unprecedented and, by recent agricultural industry standards, they are the highest adoption rates for improved crops for example, higher than the adoption of hybrid maize in its heyday in the mid-west of the USA. High adoption rates reflect farmer satisfaction with the products that offer substantial benefits ranging from more convenient and flexible crop management, lower cost of production, higher productivity and/or net returns per hectare, health and social benefits, and a cleaner environment through decreased use of conventional pesticides, which collectively contribute to a more sustainable agriculture. There is a growing body of consistent evidence across years, countries, crops and traits generated by public sector institutions that clearly demonstrate the benefits from biotech crops. These benefits include improved weed and insect pest control with biotech herbicide tolerant and insect resistant Bt crops, that also benefit from lower input and production costs; biotech crops also offer substantial economic advantages to farmers compared with corresponding conventional crops. The severity of weed and insect pests and diseases varies from year-to-year and country to country, and hence will directly impact pest control costs and the economic advantages of biotech crops in any given time or place.

Despite the continuing debate on biotech crops, particularly in countries of the European Union (EU), millions of large and small farmers in both industrial and developing countries have continued to increase their plantings of biotech crops by double-digit adoption growth rates every year since 1996, because of the significant multiple benefits that biotech crops offer. This high rate of adoption is a strong vote of confidence in biotech crops, reflecting farmer satisfaction in both industrial and developing countries. About 13.3 million farmers in 25 countries grew biotech crops in 2008 and derived multiple benefits that included significant agronomic, environmental, health, social and economic advantages. ISAAA’s 2008 Global Review (James, 2008) predicted that the number of farmers planting biotech crops, as well as the global area of biotech crops, would continue to grow in 2009.

Global population was approximately 6.5 billion in 2006 and is expected to reach approximately 9.2 billion by 2050, when around 90% of the global population will reside in Asia, Africa, and Latin America. In 2009 for the first time ever, 1.02 billion people in the developing countries suffer from hunger and malnutrition and more than 1.3 billion are afflicted by poverty (World Food Program, UN, 2009). Biotech crops represent promising technologies that can make a vital contribution, but not a total solution (not a panacea), to global food, feed and fiber security and can also make a critically important contribution to the alleviation of poverty, the most formidable challenge facing global society which has made the Millennium Development Goals pledge to decrease poverty, hunger and malnutrition by half by 2015, which will also mark the completion of the second decade of commercialization of biotech crops, 2006-2015.

The most compelling case for biotechnology, and more specifically biotech crops, is their capability to contribute to:

- **increasing crop productivity,** and thus **contributing to global food, feed, fiber security,** with benefits for producers, consumers and society at large alike; **contribution to more affordable food** as a result of coincidentally increasing productivity significantly and reducing production costs substantially;

- **self-sufficiency is optimizing productivity and production on a nations own arable land, whereas food security is "food for all" without specific reference to source** – **self-sufficiency and food security are not mutually exclusive, currently there is an increased emphasis on self-sufficiency by both national programs and donors;**

- **conserving biodiversity,** as a land-saving technology capable of higher productivity on the current 1.5 billion hectares of arable land, and thereby precluding deforestation and protecting biodiversity in forests and in other in-situ biodiversity sanctuaries;

- **reducing the environmental footprint of agriculture** by contributing to more efficient use of external inputs, thereby contributing to a safer environment and more sustainable agriculture systems; special attention to more efficient use of water in crop production and development of drought tolerant biotech crops;

- **mitigating some of the challenges associated with climate change (increased frequency and severity of droughts, floods, changes in temperature, rising sea levels exacerbating salinity and changes in temperature) and reducing greenhouse gases** by using biotech applications for "speeding the breeding" in crop improvement programs to develop well adapted germplasm for changing climatic conditions and optimize the sequestration of CO_2;

- **increasing stability of productivity and production** to lessen suffering during famines due to biotic and abiotic stresses particularly drought which is the major constraint to increased productivity on the 1.5 billion hectares of arable land in the world;
- **the improvement of economic, health and social benefits,** food, feed, and fiber security, and the alleviation of abject poverty, hunger and malnutrition for the rural population dependent on agriculture in developing countries;
- thus, **provide significant and important multiple and mutual benefits to producers, consumers and global society.**

The most promising technological option for increasing global food, feed and fiber production is to combine the best of the old and the best of the new by integrating the best of conventional technology (adapted germplasm) and the best of biotechnology applications, including molecular breeding and the incorporation of transgenic novel traits. The improved integrated crop products, resulting from the synergy of combining the best of the old with the best of the new must then be incorporated as the **innovative technology** component in a global food, feed and fiber security strategy that must also address other critical issues including population control and improved food, feed and fiber distribution. Adoption of such a holistic strategy will allow society to continue to benefit from the vital contribution that both conventional and modern innovative plant breeding, both old and new, offers global society.

The author has published global reviews of biotech crops annually since 1996 as ISAAA Briefs (James, 2008; James, 2007; James, 2006; James, 2005; James, 2004; James, 2003; James, 2002; James, 2001; James, 2000; James, 1999; James, 1998; James, 1997; James and Krattiger, 1996). This publication provides the latest information on the global status of commercialized biotech crops. A detailed global data set on the adoption of commercialized biotech crops is presented for the year 2009 and the changes that have occurred between 2008 and 2009 are highlighted. The global adoption trends during the last 14 years from 1996 to 2009 are also illustrated as well as the contribution of biotech crops to the world's 1.3 billion poor people, of which resource-poor farmers are a significant proportion.

In 2008, ISAAA invited Dr. Greg Edmeades to contribute a review of the status of drought tolerance in both conventional and biotech maize. The feature article by Dr. Edmeades was very well received by the scientific and agriculture community because drought tolerance is a trait, which virtually no crop or farmer in the world can afford to be without; using water at current rates when the world will have to support 9 billion people or more in 2050, is simply not sustainable. Given the pivotal importance of rice as a food staple, which provides sustenance for half of humanity, this year, ISAAA invited Dr. John Bennett, Honorary Professor School of Biological Sciences, University of Sydney, Australia and former senior molecular biologist and head of the Plant Molecular Biology Laboratory at the International Rice Research Institute, to contribute a timely global overview on the current status of biotech rice, and to discuss future prospects in the near, mid and long term. The contribution by Dr. John Bennett, supported by key references, is included in Brief 41 as a special feature to highlight the enormous global importance of rice – not only is rice the principal food crop in the world but it is the most important food staple of the poor and malnourished in the world, and thus has a very important humanitarian implications for poverty alleviation.

This ISAAA Annual Global Review of biotech crops (Brief 41, 2009) documents the global database on the adoption and distribution of biotech crops in 2009, and in the Appendix there are four sections: 1) a comprehensive inventory of biotech crop products that have received regulatory approvals for import for food, feed use and for release into the environment, including planting, in specific countries; 2) useful tables and charts on the international seed trade – these have been reproduced with permission of the International Seed Federation (ISF); 3) a table with global status of crop protection in 2008, courtesy of Cropnosis; and 4) a table detailing the deployment of Bt cotton hybrids and varieties in India in 2009.

Note that the words rapeseed, canola, and Argentine canola are synonymously used, as well as, transgenic, genetically modified crops, GM crops, and biotech crops, reflecting the usage of these words in different regions of the world, with biotech crops being used exclusively in this text because of its growing usage worldwide. Similarly, the words corn, used in North America, and maize, used more commonly elsewhere in the world, are synonymous, with maize being used consistently in this Brief, except for common names like corn rootworm where global usage dictates the use of the word corn. All $ dollar references in this Brief are to US dollars unless otherwise noted. Some of the listed references may not be cited in the text – for convenience they have been included because they were considered useful reading materials and were used as preparatory documents for this Brief. Global figures and hectares planted commercially with biotech crops have been rounded off to the nearest 100,000 hectares, using both < and > characters, and hence in some cases this leads to insignificant approximations, and there may be minor variances in some figures, totals, and percentage estimates that do not always add up exactly to 100% because of rounding off. It is also important to note that countries in the Southern Hemisphere plant their crops in the last quarter of the calendar year. The biotech crop areas reported in this publication are planted, not necessarily harvested hectarage in the year stated. Thus, for example, the 2009 information for Argentina, Brazil, Australia, South Africa, and Uruguay is hectares usually planted in the last quarter of 2009 and harvested in the first quarter of 2010, or later, with some countries like the Philippines planting more than one season per year. Thus, for countries of the Southern hemisphere, such as Brazil and Argentina the estimates are projections, and thus are always subject to change due to weather, which may increase or decrease actual planted area before the end of the planting season when this Brief has to go to press. For Brazil, the winter maize crop (safrinha) planted in the last week of December 2009 and more intensively through January and February 2010 is classified as a 2009 crop in this Brief consistent with a policy which uses the first date of planting to determine the crop year. Country figures were sourced from The Economist, supplemented by data from World Bank, FAO and UNCTAD, when necessary.

Over the last 14 years, ISAAA has devoted considerable effort to consolidate all the available data on officially approved biotech crop adoption globally; it is important to note that the database does not include plantings of biotech crops that are not officially approved. The database draws on a large number of sources of approved biotech crops from both the public and private sectors in many countries throughout the world. The range crops are those defined as food, feed and fiber crops in the FAO database. Data sources vary by country and include, where available, government statistics, independent surveys, estimates from commodity groups, seed associations and other groups, plus a range of proprietary databases. Published ISAAA estimates are, wherever possible, based on more than one source of information and thus are usually not attributable to one specific source. Multiple sources of information for the same data point greatly facilitate assessment, verification, and validation of a specific estimate. The "proprietary" ISAAA database on biotech crops is unique from two points of view; first, it provides global coverage; second, it has used the same basic methodology, but improved continuously for the last 14 years and hence provides continuity from the genesis of the commercialization of biotech crops in 1996, to the present. The database has gained acceptance internationally as a reliable benchmark for the global status of biotech food, feed and fiber crops and is widely cited in the scientific literature and the international press.

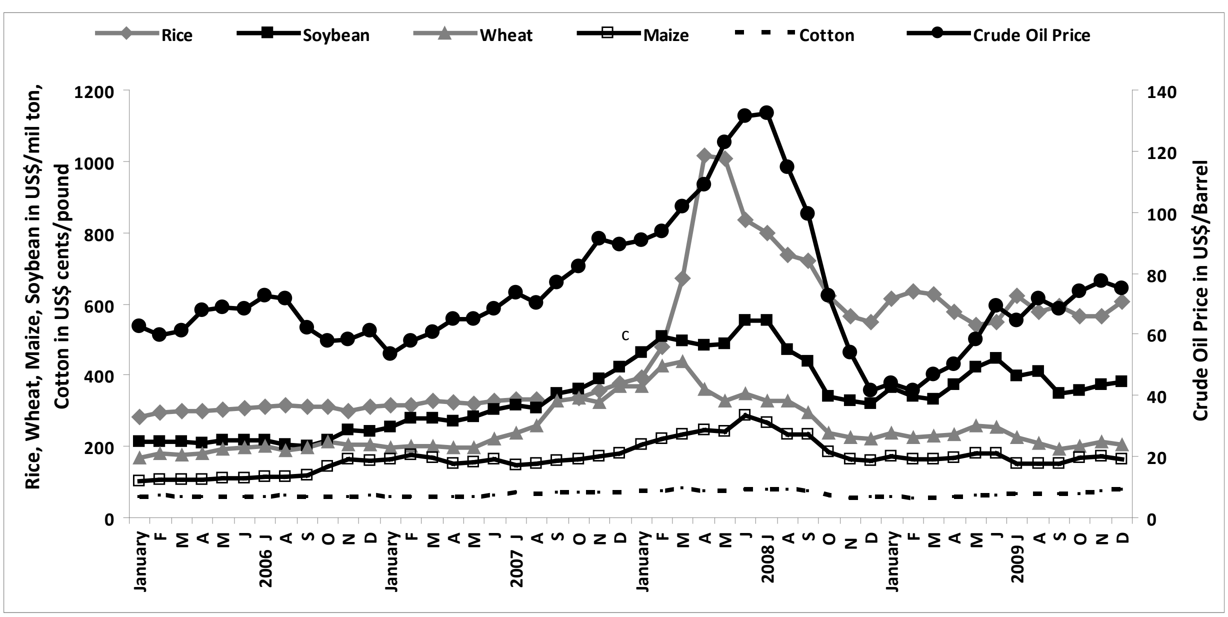
Global Area of Biotech Crops in 2009

2009 was an uncertain and volatile year for farmers globally as they faced the multiple negative effects of the most severe global economic recession for years, in the wake of 2008. The 2008/2009 period featured high prices of oil and increased demand for food and feed which drove fuel and input prices for fertilizers and pesticides, as well as commodity prices, to unprecedented high levels (Figure 1). The receding prices of oil and commodities in 2009 coupled with the global financial crisis, and a tightening credit supply led to great uncertainty which in turn impacted on farmers, particularly in the southern hemisphere, in countries like Brazil, which planted crops in November and December of 2009. The record prices of food and feed commodities in 2008 ignited a debate over food versus fuel and the high prices caused riots in many countries including Argentina, Haiti, Mexico, and Egypt. The unprecedented price increases of food have been particularly hard on the poor who spend up to 75%, or more, of their income on food.

In 2009, the 14th year of commercialization, the global area of biotech crops continued to climb at a sustained growth rate of 7% or 9 million hectares reaching 134 million hectares or 335 million acres (Table 1). The accumulated hectarage during the first fourteen years, 1996 to 2009, reached, for the first time, almost 1 billion hectares (949.9 million hectares) or 2.4 billion accumulated acres. Biotech crops have set a precedent in that the biotech area has grown impressively every single year for the past 14 years, since commercialization first began in 1996 with almost a remarkable 80-fold (78.8) increase since 1996. The number of farmers growing biotech crops in 2009 increased again by 0.7 million reaching 14.0 million (up from 13.3 million in 2008) of which over 90% or 13 million, up from 12.3 million in 2008, were mainly small and resource-poor farmers from developing countries.

Thus, in 2009, a record 134 million hectares of biotech crops were planted by 14 million farmers in 25 countries, compared with 125 million hectares grown by 13.3 million farmers in 25 countries in 2008. Germany discontinued cultivation of biotech crops in 2009 whilst Costa Rica was added to the list bringing the subtotals of countries planting biotech crops to 16 developing countries and 9 industrial countries. It is notable that 9 million hectares more were planted in 2009 by 14 million farmers in the 14th year of commercialization at a growth rate of 7% equivalent to 9 million hectares. The highest increase in any country, in absolute hectarage growth, was Brazil with 5.6 million hectares and the highest proportional increase was for Burkina Faso with a 1,383% increase from 8,500 hectares in 2008 to 115,000 hectares in 2009, in only its second year of commercialization. The total number of EU countries which grew biotech crops in 2009 was six and included in decreasing order of hectarage: Spain, Czech Republic, Portugal, Romania, Poland and Slovakia, with Germany having discontinued the cultivation of Bt maize in 2009.

Figure 1. International Prices of Crop Commodities and a Barrel of Crude Oil, 2006 to December 2009



Source: International Monetary Fund, 2009.

Table 1. Global Area of Biotech Crops, the First 14 Years, 1996 to 2009

Year	Hectares (million)	Acres (million)
1996	1.7	4.3
1997	11.0	27.5
1998	27.8	69.5
1999	39.9	98.6
2000	44.2	109.2
2001	52.6	130.0
2002	58.7	145.0
2003	67.7	167.2
2004	81.0	200.0
2005	90.0	222.0
2006	102.0	252.0
2007	114.3	282.0
2008	125.0	308.8
2009	134.0	335.0
Total	**949.9**	**2,351.1**

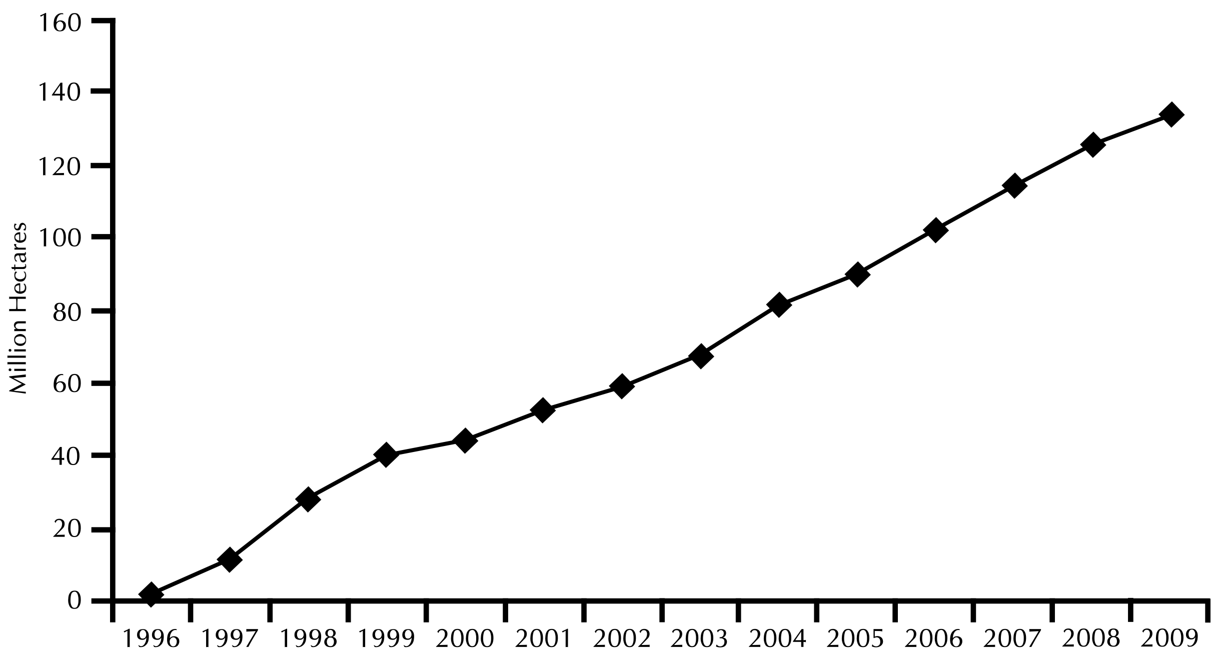
Increase of 7%, 9 million hectares (22.5 million acres) between 2008 and 2009.

Source: Clive James, 2009.

To put the 2009 global area of biotech crops into context, 134 million hectares of biotech crops is equivalent to approximately 14% of the total land area of China (956 million hectares) or the USA (981 million hectares) and more than five times the land area of the United Kingdom (24.4 million hectares). The increase in area between 2008 and 2009 of 7% is equivalent to 9 million hectares or 22.5 million acres.

During the fourteen years of commercialization 1996 to 2009, the global area of biotech crops increased almost 80-fold (78.8), from 1.7 million hectares in 1996 to 134 million hectares in 2009 (Figure 2). This rate of adoption is the highest rate of crop technology adoption for any crop technology and reflects the continuing and growing acceptance of biotech crops by farmers in both large as well as small and resource-poor farmers in industrial and developing countries. In the same period, the number of countries growing biotech crops quadrupled , increasing from 6 in 1996 to 12 countries in 1999, 17 in 2004, 21 countries in 2005, and 25, in 2009. A new wave of adoption of biotech crops is fueled by several factors which are contributing to a broad-based global growth in biotech crops. These factors include: 25 countries (16 developing and 9 industrial) already planting biotech crops in 2009 with a strong indication that new countries, like Pakistan, will join in 2010 and beyond;

Figure 2. Global Area of Biotech Crops, 1996 to 2009 (Million Hectares)



Source: Compiled by Clive James, 2009

notable and significant continuing progress in Africa in 2009 with all three African countries (South Africa, Burkina Faso and Egypt) increasing their hectarage of biotech crops significantly. Africa is the continent with the greatest challenge; significant increases in area of "new" biotech crops such as Bt maize in Brazil which opens up significant additional potential hectarage globally for biotech crops; the fastest adopted biotech crop, biotech sugarbeet occupying 95% of national hectarages in the USA and Canada, in only its third year of commercialization; continuing growth in stacked traits in cotton and maize increasingly deployed by 11 countries worldwide; new second generation events being deployed that further enhance the benefits of first generation events; last but certainly not least the momentous potential implications following the issuance of biosafety certificates for biotech rice and maize in China in November 2009. This new wave of adoption is providing a seamless interface with the first wave of adoption, resulting in continued and broad-based strong growth in global hectarage of biotech crops. In 2009, the accumulated hectarage (949.9 million hectares) planted since 1996 almost reached the one billionth hectare of biotech crops. In 2009, developing countries continued to out-number industrial countries by 16 to 9, and closed the gap with industrial countries to only 4%. This trend is expected to continue in the future with 40 countries, or more, expected to adopt biotech crops by 2015, the end of the second decade of commercialization. By coincidence, 2015 also happens to be the Millennium Development Goal year, when global society has pledged to cut poverty and hunger in half – a vital humanitarian goal that biotech crops can contribute to, in an appropriate and significant way in developing countries. The MDG goals of 2015 provide global society and the scientific community with a one-time event/opportunity to urgently set explicit humanitarian targets to harness the considerable power of biotech crops to contribute to the MDG goals and more specifically the "Grand Challenge" of reducing hunger and poverty by 50% by 2015.

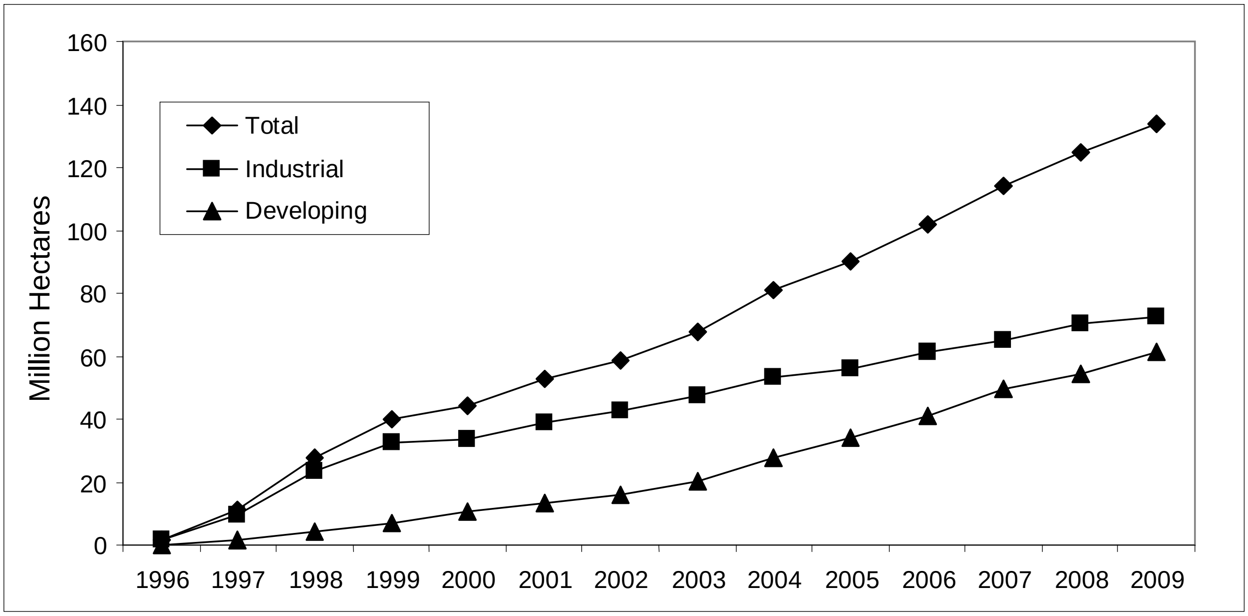
Brazil, reported, by far, the largest absolute increase in biotech crops in 2009 at 5.6 million hectares, followed by the USA at 1.5 million hectares, India at 0.8 and Canada at 0.7 million hectares. The largest proportional increases (over 10%) in 2009 on significant biotech hectarages were in Burkina Faso with a 1,353% increase in Bt cotton area, Brazil with a 35% increase, Bolivia 33% increase, Philippines 25%, Uruguay 14% and India with an 11% increase. These increases in 2009 are robust given the unprecedented negative effects of the severe economic recession on the world economy and its attendant uncertainties.

In summary, during the first fourteen years of commercialization 1996 to 2009, an accumulated total of almost 1 billion hectares (949.9 million) equivalent to over 2 billion acres of biotech crops have been successfully grown as a result of approximately 85 million repeat decisions by farmers to plant biotech crops (Table 1 and Figure 2). Farmers have signaled their strong vote of confidence in crop biotechnology by consistently increasing their plantings of biotech crops by high growth rates every single year since biotech crops were first commercialized in 1996, with the number of biotech countries quadrupling from 6 to 25 in the same 14-year period. However, even the significant hectarage of 134 million hectares does not fully capture the biotech crop hectarage planted with stacked traits, which are masked when biotech crop hectarage is expressed simply as biotech hectares rather than biotech "trait hectares". Taking into account that approximately 21% of the 134 million hectares had two or three traits (planted primarily in the USA, but also increasingly in ten other countries, Argentina, Canada, the Philippines, South Africa, Australia, Mexico, Chile, Colombia, Honduras, and Costa Rica), the true global area of biotech crops in 2009 expressed as "trait hectares" was 180 million compared with 166 million "trait hectares" in 2008. Thus, the real growth rate measured in "trait hectares" between 2009 (180 million) and 2008 (166 million) was 8% or 14 million hectares compared with the apparent growth rate of 7% or 9 million hectares when measured conservatively in hectares between 2008 (125 million hectares) and 2009 (134 million hectares).

Distribution of Biotech Crops in Industrial and Developing Countries

Figure 3 shows the relative hectarage of biotech crops in industrial and developing countries during the period 1996 to 2009. It clearly illustrates that whereas the substantial but consistently declining share (54% in 2009 compared with 56% in 2008, 57% in 2007 and 60% in 2006) of biotech crops

Figure 3. Global Area of Biotech Crops, 1996 to 2009: Industrial and Developing Countries (Million Hectares)



Source: Clive James, 2009

Table 2. Global Area of Biotech Crops, 2008 and 2009: Industrial and Developing Countries (Million Hectares)

	2008	%	2009	%	+/-	%
Industrial countries	70.5	56	72.5	54	2.0	+3
Developing countries	54.5	44	61.5	46	7.0	+13
Total	**125.0**	**100**	**134.0**	**100**	**9.0**	**+7**

Source: Clive James, 2009.

continued to be grown in industrial countries in 2009, the proportion of biotech crops grown in developing countries has increased consistently every single year from 14% in 1997, to 16% in 1998, to 18% in 1999, 24% in 2000, 26% in 2001, 27% in 2002, 30% in 2003, 34% in 2004, 38% in 2005, 40% in 2006, 43% in 2007, 44% in 2008 and 46% in 2009. Thus, in 2009, almost half of the global biotech crop area of 134 million hectares, equivalent to 61.5 million hectares, was grown in 16 developing countries where growth continued to be strong, compared with the 9 industrial countries growing biotech crops (Table 2). It is noteworthy that in 2009, all six countries that exhibited proportional growth in biotech crop area of 10% or more were developing countries; they were in descending order of percentage growth: Burkina Faso (1,353% increase), Brazil (35%), Bolivia (33%), Philippines (25%), South Africa (17%), Uruguay (14%) and India (11%). As in the past, in 2009, percent growth in biotech crop area continued to be significantly stronger in the developing countries (13% and 7 million hectares) than industrial countries (3% and 2 million hectares). Thus, year-on-year growth measured either in absolute hectares or by percent, was higher in developing countries than industrial countries between 2008 and 2009. The strong trend for higher growth in developing countries versus developing countries is highly likely to continue in the near, mid and long-term, as more countries from the South adopt biotech crops and crops like rice, 90% of which is grown in developing countries, are deployed as new biotech crops.

Of the US$51.9 billion additional gain in farmer income generated by biotech crops in the first 13 years of commercialization (1996 to 2008), it is noteworthy that half, US$26.1 billion, was generated in developing countries and the other half, US$25.8 billion, in industrial countries. In 2008, developing countries had a 50% share, or US$4.7 billion of the US$9.2 billion gain, with industrial countries at the same level of 50% at US$4.5 billion (Brookes and Barfoot, 2010, forthcoming).

Distribution of Biotech Crops, by Country

The eight principal countries that grew biotech crops on 1 million hectares, or more, in 2009 remained the same as 2008 with the significant exception that Brazil displaced Argentina as the second ranking country in the world in terms of biotech crop hectarage. This is a very important development for Brazil and foreshadows an increasing role for the country as the engine of economic growth and innovation in Latin America and more generally, technological leadership in agriculture globally. Costa Rica was added to the 2009 global biotech crop list, growing a small hectarage of biotech cotton and soybean crops for seed export only, (like Chile), with Germany discontinuing planting in 2009. The eight countries which grew over 1 million hectares in 2009 are listed by hectarage in Table 3 and Figure 4, led by the USA which grew 64.0 million hectares (48% of global total), Brazil with 21.4 million hectares (16%), Argentina with 21.3 million hectares (16%), India with 8.4 million hectares (6%), Canada with 8.2 million hectares (6%), China with 3.7 million hectares

(3%), Paraguay with 2.2 million hectares (2%), and South Africa with 2.1 million hectares (2%). An additional 17 countries grew a total of 2.0 million hectares in 2009 (Table 3 and Figure 4). It should be noted that of the top eight countries, each growing 1.0 million hectares or more of biotech crops, the majority (6 out of 8) are developing countries, Brazil, Argentina, India, China, Paraguay, and South Africa, compared with only two industrial countries, USA and Canada. The number of biotech mega-countries (countries which grew 50,000 hectares, or more, of biotech crops) increased to 15 compared with 14 in 2008 with Burkina Faso being added to the list of mega-countries; two of the three African countries (South Africa and Burkina Faso) are already mega-countries, with Burkina Faso qualifying in only the second year of commercialization. Notably, 11 of the 15 mega-countries are developing countries from Latin America, Asia and Africa. The high proportion of biotech mega-countries in 2009, 15 out of 25, equivalent to 60%, reflects the significant broadening, deepening and stabilizing in biotech crop adoption that has occurred within the group of more progressive mega-countries adopting more than 50,000 hectares of biotech crops, on all six continents in the last 14 years.

It is noteworthy that in 2009, Burkina Faso had the highest growth rate (14-fold increase) between 2008 and 2009 and Brazil had the highest absolute growth of biotech crops (5.6 million hectares) in any country in 2009.

In the first twelve years of commercialization of biotech crops, 1996 to 2007, South Africa was the only country on the continent of Africa to commercialize biotech crops, and Africa is recognized as the continent that represents by far the biggest challenge in terms of adoption and acceptance. Accordingly, the decision in 2008 of Burkina Faso to grow Bt cotton and for Egypt to commercialize Bt maize for the first time was of strategic importance for the African continent. For the first time in 2008, there was a lead country commercializing biotech crops in each of the three major regions of the continent – South Africa in southern and eastern Africa, Burkina Faso in West Africa and Egypt in North Africa. This broader geographical coverage in Africa is of strategic importance because it allows more Africans to become practitioners of biotech crops and be able to benefit directly from “learning by doing”, which has proven to be very important in China and India. Growth was reported in all three African countries in 2009 with Burkina Faso recording the highest percentage growth (+1,353%) of any country in the world increasing from 8,500 hectares in 2008 to 115,000 hectares in 2009. South Africa also recorded a significant increase of 17% in 2009, as well as Egypt (+15%). The growth in Egypt would have been considerably higher (+700%) had the planned import permit for 150 tons of seed for planting 5,000 hectares of biotech maize been issued in time for import of approved biotech Bt maize. Lower plantings of RR®soybean in Paraguay in 2009 were the result of several factors, but mainly due to a significant reduction in total plantings of soybean, and the general effects of the economic recession, continuing drought and other factors.

Table 3. Global Area of Biotech Crops in 2008 and 2009: by Country (Million Hectares)

	Country	2008	%	2009	%	+/-	%
1	USA*	62.5	50	64.0	48	+1.5	+2
2	Brazil*	15.8	13	21.4	16	+5.6	+35
3	Argentina*	21.0	17	21.3	16	+0.3	+1
4	India*	7.6	6	8.4	6	+0.8	+11
5	Canada*	7.6	6	8.2	6	+0.7	+9
6	China*	3.8	3	3.7	3	-0.1	-3
7	Paraguay*	2.7	2	2.2	2	-0.5	-19
8	South Africa*	1.8	1	2.1	2	+0.3	+17
9	Uruguay*	0.7	1	0.8	<1	+0.1	+14
10	Bolivia*	0.6	<1	0.8	<1	+0.2	+33
11	Philippines*	0.4	<1	0.5	<1	+0.1	+25
12	Australia*	0.2	<1	0.2	<1	<0.1	- -
13	Burkina Faso*	<0.1	<1	0.1	<1	+0.1	+1,353
14	Spain *	0.1	<1	0.1	<1	<0.1	- -
15	Mexico *	0.1	<1	0.1	<1	<0.1	- -
16	Chile	<0.1	<1	<0.1	<1	<0.1	- -
17	Colombia	<0.1	<1	<0.1	<1	<0.1	- -
18	Honduras	<0.1	<1	<0.1	<1	<0.1	- -
19	Czech Republic	<0.1	<1	<0.1	<1	<0.1	- -
20	Portugal	<0.1	<1	<0.1	<1	<0.1	- -
21	Romania	<0.1	<1	<0.1	<1	<0.1	
22	Poland	<0.1	<1	<0.1	<1	<0.1	- -
23	Costa Rica	- -	- -	<0.1	<1	<0.1	- -
24	Egypt	<0.1	<1	<0.1	<1	<0.1	- -
25	Slovakia	<0.1	<1	<0.1	<1	< 0.1	- -
	Total	**125.0**	**100**	**134.0**	**100**	**9.0**	**+7**

Source: Clive James, 2009.

Figure 4. Global Area (Million Hectares) of Biotech Crops, 1996 to 2009, by Country, and Mega-Countries, and for the Top Eight Countries

Biotech Mega-Countries

50,000 hectares, or more

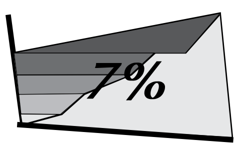
USA	64.0 million
*Brazil**	21.4 million
*Argentina**	21.3 million
*India**	8.4 million
Canada	8.2 million
*China**	3.7 million
*Paraguay**	2.2 million
*South Africa**	2.1 million
*Uruguay**	0.8 million
*Bolivia**	0.8 million
*Philippines**	0.5 million
Australia	0.2 million
*Burkina Faso**	0.1 million
Spain	0.1 million
*Mexico**	0.1 million

Less than 50,000 hectares

*Chile**	Romania
*Colombia**	Poland
*Honduras**	*Costa Rica**
Czech Republic	*Egypt**
Portugal	Slovakia

** Developing countries*

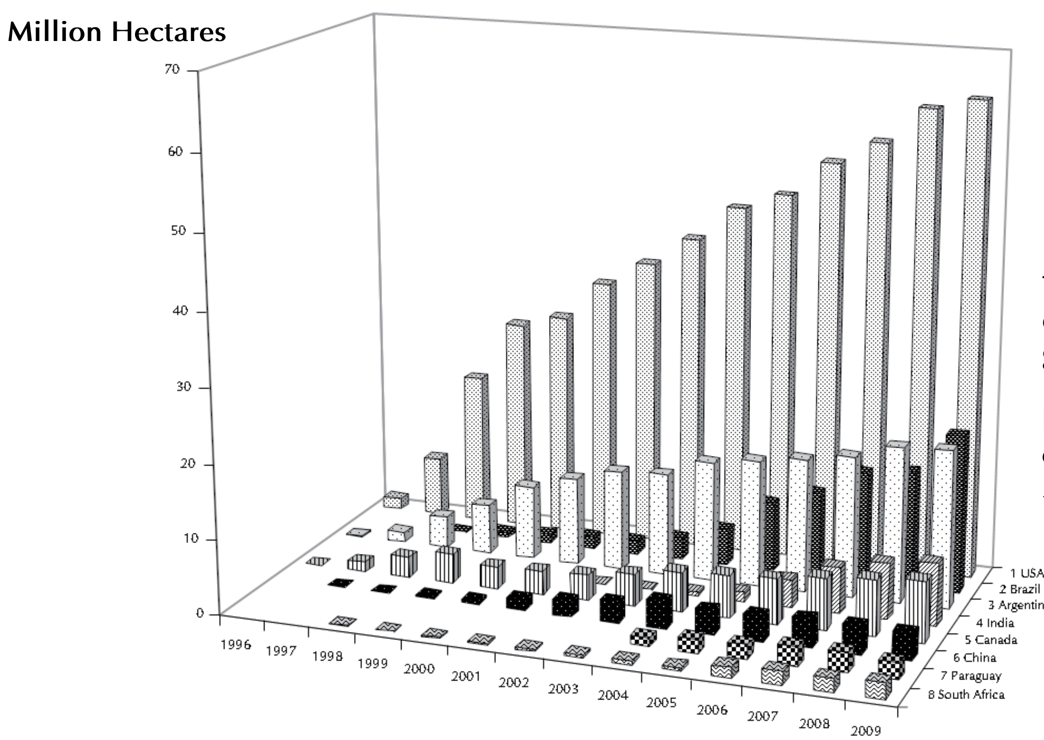
Increase over 2008



25 countries which have adopted biotech crops

In 2009, global area of biotech crops was 134 million hectares, representing an increase of 7% over 2008, equivalent to 9 million hectares.

Source: Clive James, 2009.



Top eight countries growing 1 million hectares, or more in 2009

Source: Clive James, 2009.

It is noteworthy that there are now ten countries in Latin America which benefit from the extensive adoption of biotech crops; the ten Latin American countries, listed in order of hectarage are Brazil, Argentina, Paraguay, Uruguay, Bolivia, Mexico, Chile, Colombia, Honduras and Costa Rica, the latter being a new biotech crop country in 2009. It is also noteworthy that Japan grew, for the first time, a commercial biotech flower, the “blue rose” in 2009. The rose was grown under partially covered conditions and not in “open field” conditions like the other food, feed and fiber biotech crops grown in other countries listed in this Brief. Australia and Colombia also grow biotech carnations

In 2009, six EU countries, Spain, Czech Republic, Portugal, Slovakia, Romania and Poland grew a total of 94,777 hectares of Bt maize. Despite the economic recession and the fact that France suspended Bt maize plantings in 2008 and Germany in 2009, the biotech crop hectarage in the EU was 94,777 hectares in 2009 compared with a 2008 total of 107,719 hectares (including 3,173 hectares in Germany), equivalent to a 12% decrease. Some of this decrease was due to lower total plantings of Bt maize in the EU, discontinuation of Bt maize by Germany in 2009 and to the general negative impact of the economic recession. For Spain, the country that grew 80% of all the Bt maize in the EU, percent adoption of Bt maize remained the same in 2008 and 2009 at 22% and the decrease in absolute hectares was entirely due to a decreased planting of total maize in 2009.

The three countries with significant increases in absolute area of biotech crops of 0.5 million hectares or more, between 2008 and 2009, were Brazil with 5.6 million hectares, the USA with a 1.5 million hectare increase, and India with a 0.8 million hectare increase.

Based on proportional year-to-year annual growth in biotech crop area, two countries merit mention with Burkina Faso with a 1,353% increase equivalent to a 106,500 hectare increase and Brazil with a 35% growth equivalent to 5.6 million hectares mainly attributable to the increase in biotech maize in both the summer and winter plantings.

The six principal countries that have gained the most economically from biotech crops, during the first 13 years of commercialization of biotech crops, 1996 to 2008* are, in descending order of magnitude, the USA (US$23.4 billion), Argentina (US$9.2 billion), China (US$7.6 billion), India (US$5.1 billion), Brazil (US$2.8 billion), Canada (US$2.1 billion), and others (US$1.7 billion) for a total of approximately US$51.9 billion; US$26.1 billion for developing countries and US$25.8 billion for industrial countries (Brookes and Barfoot, 2010, forthcoming).

In 2008 alone, economic benefits globally were US$9.2 billion of which US$4.7 billion was for developing and US$4.5 billion was for industrial countries. The countries that have gained the most economically from biotech crops in 2008 are, in descending order of magnitude, the USA (US$4.1 billion), India (US$1.8 billion), China (US$0.9 billion), Brazil (US$0.7 billion), Canada (US$0.4 billion), Argentina (US$0.4 billion) and others (US$0.9 billion) for a total of US$9.2 billion.

The 25 countries that grew biotech crops in 2009 are listed in descending order of their biotech crop areas in Table 3. There were 16 developing countries, and 9 industrial countries including the Czech Republic, Romania, Poland and Slovakia from Eastern Europe. In 2009, biotech crops were grown commercially in all six continents of the world – North America, Latin America, Asia, Oceania, Europe (Eastern and Western), and Africa. The top eight countries, each growing 1.0 million hectares, or more, of biotech crops in 2009, are listed in order of crop biotech hectarage in Table 3 and include the USA, Brazil, Argentina, India, Canada, China, Paraguay and South Africa. These top eight biotech countries accounted for approximately 98% of the global biotech crop hectarage with the balance of 2% growing in the other 17 countries listed in decreasing order of biotech crop hectarage – Uruguay, Bolivia, Philippines, Australia, Burkina Faso, Spain, Mexico, Chile, Colombia, Honduras, Czech Republic, Portugal, Romania, Poland, Cost Rica, Egypt and Slovakia. The individual country reports in the body of the Brief provide a more detailed analysis of the biotech crop situation in each of the 25 biotech crop countries, with more detail provided for the 15 mega-biotech countries growing 50,000 hectares, or more, of biotech crops.

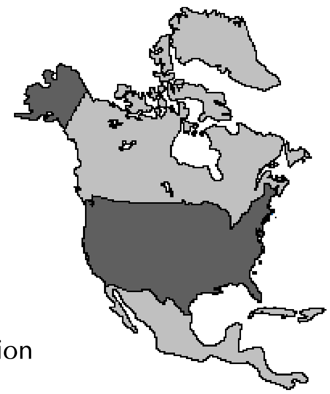
USA

In 2009, the USA was the largest producer of biotech crops in the world with a global market share of 48%. In 2009, the USA planted a record hectarage of 64.0 million hectares of biotech maize, soybean, cotton, canola, sugarbeet, alfalfa, papaya and squash, up from the 62.5 million hectares in 2008, and equivalent to a year-on-year growth rate of 2.4%. The increase in biotech crop hectarage of 1.5 million hectares between 2008 and 2009 was the second largest, after Brazil, for any country in the world. The USA also leads the way in the deployment of stacked traits in maize and cotton which offer farmers multiple and significant benefits. In 2009, the USA benefited from the third season of commercializing biotech sugarbeet which remarkably occupied 95%, equivalent to almost half a million hectares (450,000 hectares), in only its third year of commercialization. Notably, this makes RR® sugarbeet in the USA the fastest adopted biotech crop in history, with a remarkable 59% adoption in the second year and 95% in its third year, 2009. The adoption rates for the principal biotech crops in the USA: soybean, maize, cotton, canola and sugarbeet are close to optimal and further increases will be achieved only through stacking of multiple traits in the same crop or the advent of new crops/traits.

The USA is one of the six "founder biotech crop countries", having commercialized biotech maize, soybean, cotton and potato in 1996, the first year of global commercialization of biotech crops. The USA continued to be the lead biotech country in 2009 with continued growth, particularly in terms of biotech maize in which stacked traits continued to be an important feature. USDA estimates (USDA

NAAS, 2009a) indicate that soybean was 91% biotech, upland cotton 88%, and maize 85%. Herbicide tolerant sugarbeet was planted for the third time in the USA in 2009. The total hectarage planted to biotech soybean, maize, cotton, canola, sugarbeet, alfalfa, squash, papaya was 64.0 million hectares, up 1.5 million hectares or 2.4% from the 62.5 million hectares planted in 2008. With the exception of Brazil, this 1.5 million hectare increase in 2009 is the largest increase in absolute terms, for any country, despite the fact that percent adoption of all biotech crops in the USA are now close to optimal levels in the three major biotech crops of soybean, maize and cotton but also in other biotech crops – 95% for biotech sugarbeet and 85% for canola.

USA



Population: 303.9 million

GDP: US$13,751 billion

GDP per Capita: US$45,992

Agriculture as % GDP: 1.2%

Agricultural GDP: US$165 billion

% employed in agriculture: 1.2%

Arable Land (AL): 178 million hectares

Ratio of AL/Population*: 2.75

Major crops:

- Maize
- Soybean
- Cotton
- Sugarcane
- Sugarbeet
- Alfalfa
- Wheat
- Canola

Commercialized Biotech Crops:

- HT/Bt/HT-Bt Maize
- HT Soybean
- HT Canola
- Bt/HT/Bt-HT Cotton
- VR Squash
- VR Papaya
- Bt/HT Potato
- HT Sugarbeet
- HT Alfalfa

Total area under biotech crops and (%) increase in 2009:
64.0 Million Hectares (+2.4%)

Farm income gain from biotech, 1996-2008: $23.4 billion

*Ratio: % global arable land / % global population

Source: The Economist, supplemented with Data from the World Bank, FAO and UNCTAD when necessary.

Total plantings of maize in the USA in 2009 were 35.2 million hectares, approximately the same as 2008 but down significantly from the 37.9 million hectares in 2007. Biotech maize continued to be attractive in the USA in 2009 because of continued demand for ethanol and strong export sales. Maize planting started slowly with frequent rains and low temperatures in March, but warmer weather in April accelerated planting in the Mississippi Valley and in the corn belt. In May, conditions favored emergence. Despite the early weather delays, producers eventually made rapid progress and planting was completed just a little later than the average year. Total plantings of soybean at 31.4 million hectares were up only 2% compared with 2008 when the increase from 2007 was a substantial 17% equivalent to 4.5 million hectares. The relatively smaller increase in plantings in 2009 was due to significantly lower prices than the highs of mid 2008 and more generally, the effects of the economic crisis. Some farmers shifted from the high input costs for maize to soybean because farmers judged soybean to be more profitable than other crop options.

Total plantings of upland cotton at 3.5 million hectares in 2009 were down another 4.6% from the 3.66 million hectares planted in 2008; this 2009 decrease is in addition to a significant 14% decrease in upland cotton in 2008. Thus, after consecutive annual decreases, upland cotton in 2009 is at the lowest hectarage in over 25 years, since 1981. In Mississippi and Louisiana upland cotton producers planted the lowest hectarage on record at approximately 100,000 hectares each with the largest percentage decrease in California at approximately 50% less than 2008. Similarly, American Pima cotton growers planted only 60,000 hectares in 2009, a significant 35.3% lower hectarage than the 81,178 in 2008 which was significantly reduced by 31% compared with 2007. The major reasons for the sharp decline in area of upland cotton in 2009 was the continuing relatively low international price of cotton (which, unlike other commodities, did not benefit from the high mid 2008 prices) compared with the higher price of maize and soybean that led growers to switch to the higher profits that could be made with soybeans and maize which also offered a more secure market.

Canola hectarage in the USA was down 16% from 2008 (400,000 hectares) at 343,000 hectares in 2009. The major canola state of North Dakota planted 230,000 hectares down 23% from 2008 when hectarage had also decreased from 2007. Sugarbeet which featured RR® herbicide tolerant varieties for the second time in 2009 was planted on 473,684 hectares, up 8% in 2008 (437,246) of which 95% was RR®sugarbeet. Estimates of alfalfa seedings for 2009, will not be available from USDA until the first quarter of 2010, but they are not likely to be very different from 2008 seedings at approximately 1.3 million hectares – includes alfalfa harvested as hay and alfalfa haylage and green chop. Alfalfa is planted as a forage crop and grazed or harvested and fed to animals.

In 2009, the USA continued to grow more biotech crops (64.0 million hectares) than any other country in the world, equivalent to 48% of global biotech crop hectarage; this is the first year for the USA to be below 50% of global biotech hectarage. In 2009, the gain was 1.5 million hectares of biotech crops, equivalent to a 2.4% growth rate. Compared with a growth of 8% in 2008 year-over-year growth at 1.5 million hectares in 2009 was modest compared with previous years – there were several reasons for this. Firstly, like all sectors, agriculture has been significantly affected by the economic crisis. Secondly, the sharp decline in maize and soybean prices from the highs of mid 2008 provided significantly less incentive to farmers. Thirdly, there was no substantial increase in planting of soybean in 2009, as there was in 2008 when 4.4 million additional hectares of soybean were planted, of which over 90% was planted to RR®soybean. Thus, despite the severe economic crisis in 2009, absolute hectarage of biotech crops in the USA was robust under the circumstances and continued to climb modestly. This is consistent with steady increases in the percentage adoption for the major crops which is now close to optimal with biotech soybean at 91%, cotton at 88%, maize at 85%, sugarbeet at 95% and canola at 85%.

Adoption of biotech maize continued to climb with strong growth in the stacked traits, particularly in the triple stacks. However, the modest growth of 1.5 million hectares in 2009 does not fully measure the "real" as opposed to "apparent" increase in biotech crop hectarage planted. The double and triple stacked traits, which are masked when biotech crop hectarage is expressed simply as biotech "hectares" rather than biotech "trait hectares" – the same concept as expressing air travel as "passenger miles" rather than "miles." Thus, of the 64.0 million hectares of biotech crops planted in the USA in 2009, approximately 26 million hectares, (25.6 million in 2008) equivalent to about 40% compared with about the same level as 2008, had either two or three stacked traits.

The two-trait stacked products include biotech maize and cotton crops with two different insect resistant genes (for European corn borer and corn root worm control in maize) or two stacked traits for insect resistance and herbicide tolerance in the same variety in both maize and cotton. The maize stacked products with three traits feature two traits for insect control and one for herbicide tolerance. Accordingly, the adjusted "trait hectares" total for the USA in 2009 was approximately 108 million hectares (up from 102 million hectares in 2008) compared with only 64.0 million "hectares" of biotech crops. Thus, the apparent year-to-year growth for biotech crops in the USA, based on hectares is 2.4%, an increase from 62.5 million hectares to 64.0 million hectares. However, the "real" growth rate for biotech crops in the USA in 2009 is 6%, more than twice the hectare growth rate of 2.4%; this difference is due to the number of "trait hectares" increasing from 102.6 million hectares in 2008 by 5.4 million hectares (as opposed to 1.5 million in hectare growth), to approximately 108 million "trait hectares" in 2009. Furthermore, within the stacked traits category in maize, there are both double and triple stacks, and in 2009, the highest growth was in the triple stacks. Compared with 2008, triple traits in 2009 increased from 28% in 2007 to 48% in 2008 and 55% in 2009, the first time for it to exceed 50%.

It is noteworthy, that the first triple stacked construct in maize, which the USA introduced in 2005 on approximately half a million hectares, increased to over 2 million hectares in 2006, more than tripled to over 6 million hectares in 2007, more than doubled in 2008, and in 2009, and finally reached more than half the total hectarage of all biotech maize in the USA at approximately 17 million hectares, an all time high. Given that the USA has proportionally much more stacked traits than any other country, the masking effect leading to apparent lower adoption affects the USA more than other countries. It is noteworthy that 10 countries (equivalent to 40% of all 25 biotech countries) deployed stacked traits in either maize or cotton in 2009 with 7 out of the 10 being developing countries. In addition to the USA, the other ten countries which deployed stacked traits in 2009 were in order of hectarage: Argentina, Canada, the Philippines, South Africa Australia, Mexico, Chile, Honduras, Colombia, and Costa Rica while albeit at much lower proportions than the USA, but this is a trend that will increasingly affect other countries. In 2009, the total stacked trait hectarage in the other ten countries was approximately 2 million hectares. In 2009, the global "trait hectares" was 180 million hectares compared with only approximately 166 million hectares in 2008, equivalent to a growth rate of 8%. Thus, the apparent growth of 7%, or 9 million hectares based on an increase from 125 million hectares in 2008 to 134 million hectares in 2009 underestimates the real growth of 14 million hectares based on the growth in "trait hectares" from 166 million "trait hectares" in 2008 to 180 million "trait hectares" in 2009. Thus, in summary on a global basis "apparent growth" in biotech crops between 2008 and 2009, measured in hectares, was 7% or 9 million hectares, whereas the real growth measure in "trait hectares" was approximately 8% or 14 million trait hectares.

The biggest increases in USA biotech crops were for maize, with a gain of almost 1 million hectares, and soybean with a 0.5 million hectare gain. In 2009, the area of biotech soybean, 31.4 million hectares, had the highest adoption rate of any US biotech crop at over 90%, the highest ever; this compared with an increased adoption rate of over 85% in maize in 2009. The area of biotech cotton in 2009 remained constant at 3.1 million hectares out of a total planting of 3.6 million of which 88% was biotech up from 86% in 2008. Of the 3.1 million hectares of upland biotech cotton in the USA in 2009, 2.1 million or 69% was occupied by the stacked traits of Bt and herbicide tolerance, 29% were herbicide tolerance, and 2% with a single Bt trait. Total canola plantings in the USA were over 400,000 hectares with over 85% planted to herbicide tolerant biotech canola.

Sugarbeet growers have always faced significant challenges in weed management. In 2006, a small hectarage of a new and important biotech crop was planted for the first time in the USA, (Roundup Ready (RR®) herbicide tolerant sugarbeet) to evaluate the new technology and sell the sugar, pulp and molasses into the market place. In 2007, another small hectarage was planted and because of very limited biotech seed availability, only one sugarbeet company was able to transition to Roundup Ready (RR®). With greater amounts of seed production, it was estimated that in 2008, 59% of the 437,246 hectares of sugarbeet planted in the USA, equivalent to 257,975 hectares were RR®sugarbeet. Farmers welcomed the commercialization of sugarbeet and were very pleased with the biotech product, which provided superior weed control, was more cost-effective and easier to cultivate than conventional sugarbeet. Farmers cited many advantages of RR®sugarbeet over conventional including: the number of required cultivations cut by half with 30% savings in fuel; significant labor savings including elimination of supplementary hand weeding and labor time; less soil compaction; provides an incentive and facilitates adoption of minimum or no till; number of herbicide applications decreased as well as the convenience of reliance on fewer types of herbicides; less crop damage from herbicide applications; and generally more profitable and convenient to cultivate than conventional sugarbeet. In 2008, growers became convinced of the value of RR®sugarbeet and were keen to support the development of other traits, which they know to be important including disease, insect and nematode resistance, and drought and cold tolerance.

Herbicide tolerant RR®sugarbeets were quickly and widely adopted by growers in the USA and Canada in 2009. For the first time in 2009, adequate supplies of many seed varieties were now finally available for farmers. An estimated 95% of the 485,000 hectares of sugarbeets planted in the USA in 2009 were devoted to varieties improved through biotechnology. Canadian growers planted approximately 15,000 hectares of biotech varieties in 2009, representing nearly 96% of their nation's sugarbeet crop. This was the second year of commercial planting in Eastern Canada and the first year of commercial production in Western Canada. This very high adoption rate of 95% in three years makes RR®sugarbeet the fastest ever adopted biotech crop since biotech crops were first commercialized in 1996, fourteen years ago.

Independent scientific analysis shows that the sugar derived from RR®sugarbeets is identical at the molecular level to sugar from other comparably grown sugarbeets, and to the sugar from sugarcane. It is important to note that the sugar from RR®sugarbeet does not contain any DNA from the biotech transformation process, so the sugar is the same as the sugar produced from conventional sugarbeets and accordingly does not require labeling in the USA and in foreign markets like Japan. Since the USA is one of the largest importers of sugar in the world, most of the sugar and by-products from sugarbeet production are consumed domestically. However, the sugar, pulp and molasses derived from the RR®sugarbeet have been approved in all the major export markets including Japan, Canada, Mexico and the European Union, as well as South Korea, Australia, New Zealand, Colombia, Russia, China, Singapore and the Philippines.

Adoption of RR®sugarbeet by processors, and the consumers understanding and acceptance that the "sugar is the same" pure and natural sweetener as it has always been, has important implications regarding acceptance of biotech sugarbeet in other countries including the EU, and more generally by developing countries which grow sugarcane for food and ethanol production, such as Brazil.

In September 2009, a California court ruled that the U.S. Department of Agriculture (USDA) did not adequately study RR®sugarbeet's environmental risks when it allowed the commercialization of RR®sugarbeet in the US and ordered the USDA to conduct a more intensive study, which was pending when this Brief went to Press. It should be noted that the court's decision did not question the safety or efficacy of RR®sugarbeets. The very high level of satisfaction and demand by US and Canadian farmers for RR®sugarbeet launch probably has implications for sugarcane, (80% of global sugar production is from cane) for which biotech traits are under development in several countries and approval for field trials was granted in Australia in October 2009. Sugarcane crops improved through biotechnology have not yet been commercialized. However, significant research is actively under way in Australia, Brazil, Columbia, Mauritius and South Africa, as well as the United States. Traits under study in cane include herbicide tolerance, pest resistance, disease resistance and drought, cold and salt tolerance.

Luther Markwart, executive vice president of the American Sugarbeet Association, said ***"Biotech sugarbeet seeds arrived just in time to save a struggling industry that is essential to our nation's food security. Sugar from sugarbeets currently provide about half of the nation's sugar consumption. Our industry leaders have spent over 10 years to develop, approve, adopt and transition our U.S. production to this important technology. Growers simply said if our industry is going to survive, we've got to have these kinds of tools. Roundup Ready beet seeds are saving producers money and making the crop much easier to manage. Weeds***

are our biggest problem. Typically, with conventional beets you have to use four to five applications of a combination of various herbicides. Now farmers are using fewer chemicals and less fuel, and Roundup Ready doesn't stress the beets."

There was no change in the RR®alfalfa hectarage of 100,000 hectares between 2008 and 2009 pending resolution of the court suspension. Herbicide tolerant RR®alfalfa was approved for commercialization in the USA in June 2005. The first pre-commercial plantings (20,000 hectares) were sown in the fall of 2005, followed by larger commercial plantings (40,000 hectares) in the spring of 2006. Another planting of 20,000 hectares in the fall of 2006 resulted in a total of 80,000 hectares seeded in the 2006 launch of RR®alfalfa in the USA. Whereas there is approximately 11 million hectares of the perennial alfalfa crop in the USA, only 1.3 million hectares were probably seeded in 2006. Thus, the 60,000 to 80,000 hectares of RR®alfalfa represent approximately 5% of all the alfalfa seeded in 2006.

RR®alfalfa was very well received by farmers in the USA with all available seed sold in 2006 and demand was expected to grow over time. Benefits include improved and more convenient weed control resulting in significant increases in quantity and quality of forage alfalfa as well as the crop and feed safety advantages that the product offers. Gene flow has been studied and 300 meters provide adequate isolation between conventional and biotech alfalfa and 500 meters for seed crops. RR®alfalfa plants were first produced in 1997 and field trials were initiated in 1999, followed with multiple location trials to determine the best performing varieties. Import approvals have already been secured for RR®alfalfa in major US export markets for alfalfa hay including Mexico, Canada, Japan, the Philippines and Australia, and pending in South Korea – these countries represent greater than 90% of the USA alfalfa hay export market. Japan is the major market for alfalfa hay exports, mainly from California and the west coast states. The USA is a major producer of alfalfa hay which occupies approximately 9 million hectares with an average yield of 7.59 metric tons per hectare of dry hay valued at US$105 per ton, worth US$7 billion per year. In addition, there is approximately 2 million hectares of alfalfa used for haylage/green chop with a yield of approximately 14.19 metric tons per hectare. The crop is sown in both the spring and the fall, with 1 to 4 cuttings per season, depending on location. Over 90% of the alfalfa in the USA is used for animal feed with about 7% used as sprouts for human consumption. Monsanto developed the biotech alfalfa in partnership with Forage Genetics International. RR®alfalfa is likely to be more of a niche biotech crop than the other row biotech crops.

A Council for Agricultural Science and Technology (CAST, UC Davis News and Information, 2008) report in the USA concluded that, "We now have enough scientific data to design strategies for preventing gene flow from genetically engineered to conventional or organic alfalfa hay and seed operations." This important new evidence from CAST provided factual evidence for USDA to complete its environmental impact study for submission to lift the court order on planting of RR®alfalfa, however the latest court judgment upheld the original decision to halt planting.

As ISAAA Brief 41 went to press, Monsanto announced that it had filed a petition requesting the U.S. Supreme Court to review a federal appeals court's decision to block the cultivation of the company's RR®alfalfa until the USDA completes its environmental assessment (Tomich, 2009). Monsanto said that, "We have asked the U.S. Supreme Court to review the case because we believe the lower courts were wrong to impose a ban on planting Roundup Ready alfalfa while the U.S. Department of Agriculture conducts additional environmental reviews." Monsanto added that the law is clear that courts should only take this drastic action when it is likely that irreparable harm will result. "Yet, there is no evidence of any harm resulting from Roundup Ready alfalfa, and the trial court failed to consider relevant scientific evidence in reaching its decision to ban planting. Roundup Ready alfalfa meets the needs of farmers for dependable, cost-effective control of weeds in alfalfa and reduces herbicide applications with a system that has a 30-year history of safe use." Monsanto said that "The appellate court upheld the lower court's injunction even after a 2008 Supreme Court decision that reinforced the importance of considering relevant scientific evidence and, they looked forward to successful completion of the additional environmental review ordered by the court, but hoped the Supreme Court would agree that it was wrong to make farmers wait for years to get the benefit of a safe and effective product." In June, a U.S. appeals court upheld an injunction blocking the sale of Monsanto's Roundup Ready alfalfa seed until the U.S. Department of Agriculture finalizes research on the environmental impact of the biotech seed on nearby crops. The Ninth Circuit Court of Appeals denied Monsanto's request for a rehearing of its appeal and said it would accept no more petitions for rehearing in the case, which began three years ago (*Feedstuffs*, 2006). The permanent injunction prevents further planting until USDA completes an environmental impact statement, which is anticipated by this fall (*Feedstuffs*, 2008). Immediately before this Brief went to press, USDA published its environment impact assessment on RR®alfalfa for public comment; USDA recommends deregulation of the product (*Feedstuffs*, 2009).

In addition to the four major biotech crops, soybean, maize, cotton and canola, and the RR®alfalfa introduced in 2006, small areas of virus resistant squash (2,000 hectares) and virus resistant papaya (2,000 hectares) continued to be grown successfully in the USA in 2009.

Benefits from Biotech Crops in the USA

In the most recent global study on the benefits from biotech crops, Brookes and Barfoot (2010, forthcoming) estimate that USA has enhanced farm income from biotech crops by US$23.4 billion in the first thirteen years of commercialization of biotech crops 1996 to 2008, (representing 45% of global benefits for the same period) and the benefits for 2008 alone are estimated at US$4.1billion (representing 45% of global benefits in 2008) – these are the largest gains for any biotech crop country.

A study by the University of Arizona (Frisvold et al. 2006) examined the impact of Bt cotton in the USA and China in 2001. The two countries increased total world cotton production by 0.7% and reduced world cotton price by US$0.31 per kg. Net global economic effects were US$838 million worldwide with consumers benefiting US$63 million. Chinese cotton farmers gained US$428 million and US farmers gained US$179 million whereas cotton farmers in the rest of the world lost US$69 million because of the reduced price of cotton.

Farmer Experience

Quote from **Rickey Bearden**, an American farmer growing biotech soybean:
"Biotechnology is important to agriculture producers in the United States and the world. Biotech crops will continue to be a great tool for global agriculture use. If wisely used, this tool can help sustain the future of the agriculture industry" (Bearden, 2006).

BRAZIL

In 2009, Brazil narrowly displaced Argentina to become the second largest grower of biotech crops in the world. For 2009, biotech crops in Brazil are estimated to occupy 21.4 million hectares, an increase of 5.6 million hectares, the largest increase in any country in the world and equivalent to a 35% increase over 2008; Brazil now plants 16% of all the biotech crops in the world. Of the 21.4 million hectares of biotech crops grown in Brazil in 2009, 16.2 million hectares were planted for the seventh consecutive year to RR®soybean, up from 14.2 million hectares in 2008 and representing a record 71% adoption rate, versus 65% in 2008. In addition, in 2009, Brazil planted 5 million hectares of Bt maize for the second time in both the summer and after winter seasons (safrinha). The hectarage of Bt maize increased by 3.7 million hectares or almost a 400% increase over 2008, and was by far the largest increase for any biotech crop in any country in the world in 2009; the adoption rates for the summer maize were 30%, and 53% for the winter maize. Finally, 145,000 hectares of Bt cotton at an adoption rate of 18% were grown officially for the fourth time in 2009, of which 80% was Bt and 20% was herbicide tolerant. Thus in 2009, the collective hectarage of biotech soybean, maize and cotton in Brazil led to a national year-over-year growth of 35% over 2008, equivalent to 5.6 million hectares, the largest absolute increase for any country in the world, and most importantly resulted

in Brazil becoming, for the first time, the number two country in the world in terms of biotech hectarage. Stacked gene products for herbicide tolerance and insect resistance have already been approved for both cotton and maize. This augers well for the future of biotech crops in Brazil which is also field testing a "home-grown" virus resistant bean developed by EMBRAPA, which also gained approval in 2009 for a herbicide tolerant soybean developed in conjunction with BASF.

__BRAZIL__

Population: 191.3 million

GDP: US$1,313 billion

GDP per Capita: US$46,860

Agriculture as % GDP: 6%

Agricultural GDP: US$78.8 billion

% employed in agriculture: 21%

Arable Land (AL): 59.6 million hectares

Ratio of AL/Population*: 1.3

Major crops:
- Sugarcane
- Soybean
- Maize
- Cassava
- Oranges

Commercialized Biotech Crops:
- HT Soybean
- Bt Cotton
- Bt Maize

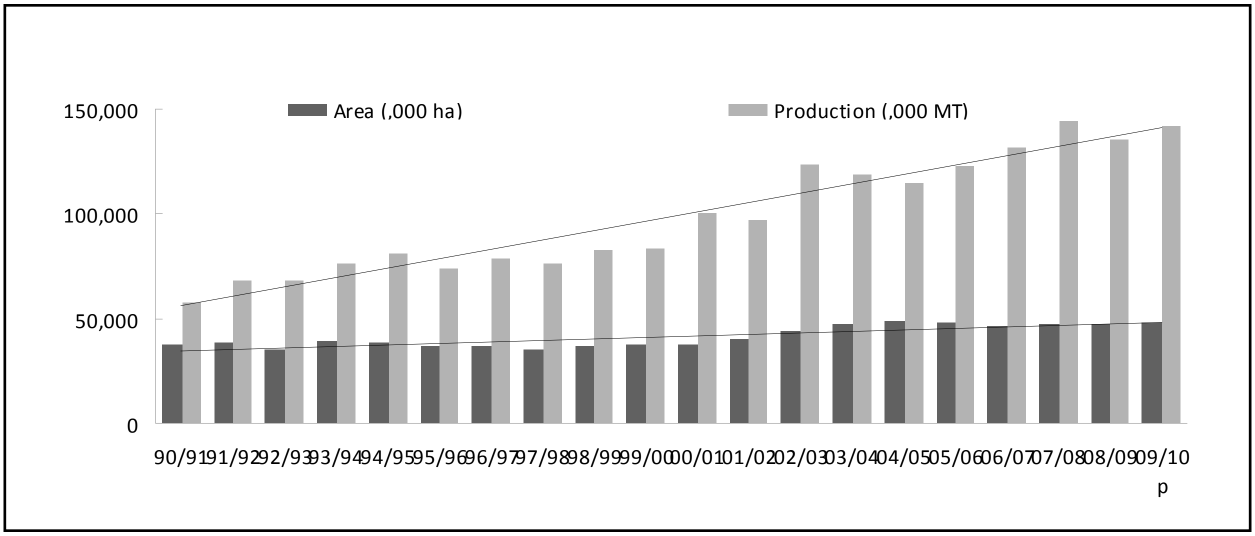
Total area under biotech crops and (%) increase in 2009:
21.4 Million Hectares (+35%)

Farm income gain from biotech, 2003-2008: US$2.8 billion

*Ratio: % global arable land / % global population

The salient aspect of Brazil's grain production in the last 20 years or so, is the doubling of production to approximately 140 million tons of grain or 145% growth since 1990 while the total planted area just expanded 27% (Figure 5). This increase in productivity is the result of improved technology, including better agronomic practices as well as deployment of higher yielding improved varieties and hybrids. The comparative advantage of the new, more economic technology, is very important for Brazil even though it is the only country in the world with up to 100 million hectares of new land that it can bring into production to meet its own increasing domestic need for grain as well as that of increasing export markets, particularly Asia and more specifically China. Biotech crops are especially important for Brazil because they offer an enormous new untapped potential in the remaining years of the second decade of commercialization of biotech crops, 2006 to 2015, and beyond. Failure to take full advantage of crop biotechnology would place Brazil at a significant disadvantage compared with other lead countries, such as the USA which is already aggressively expediting the deployment of second generation technology including advanced stacked traits.

Figure 5. Brazilian Grain Production, 1990 to 2009



Source: CONAB/Céleres, 2008. Elaboration and projections: Céleres.

Following two Presidential decrees in 2003 and 2004 to approve the planting of farmer-saved biotech soybean seed for the 2003/04 and 2004/05 seasons, the Brazilian Congress passed a Biosafety Bill (Law #11,105) in March 2005 that provided for the first time a legal framework to facilitate the approval and adoption of biotech crops in Brazil. The Bill allowed, for the first time, sale of commercial certified RR®soybean seed and the approved use of Bt cotton (event BC 531) as the first registered variety DP9B. However, the latter was not planted as officially approved registered seed in 2005 because of unavailability of seed; the first planting of Bt cotton in Brazil was in 2006 and expanded in 2007. The first approval of biotech maize was in 2007 but could not be deployed until 2008 because of regulatory constraints related to environmental impact assessments. As in the past, again, delays in relation to final regulatory approval for commercialization have eroded Brazil's comparative advantage in the deployment of the technology versus competitor countries. This is even more important at times when there are several factors contributing to uncertainty.

Projecting the adoption rate for RR®soybean in the southern hemisphere country of Brazil has always been a challenge because crops are not planted until the last quarter of the year when the Brief is being prepared and the projections involve many factors that are unrelated to biotech crops *per se*. The major uncertainties were the high volatility in the price of soybean and the strength of the Brazilian Real against the US dollar. Soybean growers in Brazil benefited from some reduction in the production cost, when compared to the 2008/09 crop year, especially in fertilizer costs and to a lesser extent herbicide costs. Better margins for oil crops than summer maize production led Brazilian growers to switch hectares from maize to soybean in all the main farming areas of Brazil.

The key growth in Brazil in grain crops will be in soybean which is expected to expand significantly in 2009/10, especially in Center-West states such as Mato Grosso, the leading soybean state in Brazil. New soybean varieties adapted to the central west region will allow farmers more access to higher yielding and more competitive biotech varieties, compared to conventional varieties. In contrast to 2008/09, glyphosate prices in the 2009 Brazilian market were more competitive than the traditional post emergence herbicides.

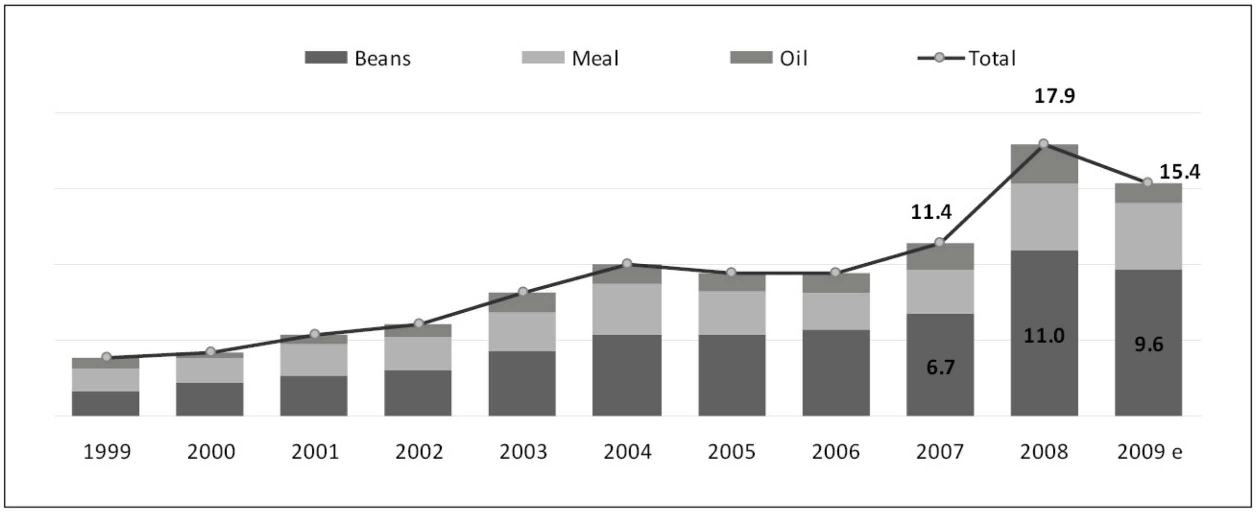
Also in contrast to 2008, there was a positive farmer perception of the direct and indirect benefits from RR®soybean compared with conventional soybean. Furthermore, RR®soybean is less prone to economic losses from Asian soybean rust because effective weed control allows more aeration between rows, resulting in decreased humidity which can delay the development of the disease to epidemic levels that result in severe losses. Soybean rust is a major economic constraint in important states like Mato Grosso requiring up to 6 applications of fungicide costing US$25 per application, which can make soybean production less profitable.

It is estimated that there are now at least 150,000 farmers growing soybean in Brazil. After Mato Grosso, the state of Parana was the second biggest state for soybeans in Brazil. In the past, Parana attempted to ban the planting of RR®soybean and its export from its state port of Paranagua. However in 2009, Parana is expected to plant around 70% of its 4.3 million hectares of soybean to RR®soybean, and the port of Paranagua is now exporting significant tonnages of RR®soybean.

According to the Brazilian External Trade Secretariat (Secex), in 2007, China bought 10.1 million metric tons of soybeans from Brazil. In 2008, the figure increased to 11.8 million metric tons worth US$5.3 billion, representing 48% of total soybean exports. China is by far the most important market for the export of Brazilian soybeans. The export and trade figures in Table 4 confirm the importance of agricultural exports in Brazil which constituted almost US$70 billion in 2008 with a growth of 18.7% between 2007 and 2008. Similarly, the trade data indicates net agricultural trade of US$57.7 billion, growing at a vigorous 16.1% per year and agricultural trade constituting 23.3% of total net trade. The three soybean products: grain, meal, and oil have different markets. China is the major destination for soybean grain, Europe for the soybean meal, with soybean oil exported to vegetable oil deficit countries like Iran and India. The total soybean export market for Brazil in 2008 was worth US$17.9 billion, comprising US$11.0 billion for the soybean grain, setting a historical record for the external revenue of soybean products in Brazil. The projected market for 2009 is US$15.4 billion for the total of soybean complex exports, of which US$9.6 billion is projected for beans alone (Figure 6).

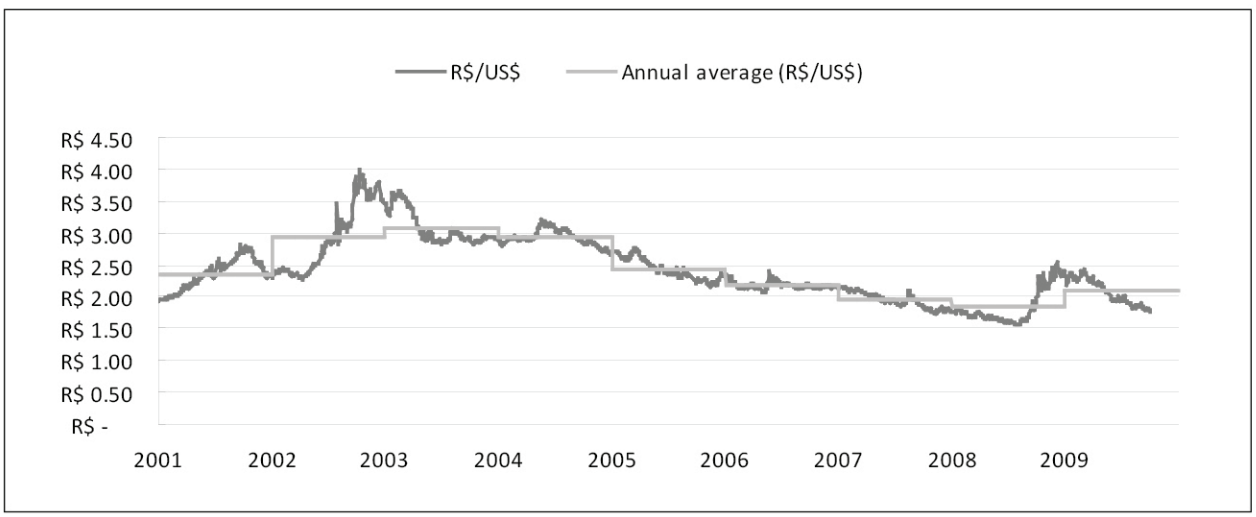
In March 2006, Brazilian authorities confirmed that China had authorized importation of Brazilian soybeans for the next five years, as opposed to the usual annual authorization. This was an important development and provides Brazil with the assurance of longer-term future markets and a stable

Figure 6. Brazilian Soybean Export Revenue (US$ billion) for 1999 to 2009 Estimates



Source: SECEX. Elaboration (e) and Projection (p): Céleres, 2009.

Figure 7. Brazilian Real Versus US$ Exchange Rate, 2001 to 2009



Source: Brazilian Central Bank, 2009.

Table 4. Agricultural Exports and Net Agricultural Trade in Brazil, in US$ Billions, for 2005 to 2008

	2005	2006	2007 (a)	2008 (b)	Change (a/b)	Share
Ag Exports	43.6	49.4	58.4	69.3	18.7%	35.0%
Total Exports	118.3	137.5	160.7	197.9	23.2%	
Ag Imports	5.2	6.8	8.7	11.6	33.4%	6.7%
Total Imports	73.6	91.4	120.6	173.2	43.6%	
Net Trade						
Ag Trade	38.4	42.6	49.7	57.7	16.1%	23.3%
Total Trade	44.7	46.1	40.1	24.7	-38.8%	

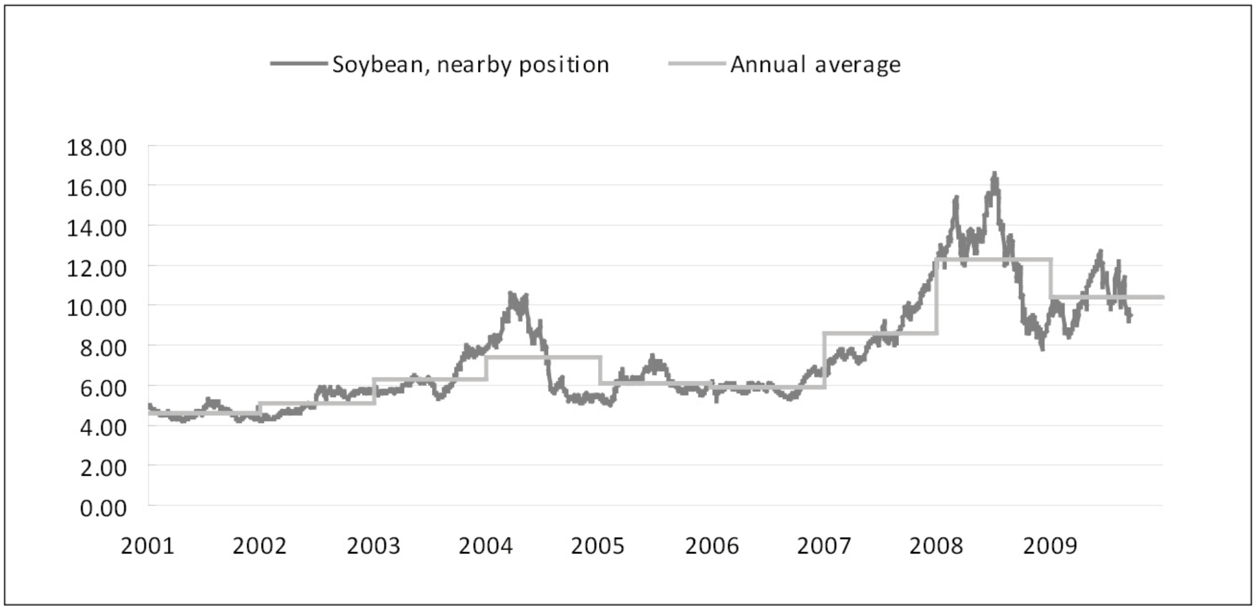
Source: Brazilian External Trade Secretariat (SECEX), 2009. Elaboration: Céleres

supply line to China. Soybean exports now account for 48% of Brazil's total exports to China and worth US$5.3 billion in 2008 compared to US$1.7 billion in 2005 and, according to China, Brazilian soybean accounts for 30% of total soybean imports.

After a period of weakness, soon after the outbreak of the recent international financial crisis, the Brazilian Real resumed its pattern of strengthening against the US dollar (Figure 7). However, strengthening of the Real is of concern to Brazilian soybean growers because their profitability is at risk, particularly as this coincides with lower prices for soybean in international markets (Figure 8). Thus, lower production costs may not be enough to off-set a stronger Real and this has contributed to increasing uncertainty for the 2009/10 soybean planting and in turn the planned hectarage of RR®soybean. Furthermore, agribusiness in Brazil, in contrast to Argentina, is financed increasingly by the private sector, rather than the traditional public sector, and this can cause more uncertainty in terms of access to credit, as those in the private sector are still facing difficulties in raising capital in overseas financial markets.

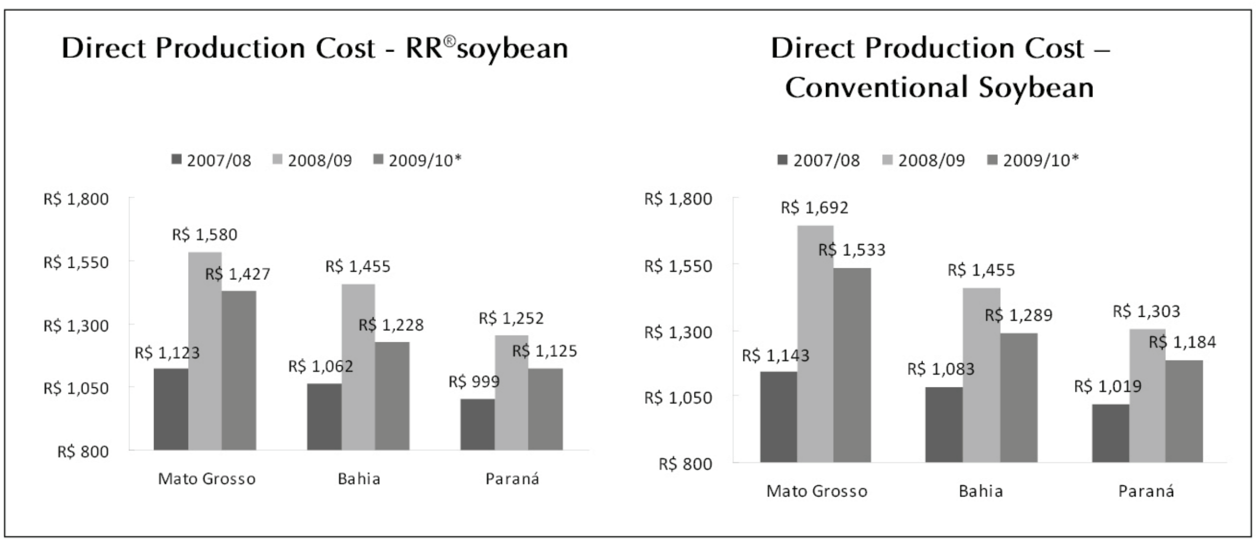
Despite these issues, Brazil remains strong agriculturally, being the world's largest producer of sugarcane and oranges, has the largest commercial cattle herd globally, and is the world leader in beef exports. It is the second biggest producer of soybean and ethanol in the world and agricultural exports reached US$69.3 billion in 2008, comprising a substantial 35% of total exports (Table 4 and Figure 6). Brazil has several factors in its favor that will likely stimulate strong growth in the agricultural sector in the next decade. These include an enormous area of new land (up to 100 million hectares) with an adequate water supply which is critical; strong domestic and export markets for

Figure 8. Global Soybean Prices, 2001 to 2009



Source: Chicago Board of Trade, 2009. Values in US$/bushel

Figure 9. Soybean Production Cost in Brazil, 2007/08 to 2009/10

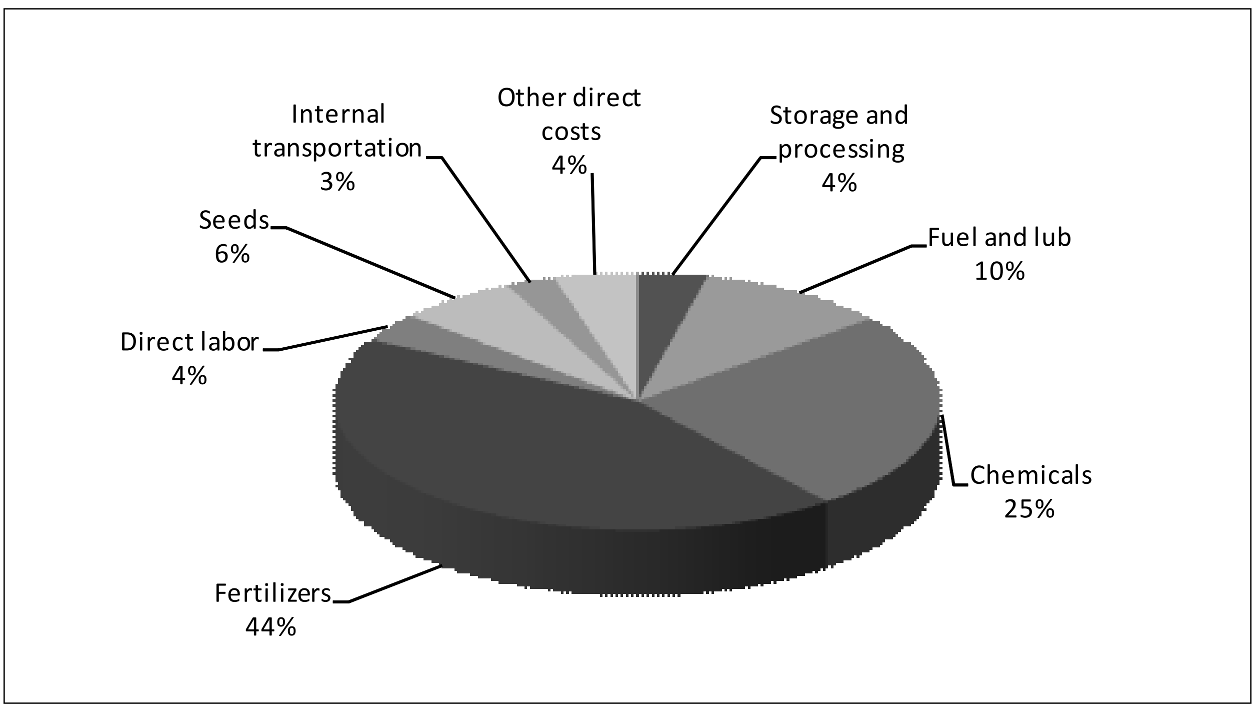


Source: Céleres, 2009. Values in BRL/hectare Estimated in October, 2009 grain and oil seeds for feed, poultry and pork production; large productivity gaps in crops such as maize, cotton, and rice with entrepreneur farmers who will quickly adopt innovative technology like biotech to close those gaps. The challenges are the lack of infrastructure in transportation and marketing, and the increasing dependency on Asian markets.

After a significant increase in cost of production of soybean in Brazil between 2007 and 2008, the 2009/10 crop year featured lower costs of production as the main inputs, especially fertilizer which registered a significant drop in cost (Figure 10). It is noteworthy that in 2009 the costs of production for RR®soybean has been about 6% cheaper than the conventional soybean in the key selected states of Brazil (Figure 9). It is also noteworthy that the seed share as percentage of the total production cost, even with biotech adoption, still represents only a minimal 6% of the total cost of production (Figure 10).

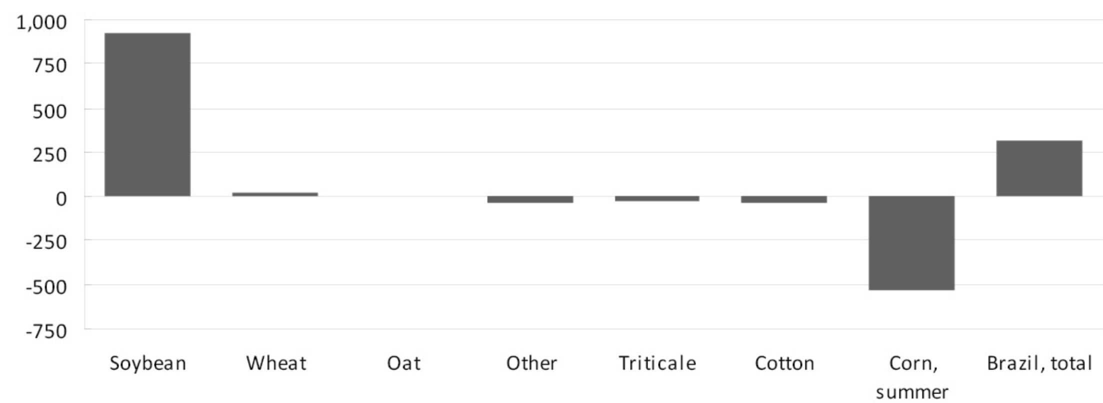
Thus, adoption of technologies that confer comparative advantage, such as biotech crops, will become increasingly important for Brazil to remain competitive in the current more challenging economic circumstances and provide Brazil with the comparative advantage at the time when it is needed the most. As in 2008, farmers in 2009 switched from crops with higher production costs

Figure 10. Soybean Cost of Production in Brazil, 2009/10



Source: Céleres, 2009. Values in BRL/hectare Estimated in October, 2009

Figure 11. Projected Changes in Grain Planted Area, Brazil, 2008/09 and 2007/08



Source: Céleres October, 2009 Survey. Values in thousand hectares

such as maize and cotton to crops such as soybean which has relatively lower production costs. The data presented in Figure 11 projects lower hectarages for maize, cotton and triticale with small increases in oat and wheat and a larger increase of approximately 900,000 hectares in soybean, resulting in a net reduction in grain hectarage of 318,000 hectares.

In 2009, more hectares of RR®soybean were planted in virtually all of the states in Brazil with the largest plantings in the states of Rio Grande do Sul (4.0 million hectares), Mato Grosso (3.6), Parana (3.0), Goias (1.6), and Mato Grosso do Sul (1.3 million hectares). Given farmer options, and profitability of alternate crops, total planting of soybean in Brazil in 2009/10 is projected at 22.9 million hectares. Planting of soybean in Brazil starts in the Northern provinces in September and finishes in the southern provinces by mid-to late December. At the time when this Brief went to press in December 2009 approximately half to two-thirds of the soybean crop had been planted in Brazil.

Whereas RR®soybean was approved in Brazil in 1998 (Table 5) legal issues delayed its official planting until 2003 when the first RR® varieties were registered (Figure 12). It is provisionally projected that RR®soybean will occupy approximately 16.2 million hectares of the 22.9 million hectare crop in Brazil in the 2009/10 season, equivalent to an adoption rate of 71% which represents a significant growth when compared to a 65% adoption rate in 2008/09 equivalent to 14.2 million hectares, an increase of 2 million hectares over 2008. A total of 51 varieties were registered for sale in 2008 of which 38, equivalent to 75% were RR®soybean with the remaining 13 varieties

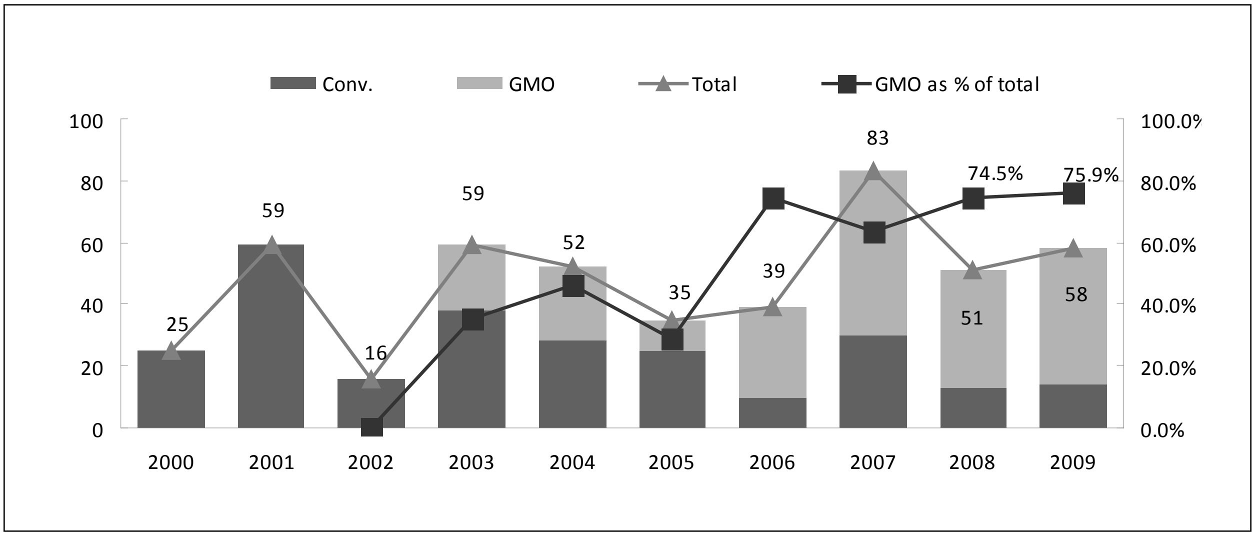
Table 5. Biotech Crops Approved for Commercial Planting in Brazil, 1998 to 1 December 2009

Crop	Event	Trait	Approved by CTN Bio in
Soybean	GTS-40-3-2	Herbicide tolerance (HT)	September 1998
Maize	T25	HT	May 2007
Maize	MON 810	Insect resistance (IR)	August 2007
Maize	BT11	IR	September 2007
Maize	NK 603	HT	September 2008
Maize	GA21	HT	September 2008
Maize	HERCULEX	IR/HT	December 2008
Maize	MIR162	IR	September 2009
Maize	MON 810 x NK603	IR/HT	September 2009
Maize	Bt11 x GA21	IR/HT/HT	September 2009
Maize	MON89034	IR	October 2009
Maize	TC1507 x NK603	IR/HT/HT	October 2009
Cotton	MON 531 - BOLLGARD I	IR	March 2005
Cotton	LLCOTTON25	HT	September 2008
Cotton	MON 1445	HT	September 2008
Cotton	DAS-21023-5 x DAS-24236-5 (Widestrike)	IR	March 2009
Cotton	MON 15985 - BOLLGARD®II	IR	May 2009
Cotton	MON 531 x MON 1445	IR/HT	October 2009

Source: CTN Bio Website and BIC Brazil, Personal Communication, 1 December 2009.

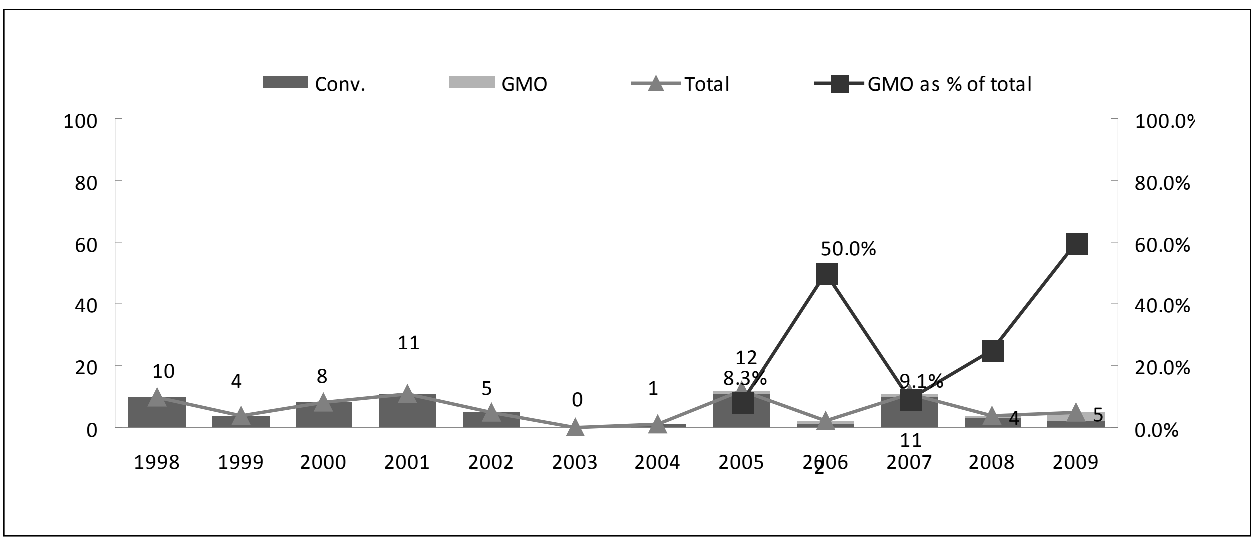
(25%) conventional (Figure 12). In 2009, from January to September, another 58 soybean varieties were approved in Brazil of which 44 were RR®soybean or 76% of the total. Since RR®soybean was approved in 2003 a total of 377 new varieties have been approved of which 219 or 58% were biotech and 158 or 42% were conventional. The data for the registration of both conventional and biotech soybean varieties for the period 2000 to 2009 are detailed in Figure 12 showing more RR®soybean varieties than conventional, and this trend is expected to continue. As the number of RR®soybean varieties adapted to the Central West region increases year by year, the adoption rate in the region is expected to increase in parallel. Notably, the soybean with tolerance to the herbicide imidazolinone, approved in December 2009 is the first "home grown" product developed in a collaborative effort by EMBRAPA and BASF.

Figure 12. Soybean Cultivars Registered in Brazil, 1999 to 2009



Source: Brazilian Ag Minister/SNRC, 2009. Elaboration: Céleres

Figure 13. Cotton Varieties Registered in Brazil, 1999 to 2009



Source: Brazilian Ag Minister/SNRC, 2009. Elaboration: Céleres

The approval in 2005 of one biotech Bt cotton event (BCE 531) in the variety DP9B allowed cotton growers in Brazil to legally plant Bt cotton for the first time in the 2006/07 season. This variety underwent field-testing in Brazil prior to the events that delayed registration due to legal considerations. In July 2006, another Bt cotton variety NuOpal was registered, thus two varieties of Bt cotton were available for planting in 2007. In 2008, two other varieties of herbicide tolerant cotton were approved in Brazil but were not planted in the 2008 season, followed by 2 varieties with insect resistance in 2008 and notably the first stacked IR/HT product in 2009 – this was the first stacked biotech crop to be approved in Brazil (Table 5). Input costs on cotton production in Brazil are very high with insecticides comprising up to 40% of total production costs and involving up to 14 sprays per season. Benefits from Bt cotton are estimated at US$100 to US$300 per hectare and accordingly Bt cotton is expected to offer significant benefits to Brazil, particularly for the large cotton growing states of Mato Grosso and Bahia. Brazil is expected to grow approximately 820,000 hectares down from the 845,000 hectares of cotton in 2008/09, making it the sixth largest grower of cotton, by area, in the world after India, China, USA, Pakistan, and Uzbekistan.

The adoption of approved biotech cottons in Brazil in 2009/10 was projected at 145,000 hectares. Whereas Bt cotton occupies about 80% of the total biotech hectarage of 145,000 hectare in Brazil in 2009 this was the first crop year when limited quantities of herbicide tolerant cotton was also planted. It is estimated that of the 145,000 hectares of biotech cotton in Brazil in 2009, approximately 29,000 hectares was herbicide tolerant for the first time. The long-time awaited approval of Bollgard®II has resulted in an increased interest by farmers in 2009, and is expected to reach high levels in the near term as more adapted varieties of biotech cotton are submitted for approval and registration by industry. Given that deployment of biotech varieties of cotton is more difficult to control than biotech maize hybrids, the estimate of Bt cotton in Brazil in 2009 maybe conservative. The challenge of estimating biotech cotton hectarage is exacerbated by the fact that farmer-saved seed is common with only five varieties of biotech cotton registered since 2005 (Figure 13) compared with 250 biotech maize hybrids (Figure 14).

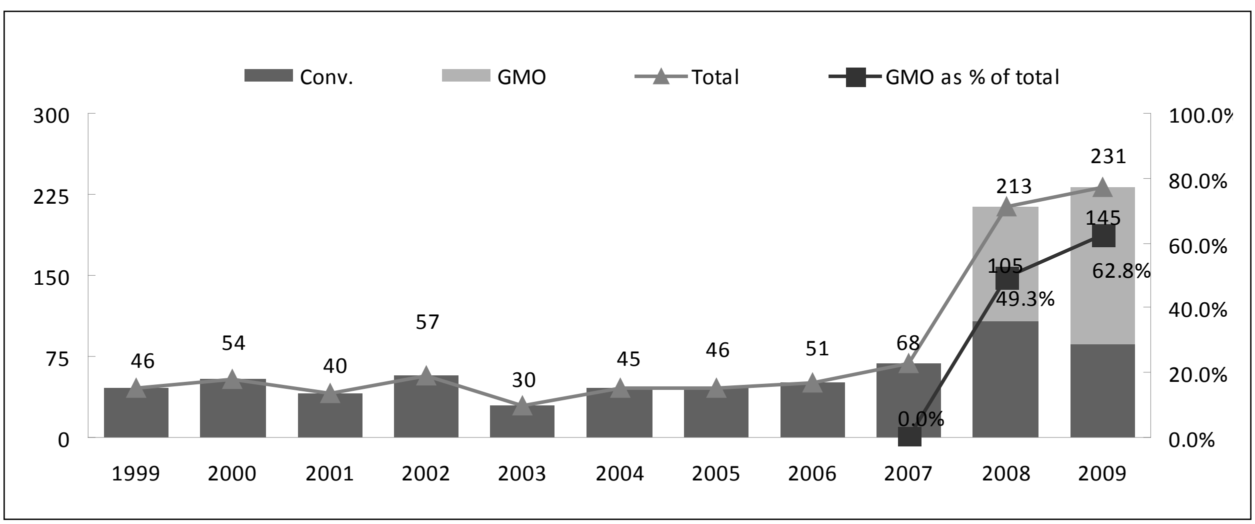
Cotton is grown by both large and small farmers, and Bt cotton offers the poor small farmers in the impoverished North East (NE) region of Brazil significant socio-economic benefits, similar to those experienced in China and India. In fact the heavy losses from insects in the North East led to the collapse of cotton production by small farmers. Bt cotton offers the opportunity to revive the cotton plantings in the NE and provide critically important benefits to small farmers which will allow national policies related to poverty alleviation to be realized at the grass root level. Thus, the potential for biotech Bt cotton in Brazil is significant because economic losses from insect pests have resulted in a reduction in the cotton area from 4 million hectares in the late 1970's to the current one million hectares, or less. There is the potential for reversing the decline in cotton area in Brazil with the adoption of Bt cotton and re-establish Brazil as a resilient net exporter of cotton to meet growing world market needs.

In 2008, one Bt maize hybrid was approved and cultivated and two hybrids of herbicide tolerant maize were approved but not cultivated (Table 5 and Figure 14). The Bt maize hybrid approved and planted in 2008 was a Bt11 product and sown in two seasons: the summer season harvested in September 2008 and the second season with planting starting in December 2008 but with most of the plantings in January 2009 and beyond. It is important to note that given that the second winter maize planting, which starts in the latter part of December, the winter maize planted in December 2009 and onwards to January and February 2010 is classified as a 2009 crop for the purposes of this Brief, because planting starts in the last week of the calendar year 2009.

Of the 8.0 million hectares in the 2009/10 summer crop planted after September 2009, about 2.4 million hectares were estimated to be Bt maize equivalent to an adoption rate of 30%. For the second planting of the winter maize starting in December 2009/January 2010 of 5.0 million hectares, a projected 2.6 million hectares is estimated to be Bt maize equivalent to an adoption rate of 53%. Consolidating these two separate maize plantings in Brazil in 2009 brings the total maize hectarage to 13.0 million hectares of which 5.0 million hectares, or 39% was Bt maize. The potential for biotech maize, both Bt and herbicide tolerant on the 13 million hectares of maize in Brazil is significant in 2010 and beyond. Notably the first stacked maize event (herbicide tolerance and Bt) was approved in December 2008 (PAT/cry1Fa2) (Table 5) followed by another three approvals for stacked maize in 2009.

Importantly in 2009, Brazil displaced Argentina to become the second largest grower of biotech crops in the world. For 2009, biotech crops in Brazil were estimated to occupy 21.4 million hectares, an increase of 5.6 million hectares, the largest in any country in the world and equivalent to a

Figure 14. Maize Hybrids and Lines Registered in Brazil, 1999 to 2009



Source: Brazilian Ag Minister/SNRC, 2009. Elaboration: Céleres

35% increase over 2008. Of the 21.4 million hectares of biotech crops grown in Brazil in 2009, 16.2 million hectares were planted to RR®soybean, for the sixth consecutive year, 145,000 hectares planted with a biotech cotton, grown officially for the fourth time in 2009, and 5.0 million hectares of biotech maize in its second year of commercial planting. The year-over-year growth between 2008 (15.8 million hectares) and 2009 (21.4 million hectares) was 35%. Brazil is currently the second largest producer of soybeans in the world after the USA and eventually expected to become the first. Brazil is also the third largest producer of maize, the sixth largest producer of cotton, the tenth largest grower of rice and the only major producer of rice (3.7 million) outside Asia. Brazil is also the largest sugarcane producer in the world with 8.1 million hectares planted in 2009 and uses approximately 60% of its sugarcane production for generating ethanol for biofuels. In the coming ten years the sugarcane hectarage in Brazil is expected to increase by more than 35%, to approximately 12.2 million hectares by 2018. By 2018, Brazil will produce over 1 billion tons of sugarcane. The share of sugarcane hectarage devoted to bioethanol is expected to increase from the current 60 to 63% by 2018. Thus, Brazilian ethanol production should reach 49.1 billion liters of which 6.2 billion liters will be exported in 2018.

The re-instatement of authority to the Comissão Técnica Nacional de Biossegurança (CTNBio) to approve RR®soybean and Bt cotton in March of 2005, was by far the most important biotech crop regulation development in Brazil in the last five years. CTNBio's challenge was to deal with applications that had accumulated whilst the long debate over its authority, delayed all decisions related to approval of biotech crops. In 2009, CTNBio made significant progress by approving eight products (Table 5).

In 2007, CTNBio approved two Bt maize products for commercialization and the intent was to deploy these Bt maize varieties in the 2007/08 season. However, subsequent to CTNBio's approval, a judicial intervention required an environmental impact study to be completed and approved before deployment, and this precluded planting of biotech maize until the 2008/09 season. Biotech maize has significant potential in Brazil to meet domestic demand, as well as demand of new export markets for maize. It is notable that Brazil exported its first consignment of 10 million tons of maize in 2007. The lessons learned from delayed approvals of RR®soybean should be applied to expedite the approvals of new events of biotech maize. Long delays in the approval of pending applications could result in Brazil losing out on the benefits of first and second generations of biotech crops.

Recent work in Brazil (Aragao and Faria, 2009) using RNAi interference technology to confer resistance to bean golden yellow mosaic virus (BGYMV) in beans (*Phaseolus vulgaris*) is a potential breakthrough. It is notable because it is the first group to report success in using biotech crops to control gemini viruses which cause devastating losses in many important crops in developing countries: these include maize, tomato and orphan crops like cassava and beans in developing countries where beans are the most common source of protein for 1 billion people world wide. The other important feature of the new EMBRAPA biotech virus-resistant bean is that the technology, like that in China, has been sourced by the public sector agricultural institute EMBRAPA – the national agricultural research organization of Brazil. BGYMV is estimated to cause annual losses of 90,000 to 280,000 tons in Brazil, which if averted, could feed 6 to 20 million people. In addition to losses incurred in planted bean crops, in Brazil alone it is estimated that beans cannot be planted on a further 180,00 hectares because of the potential severe losses from BGYMV, which can range from 40 to 100%. It is reported that the increased severity of BGYMV in Brazil during the last few years has been associated with higher populations of white fly, the vector for the virus, for which application of insecticides is the only option because there is no source of adequate resistance in beans. The BGYMV resistant beans developed in Brazil are currently being field-tested with a view to obtaining approval for commercialization of the biotech beans. Approval of this product, which is notably a "home grown" biotech crop developed by the public sector in Brazil, could be as early as 2012. BGYMV beans could be a potentially important contribution for poor people in Latin America where beans is a very important crop. Beans in Brazil alone occupy 3.8 million hectares, the second largest area in the world after India with 10 million hectares. The authors (Aragao and Faria, 2009) point out that the development of the first gemini-virus resistant crop opens up the new possibility of applying the RNAi technology for the control of important gemini viruses in Africa in pro-poor crops such as cassava, maize and tomatoes.

Other biotech crop products in the pipeline include new varieties of biotech sugarcanes, virus resistant papaya and potatoes from Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), and low lignin *Eucalyptus*.

Brazil is, by far, the largest grower of sugarcane in the world (8.1 million hectares, Figure 15), and it is also the world leader in the production of ethanol from sugarcane with ambitious plans to significantly increase production of biofuels in the future (Table 6). Brazil has approximately 350 sugar mills/distilleries, another 46 under construction and yet another 46 being considered for construction. Brazil produces 21% of the 147.4 million tons of sugar produced globally in 2009, and based on value, sugar and ethanol are the third and eighth most important exports, from the country. Brazil has significant investments in sugarcane biotechnology and has completed sequencing the crop's genome in 2003, which involved more than 200 scientists from 22 institutes in Brazil. This development opens up important new opportunities for improving the biofuel yield of sugarcane per hectare through biotech applications. The phasing out of EU subsidies for sugar processors provides Brazil with an opportunity to become the dominant leader in the global sugar market where it already exports sugar worth more than US$2 billion per year.

In 2009, the Brazilian biodiesel production is expected to reach 1.65 million cubic meters, 82% of this is expected to be produced from soybean, which in 2009 would have required an estimated 2.3 million hectares, equivalent to 10% of the total hectarage of 22.9 million hectares. Thus, about 1.4 million hectares of RR®soybean in Brazil were planned to be used for biodiesel production in 2009

Table 6. 2008 World Fuel Ethanol Production

Country	Millions of Gallons	Millions of Liters
USA	9,000.0	34,068.60
Brazil	6,472.2	24,499.87
European Union	733.6	2,776.97
China	501.9	1,899.89
Canada	237.7	899.79
Others	128.4	486.04
Thailand	89.8	399.93
Colombia	79.2	299.90
India	66.0	249.84
Australia	26.4	99.93
Total	**17,335.2**	**65,620.67**

Source: F.O. Licht, Renewable Fuels Association, 2009.
1 US gallon = 3.7854 liters

(Figure 16). Cotton seed is a potentially important source of vegetable oil and biodiesel in Brazil and the revival of the cotton industry through biotech could be very important strategically.

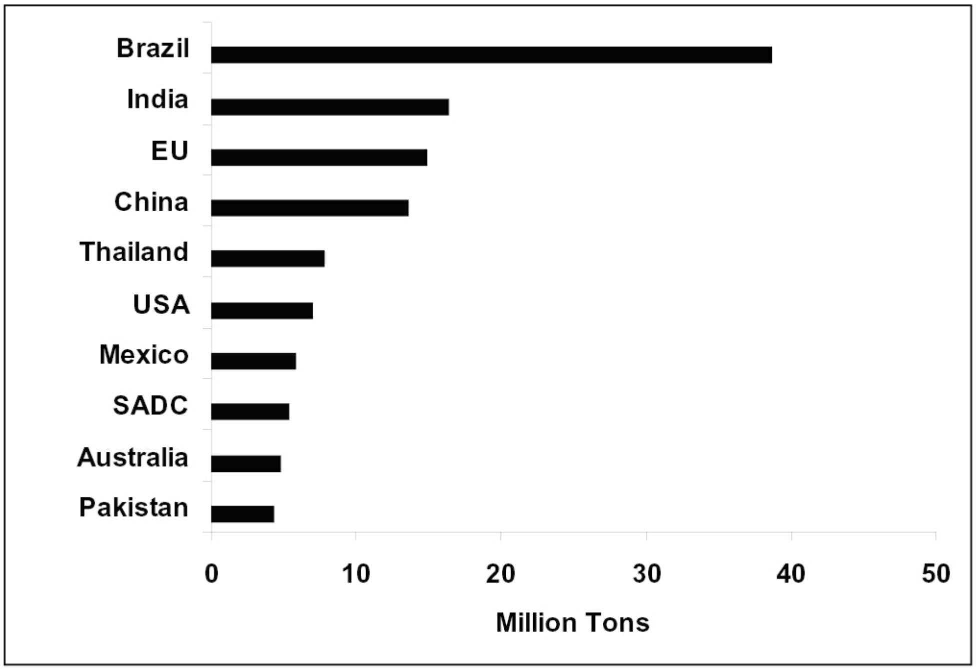
In summary, Brazil is poised to become a world leader in the adoption of biotech crops in the near-term with significant growth in RR®soybean hectarage, expansion in Bt cotton supplemented with herbicide tolerance, substantial opportunities on the 13 million hectares of Bt and herbicide tolerant maize, and on the 8.1 million hectares of sugarcane, the largest in any country in the world. Brazil also has 3.7 million hectares of rice that can benefit from biotechnology in the near term. In addition, Brazil plans to deploy virus resistant beans and papaya being developed by EMBRAPA, which is a strong national agricultural research organization, with significant public sector investments in crop biotechnology.

The Status of Investments in Bioethanol in Brazil

Readers are referred to ISAAA Brief 37 (James, 2007) for an historical overview of the situation regarding ethanol in Brazil. The production situation has not materially changed since 2007, however cost factors (due to the financial crisis), which are pivotal to any analysis, are still so volatile making any commentary premature at the time when this Brief went to press.

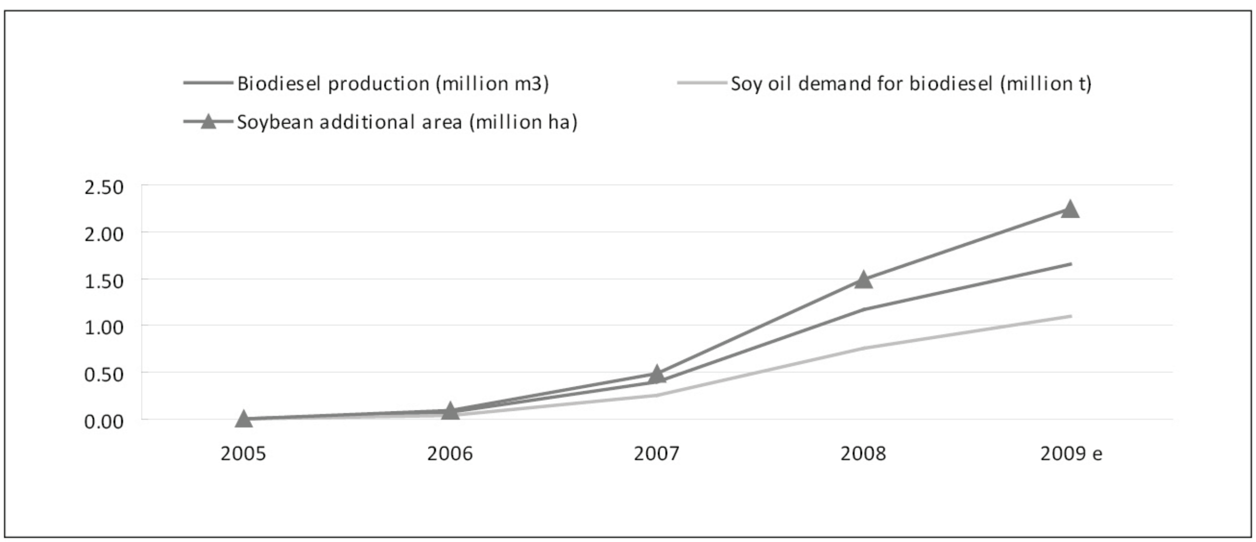
Updated information for 2008 on the global production, by country, and the top ten countries producing ethanol are provided in Table 6. Brazil remains the second largest producer of ethanol in

Figure 15. Top Sugar Producers, 2008/2009 (Estimates)



Source: International Sugar Statistics, Illovo Sugar, 2009.

Figure 16. Biodiesel Production in Brazil, 2005 to 2009



Source: Brazilian National Oil Agency, 2009. Estimates for 2009: Céleres the world. Based on 1 US gallon equivalent to 3.7854 liters in 2008, Brazil produced 24.5 billion liters of ethanol (up by 29% from 19.0 billion liters in 2007) compared with 34.1 billion liters for the USA, up by 38.5% from 24.6 billion liters in 2007.

Globally, more than 100 countries produce sugar. Worldwide 80% of sugar is produced from sugarcane (the balance of 20% from sugarbeet) grown principally in the tropical/sub-tropical zones of the southern hemisphere. The production and processing costs of sugarcane is lower than sugarbeet. About 70% of the world's sugar is consumed in the countries where it is produced and the balance of 30% traded in a volatile international market. In terms of sugar production, in 2008, Brazil continued to be the top producer in the world at 38.6 million tons followed by India at 16.3 million tons and the EU 27 at 14.9 million tons (Figure 15).

Benefits from Biotech Crops in Brazil

Brazil is estimated to have enhanced farm income from biotech soybean by US$2.8 billion in the six-year period 2003 to 2008 and the benefits for 2008 alone is estimated at US$0.7 billion (Brookes and Barfoot, 2010, forthcoming).

In addition to economic benefits there were also environmental benefits associated with RR®soybean which have been determined by modeling (Carneiro, 2009). The study indicated that 82.3 million liters of diesel have been saved from 1997 to 2008 as a result of a saving of 1.5 herbicide sprays on RR®soybean. In addition, it is estimated that 9.9 billion liters of water have been saved (through reduced herbicide sprays) plus a reduction of 212,000 tons of CO_2 emissions. For the next 10 years, 2008/09 to 2017/18, assuming a cumulative hectarage of 288.8 million hectares of biotech soybean in Brazil, savings of 492.7 million liters of diesel is projected in addition to savings of 59.1 billion liters of water and a reduction of 1.3 million tons of CO_2 emissions (Table 7).

Environmental benefits can also be generated from biotech crops other than soybean. Assuming an accumulated area of 17.7 million hectares of biotech cotton in the period 2008/09 to 2017/18, it is projected that biotech cotton alone could save 58.6 million liters of diesel, save 10.3 billion liters of water, and reduce CO_2 emissions by 150.2 thousand tons (Table 7). Similar environmental benefits will accrue from the deployment of other biotech crops such as biotech maize, grown in Brazil since 2008 and other biotech crops such as sugarcane that is expected to be grown in the near-term.

In a detailed study (Anderson Galvão Gomes, 2009. Personal Communication), the economic benefits were calculated for RR®soybean for the period 1997 to 2008; RR®soybean was planted unofficially from 1998 to 2002 and officially from 2003 onwards. The data shows (Table 8) that

Table 7. Environmental Benefits of Biotech Adoption in Brazil, 2008/09 to 2017/18

		Cotton	Maize	Soybean	Total
Water	Billion liters	10.3	35.7	59.1	105.1
Diesel	Million liters	58.6	255.1	492.7	806.5
CO_2	Million tCO_2	0.15	0.66	1.27	2.1
Active ingredient (a.i.)	Thousand tons	65.8	133.2	22.7	221.7

Note: Assuming insect resistance for cotton and corn, herbicide tolerance for soybean
Source: Carniero, 2009.

farmers gained US$1.72 billion in the period 1997 to 2008 and technology developers gained US$0.86 billion – thus, the farmers gained 66.6% of the profits and technology developers 33.4%. This is consistent with other analyses which confirm that farmers usually gain the major share, about two-thirds or more, of the benefits from biotech crops. Galvão Gomes (2009) also calculated the opportunity cost in terms of the estimated benefits lost to Brazilian farmers because of delayed approvals due to a cumbersome approval process, particularly the legal challenges from various interest groups, including Ministries within the Government. Taking the fast adoption rates of RR®soybean in neighboring Argentina, as an optimal bench mark, it was concluded that delayed approval of RR®soybean in Brazil for the period 1997 to 2008 cost farmers US$3.21 billion and technology developers an additional US$1.62 billion for total lost benefits of US$4.83 billion. Thus, the total potential benefits for both farmers and technology developers in the period 1997 to 2008 was US$7.41 billion of which only US$2.58 billion equivalent to 34.9% was realized – US$4.83 billion was lost due to legal/regulatory delays which is a significant sacrifice for Brazil and the major losers were Brazilian farmers (Table 8).

Table 8. Benefits and "Lost Benefits" (US$ Billions) from RR®Soybean in Brazil, 1997 to 2008

Beneficiary	Realized Benefits	Lost Benefits	Total Potential Benefits
Farmer Benefits	1.72	3.21	4.93
Tech Developer Benefits	0.86	1.62	2.48
Total	2.58	4.83	7.41

Source: Galvão Gomes, A. 2009, (Personal Communication).

Investments in Brazil in Crop Biotechnology

The commitments by the Brazilian government totaling Real 10 billion (US$7 billion) equivalent to US$700 million per year (60% public and 40% private) for each of the next ten years to biotechnology confirms the strong Brazilian Government support for crop biotechnology. Moreover, a significant part of the US$7 billion is devoted to biofuels and agriculture – this is a reassuring development reflecting the political will and support of the current Government to biotechnology (Brazilian Government, 2007). Considering only the biotech crops that are already deployed in Brazil, over US$60 billion will be generated by Brazilian farmers growing these crops for the next decade alone (Table 9).

Table 9. Potential Economic Benefits of Biotech in Brazil if Adopted in Reasonable Time Frame in the Next Decade (US$ Billions)

Beneficiary	Soybean	Cotton	Maize	Total
Farmer Benefits	6.64	3.53	42.45	52.63
Tech Developer Benefits	5.21	0.71	4.35	10.27
Total	**11.86**	**4.24**	**46.80**	**62.90**

Source: Galvão Gomes, A. 2009, (Personal Communication).

The key points of the new Brazilian Program of Biotechnology are as follows:

- Launched by President Luis Inacio Lula da Silva on February 8, 2007, the executive decree creates the Brazilian Policy for Development of Biotechnology and also creates the National Committee for Biotechnology.
- The policy aims to replicate the success of biofuel production, especially ethanol from sugarcane, in crop biotechnology.
- The executive decree projects public and private investment of Real 10 billion (US$7 billion) over the next 10 years, 60% from public resources and 40% from private resources.
- The policy aims to strengthen coordination among the national agricultural, environmental, health and industry and trade Ministers.
- The Brazilian Bank of Development (BNDS) to provide special credit lines to the biotech companies to boost investment in biotech research and development.
- The Brazilian Association of Biotech Companies (ABRABI), which represents the private biotech sector in Brazil, estimated current investment in biotech at Real 5.4 billion (US$3.8 billion) to Real 9.0 billion (US$6.3 billion), and employing 28,000 workers nationwide.

ARGENTINA

Argentina was narrowly displaced from being the second largest producer of biotech crops in the world in 2009, by its neighbor Brazil which became the newly ranked number two in the world. The projected biotech hectarage for Argentina in 2009 is 21.3 million hectares in 2009, compared with 21.4 million hectares for Brazil, and equivalent to a global market share of 16%. In 2009, Argentina was expected to plant a total hectarage of 21.3 million hectares of biotech soybean, maize and cotton, up from 21.0 million hectares in 2008. Projecting the biotech hectarage for 2009, particularly for soybean, was challenging because of the uncertainty caused by the continuing drought in 2009. Benefits from RR®soybean alone for the first decade, 1996 to 2005, was estimated at close to US$20 billion.

ARGENTINA

Population: 39.5 million

GDP: US$262 billion

GDP per Capita: US$6,640

Agriculture as % GDP: 9.5%

Agricultural GDP: US$24.9 billion

% employed in agriculture: 1%

Arable Land (AL): 32.5 million hectares

Ratio of AL/Population*: 3.3

Major crops:
- Soybean
- Maize
- Sugarcane
- Sunflower seed
- Wheat

Commercialized Biotech Crops:
- HT Soybean
- Bt/HT Cotton
- Bt/HT/Bt-HT Maize

Total area under biotech crops and (%) increase in 2009:
21.3 Million Hectares (+1%)

Farm income gain from biotech, 1996-2008: US$9.2 billion

*Ratio: % global arable land / % global population

Argentina is also one of the six "founder biotech crop countries", having commercialized RR®soybean and Bt cotton in 1996, the first year of global commercialization of biotech crops. After retaining the second ranking position in the world for biotech crops area for 13 years, Argentina was narrowly displaced from being the second largest producer of biotech crops in the world in 2009, by Brazil (21.4 million hectares) which became the newly ranked number two in the world. Argentina became the third largest grower of biotech crops (21.3 million hectares) in 2009 comprising 16% of global crop biotech hectarage. The 13 biotech crop products approved for commercial planting in Argentina and for import as food and feed products are listed in Table 10 including the designation of the event and the year of approval.

Table 10. Commercial Approvals for Planting, Food and Feed in Argentina, 1996 to 2009.

Crop	Event	Trait	Year
Soybean	Herbicide tolerance	40-3-2	1996
Maize	Insect resistance	176	1998
Maize	Herbicide tolerance	T25	1998
Cotton	Insect resistance	MON531	1998
Maize	Insect resistance	MON810	1998
Cotton	Herbicide tolerance	MON 1445	2001
Maize	Insect resistance	Bt11	2001
Maize	Herbicide tolerance	NK603	2004
Maize	Herbicide tolerance and Insect resistance	TC1507	2005
Maize	Herbicide tolerance	GA21	2005
Maize	Herbicide tolerance x Insect resistance	NK603 MON810	2007
Maize	Herbicide tolerance x Insect resistance	NK603 TC 1507	2008
Cotton	Herbicide tolerance x Insect resistance	MON1445 x MON531	2009

Source: ArgenBio, 2009 (Personal Communication).

In 2009, the year-over-year increase, compared with 2008, was 0.3 million hectares, and the annual growth rate in 2009 was 1% over 2008. Projecting the biotech hectarage for 2009, particularly for soybean, was challenging because of the uncertainty caused by the continuing drought. Of the 21.3 million hectares of biotech crops in Argentina in 2009, 18.8 million hectares were expected to be planted to biotech soybean, up 0.7 million hectares over 2008. The 18.8 million hectares of biotech soybean is equivalent to 99% of the record planting of 19.0 million hectares of the national soybean crop in Argentina in 2009.

Total plantings of maize in Argentina in 2009 were expected to be 20% lower than 2008 as farmers elected to switch to soybean which is more profitable than maize, and with a lower cost of production. The hectarage of biotech maize hybrid plantings in 2009 was approximately 2.18 million hectares. Of the 2.18 million hectares of biotech hybrid maize, about 1.1 million hectares were planted to the stacked product Bt/HT maize, 860,000 hectares to the Bt product, and 215,000 hectares to herbicide tolerant maize. The stacked gene Bt /HT maize product, occupied more than the other two products, Bt and HT, for the first time in Argentina in 2009 and the stacked product is expected to retain its premier position in the future. Thus, the adoption rate in the 2.58 million hectares of hybrid maize was approximately 83% with the stacked Bt/HT product representing 50%, Bt 40% and HT at 10%.

Argentina reported a total planted area of 350,000 hectares of cotton for 2009, down from 400,000 hectares in 2008. Of the 350,000 hectares of total cotton plantings in 2009, 332,500 hectares were biotech, of which 192,500 hectares were the Bt/HT stacked product approved for commercialization for the first time in 2009, about 87,500 hectares were herbicide tolerant (HT) cotton and 52,500 hectares were Bt and the balance of 17,500 hectares were conventional. The general increase in biotech cotton during the last three years is related to various factors including the availability of better adapted biotech varieties, improved returns and more awareness by farmers of the benefits associated with the technology, and improved reporting. It is important to note that farmer-saved seed, which is prevalent in Argentina, can lead to problems with Bt cotton if the purity drops to a point where larvae can establish on non-Bt cotton plants and start an infestation which can compromise insect resistant management strategies.

Benefits from Biotech Crops in Argentina

A detailed analysis by Eduardo Trigo from the FORGES Foundation and Eugenio Cap of the Institute of Economics and Sociology of the National Institute of Agricultural Technology (INTA, Trigo and Cap, 2006), estimated that the total global direct and indirect benefits from RR®soybean in Argentina for the first 10 years of commercialization, 1996 to 2005 was US$46 billion. This was generated from increased farmer incomes, a million new jobs and more affordable soybean for consumers and significant environmental benefits, particularly the practice of no till for conserving soil and moisture and double cropping. Of the global US$46 billion indirect and direct benefits, Argentina gained approximately US$20 billion in direct benefits from RR®soybean in the decade 1996 to 2005 (Table 11). The study estimated benefits on the basis of production increases which could be identified as resulting from the adoption of the new technologies, including the impact of increased productivity in animal production related to RR®soybean.

Table 11. Beneficiaries of Direct Benefits of Biotech Soybeans in Argentina, 1996 to 2005.

	Gross Value	Farmer	Technology Developers	Argentine Government
Total (Billion US$)	19.7	15.3	1.8	2.6
% Share	100%	77.4%	9.2%	13.4

Source: Trigo and Cap, 2006.

Herbicide tolerant RR®soybean was first planted in Argentina in 1996, and after a decade it accounts for virtually all (99%) of the total soybean hectarage. In addition an estimated 83% of maize and 95% of cotton planted in Argentina were also biotech varieties in 2009. The remarkably rapid adoption was the result of several factors including: a well-established seed industry; a regulatory system that provided a responsible, timely and cost-effective approval of biotech products; and a technology with high impact. The total direct benefits were as follows: US$19.7 billion for herbicide-tolerant soybean for the decade 1996 to 2005; US$482 million for insect-resistant maize for the period 1998 to 2005; and US$19.7 million for insect-resistant cotton for the period 1998 to 2005 for a total of US$20.2 billion (INTA, Trigo and Cap, 2006) .

The direct benefits from herbicide tolerant soybeans are from lower production costs, an increase in planted hectarage, plus the very important practice of second-cropping soybeans after wheat, that RR®soybean facilitated. It is noteworthy that it was the farmers that captured the majority of the benefits equivalent to 77.4% of the total gains, with the Argentine government and technology developers only capturing 13.4% and 9.2% respectively (Table 11).

The major findings of the study were:

Herbicide tolerant RR®soybeans delivered substantial direct and indirect benefits totaling US$46 billion to the global economy during the decade 1996 to 2005. More specifically:

- In the period 1996 to 2005, US$20 billion was created in direct benefits in Argentina.
- The majority of the benefits from biotech soybean were captured by farmers (77.4%), approximately 13.4% for the Argentine government and only 9.2% for the technology developers.
- Herbicide-tolerant soybeans accounted for 1 million new jobs equivalent to 36% of all new jobs created in the decade 1996 to 2005.
- Indirect benefits of increased biotech soybean production generated consumer savings of US$26 billion.

Biotech soybeans greatly facilitated fast adoption of low/no-till systems which conserved both soil and water.

- No/low-till hectarage increased from 120,000 hectares in 1991 to over 7.5 million hectares in 2005.
- Herbicide-tolerant soybeans were a principal factor in the adoption of no/low-till practices.
- No/low-till practices mitigated the serious problems with soil erosion and conservation of moisture in the Pampas in the 1980s resulting from intensification of conventional agriculture.

In the most recent global study on the benefits from biotech crops (Brookes and Barfoot, 2010, forthcoming) estimates that Argentina has enhanced farm income from biotech crops by US$9.2

billion in the first thirteen years of commercialization of biotech crops 1996 to 2008, and the benefits for 2008 alone were estimated at US$1.1 billion.

Farmer Experience

Johnny Avellaneda, a farmer from Argentina cultivates soybean, maize and wheat on 4,000 hectares. He said if it wasn't for the access to the technology, he wouldn't be working on the farm. For the past ten years he has cultivated biotech soybean and maize. He says:

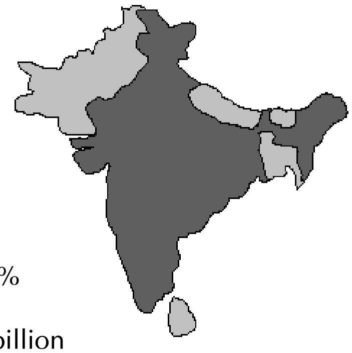
"I chose to use biotech crops because the technology is innovative, provides food security for humanity and generates higher yields. This kind of technology allows you to cut half the time your tractors are in the field, allowing us more time to be with our families" (Avellaneda, 2006).

INDIA

Remarkably, for the eighth consecutive year the hectarage, adoption rate and the number of farmers using Bt cotton hybrids in India in 2009, all continued to soar to record highs. In 2009, 5.6 million small and marginal resource-poor farmers in India planted and benefited from 8.381 (~8.4) million hectares of Bt cotton, equivalent to 87% of the 9.636 (~9.6) million hectare national cotton crop. Given that the adoption rate was already very high in 2008, when 5 million farmers planted 7.6 million hectares of Bt cotton, equivalent to 80% of the 9.4 million hectare national cotton crop, all the increases in 2009 are robust. The increase from 50,000 hectares in 2002, (when Bt cotton was first commercialized) to 8.4 million hectares in 2009 represents an unprecedented 168-fold increase in eight years. There were three notable developments in Bt cotton in India in 2009. First, there has been a consistent trend in India for increased adoption of multiple gene Bt cotton, over single gene products, since 2006, when multiple gene products were introduced. In 2009, for the first time, multiple gene Bt cotton occupied more hectares (57%) than single gene Bt cotton (43%); this reflects the superiority of the multiple gene products and farmer preference. Second, 2009 was the first year for an indigenous public sector bred Bt cotton variety (*Bikaneri Nerma*) and a hybrid (NHH-44) commercialized in India, thus redressing the balance between the role of the private and public sector in biotech crops in India. Third, was the approval to commercialize a new Bt cotton event, (bringing

the total to six approved events) featuring a synthetic *cry1C* gene, developed by a private sector Indian company. The deployment of Bt cotton over the last eight years has resulted in India becoming the number one exporter of cotton globally as well as the second largest cotton producer in the world. Equally important, India is now poised to benefit from the continued productivity gains that biotech cotton hybrids and varieties offer for the short, medium and long term future. In summary, Bt cotton has literally revolutionized cotton production in India. In the short span of seven years, 2002 to 2008, Bt cotton has generated economic benefits for farmers valued at US$5.1 billion, halved insecticide requirements, contributed to the doubling of yield and transformed India from a cotton importer to a major exporter. Socio-economic surveys confirm that Bt cotton continues to deliver significant and multiple agronomic, economic, environmental and welfare benefits to farmers and society. In October 2009, a landmark decision was made by India's Genetic Engineering Approval Committee (GEAC), to recommend the commercial release of Bt Brinjal (*Eggplant/Aubergine*), which is now pending, subject to final clearance by the government of India. Brinjal is the "King of Vegetables" but requires very heavy applications of insecticide. Thus, Bt brinjal, is expected to be the first food crop to be commercialized in India, requiring significantly less insecticide and capable of contributing to a more affordable food product for consumers and the alleviation of poverty of 1.4 million small, resource-poor farmers who grow brinjal in India. A 2007 IIMA study reported that 70% of the middle class in India accept biotech foods, and furthermore are prepared to pay a premium of up to 20% for superior biotech foods, such as Golden Rice, with

INDIA



Population: 1,135.6 million

GDP: US$1,177 billion

GDP per Capita: US$ 1,050

Agriculture as % GDP: 18.1%

Agricultural GDP: US$213 billion

% employed in agriculture: 64%

Arable Land (AL): 177 million hectares

Ratio of AL/Population*: 0.60

Major crops:

- Sugarcane
- Rice, paddy
- Wheat
- Vegetables
- Potato
- Cotton

Commercialized Biotech Crop: Bt Cotton

Total area under biotech crops and (%) increase in 2009:
8.4 Million Hectares (+11%))

Farm income gain from biotech, 2002-2008: US$5.1 billion

*Ratio: % global arable land / % global population

enhanced levels of pro-Vitamin A, expected to be available in 2011/12. India has several other biotech food crops in field trials, including biotech Bt rice.

India, the largest democracy in the world, is highly dependent on agriculture. The performance of the agriculture sector continues to influence the growth of the economy – it is a major factor in driving India's national economy. In recent years, there has been a decline in the share of agriculture in the national economy from almost a quarter to 17.8% of its Gross Domestic Product (GDP). In contrast, there has been a very small decline in the workforce engaged in agriculture which still provides a means of survival to 52% of the population – more than half of India's population (Economic Survey, 2009). India is a nation of small resource-poor farmers, most of whom do not make enough income to cover their meager basic needs and expenditures. The latest National Sample Survey conducted in 2003, reported that 60.4% of rural households were engaged in farming indicating that there were 89.4 million farmer households in India (National Sample Survey, India, 2003). Sixty percent of the farming households own less than 1 hectare of land, and only 5% own more than 4 hectares. Only 5 million farming households (5% of 90 million) have an income that is greater than their expenditures. The average income of farm households in India (based on 40 Rupees per US dollar) was US$50 per month and the average consumption expenditures was US$70. Thus, of the 90 million farmer households in India, approximately 85 million, which represent about 95% of all farmers, are small and resource-poor farmers who do not make enough money from the land to make ends meet – in the past, these included the vast majority of over 6 million Indian cotton farmers.

India has a larger area of cotton than any country in the world. Based on the latest estimate (Table 12), the Directorate of Cotton Development, Ministry of Agriculture reports that 6.3 million farmers planted cotton on 9.4 million hectares in 2008 with an average cotton holding of 1.5 ha (Ministry of Agriculture, India, 2007). In 2009, the total hectarage of cotton in India was estimated at 9.6 million hectares approximately 3% higher than the 9.4 million hectares in 2008, and farmed by 6.3 million farmers in 2008 and 2009. This increase is in contrast to the 2% decrease in cotton area globally in 2009 versus 2008. Comparing the distribution of cotton hectarage by States in India in 2008 (Table 12), Maharashtra, the largest cotton-growing State, had 2.15 million farmers growing cotton, which occupied approximately 34% of India's total cotton area; this was mostly cultivated on dry land. Gujarat had 1.30 million farmers, followed by 0.96 million in Andhra Pradesh, 0.45 million in Madhya Pradesh, 0.30 million in Rajasthan, 0.26 million in Haryana, 0.20 million farmers each in Punjab, Karnataka and Tamil Nadu and the balance in other states of India.

Table 12. Land Holdings Distribution and Production of Cotton in India, 2008-2009

No.	State	Average Cotton Holding per Farm (Hectare)	Area of Cotton (Million Hectare)	Production (Million Bale)	Average Yield (Kg/ha)	No. of Cotton Farmers (Million)
1	Punjab	2.64	0.527	1.75	564	0.199
2	Haryana	1.72	0.456	1.40	522	0.265
3	Rajasthan	0.98	0.302	0.75	422	0.308
4	Gujarat	1.80	2.354	9.00	650	1.307
5	Maharashtra	1.46	3.142	6.20	3357	2.152
6	Madhya Pradesh	1.38	0.625	1.80	489	0.452
7	Andhra Pradesh	1.45	1.399	5.33	648	0.964
8	Karnataka	1.56	0.408	0.90	375	0.261
9	Tamil Nadu	0.52	0.109	0.50	780	0.209
10	Orissa	0.76	0.058	0.15	510	0.076
11	Others	0.30	0.026	1.250	-	0.086
	(Weighted Average) or Total	**(1.50)**	**9.406**	**29.03**	**524**	**6.279**

Source: Ministry of Agriculture, 2007 and Cotton Advisory Board, 2009.

Whereas, India's cotton area represents 25% of the global area of cotton, in the past it produced only 12% of world production because Indian cotton yields were some of the lowest in the world; the advent of Bt cotton over the last 8 years has coincided with almost a doubling of yield from 308 kg per hectare in 2001 to 568 kg/ha in 2009, with 50% or more of the increase attributed directly to yield increases from Bt cotton.

The majority of the cotton in India is grown in ten States which are grouped into three different zones namely, Northern zone (Punjab, Haryana and Rajasthan), Central zone (Maharashtra, Madhya Pradesh, Gujarat and Orissa) and Southern zone (Andhra Pradesh, Karnataka and Tamil Nadu) (Table 13). Approximately 65% of India's cotton is produced on dry land and 35% on irrigated lands. Except for the Northern Zone, which is 100% irrigated, both Central and Southern cotton growing zones are predominantly rainfed. In 2009, of the total 9.6 million hectares, hybrids occupied 90% (8.6 million hectares) of the cotton area and only 10% (1.0 million hectares) were occupied by varieties. The percentage devoted to hybrids has increased significantly over the last few years, a trend that has been accentuated by the introduction in 2002 of high performance Bt cotton hybrids, which have out-performed conventional hybrids. Cotton is the major cash crop of India and accounts for 75% of the fiber used in the textile industry, which has 1,063 spinning mills, and accounts for 4% of GDP. Cotton impacts the lives of an estimated 60 million people in India, including farmers who cultivate the crop, and a legion of workers involved in the cotton industry from processing to trading. India is the only country to grow all four species of cultivated cotton *Gossypium arboreum* and *G. herbaceum* (Asian cottons), *G. barbadense* (Egyptian cotton) and *G. hirsutum* (American upland cotton). *Gossypium hirsutum* represents more than 90% of the hybrid cotton production in India and all the current Bt cotton hybrids are *G. hirsutum* (Table 13).

Table 13. Cotton Growing Zones in India, 2008-2009

Zones	North Zone	Central Zone	South Zone
States	Punjab, Haryana, Rajasthan	Maharashtra, Madhya Pradesh, Gujarat, Orissa	Andhra Pradesh, Karnataka, Tamil Nadu
Area	1.285 Million hectares	6.121 Million hectares	1.916 Million hectares
Production	3.9 Million bales	17.0 Million bales	6.7 Million bales
Productivity	516 kg/ha	472 kg/ha	594 kg/ha
Conditions	100% irrigated	Irrigated and rainfed	Irrigated and rainfed
Nature of Genotype	Hybrids and varieties	Hybrids and varieties	Hybrids and varieties
Species	*G. hirsutum, G. arboreum*	*G. hirsutum, G. arboreum,* Intra hirsutum, *G. herbarium*	*G. hirsutum, G. arboreum, G. herbaceum, G. barbadense,* Interspecific tetraploids (HB)
Insect/Pest	Heliothis, Whitefly, Jassids, Pink bollworm, Mealy bug	Heliothis, Whitefly, Jassids, Aphids, Pink bollworm, Mealy bug	Heliothis, Whitefly, Jassids, Aphids, Pink bollworm
Diseases	Leaf curl virus, Wilt	Wilt	Wilt, Foliar disease
Sowing Method	Drill Sown	Hand dibbling	Hand dibbling
Time of Sowing	April-June	June-July	July-August

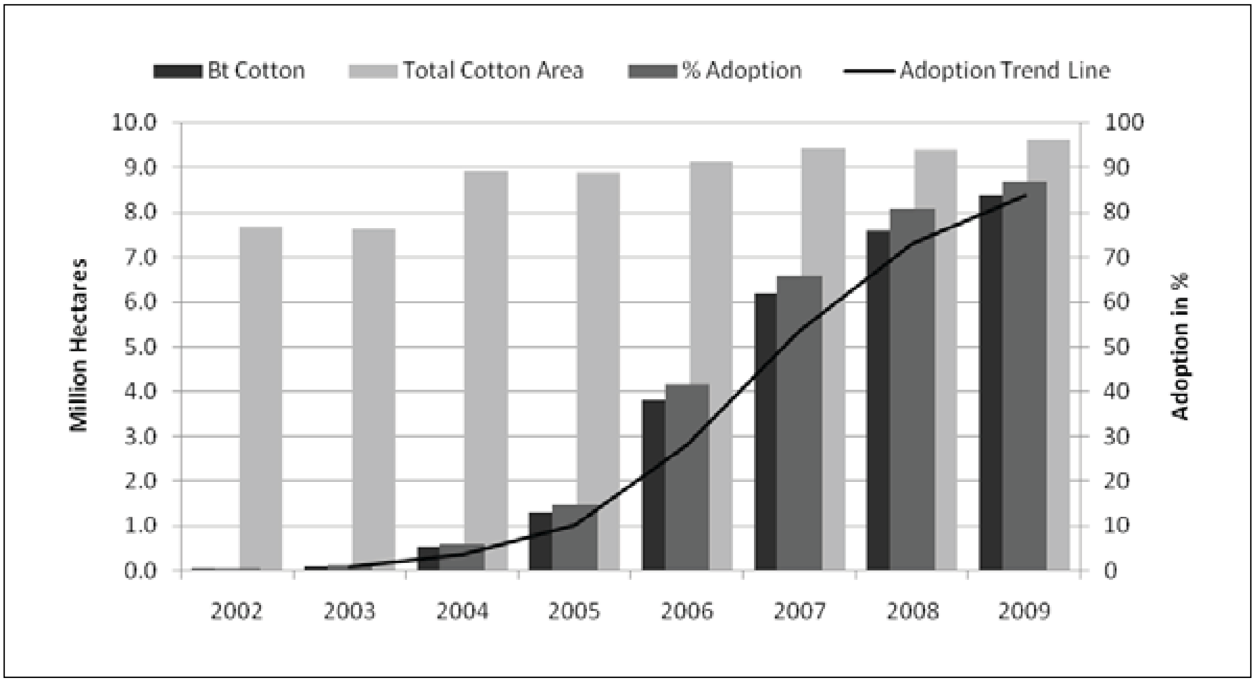
Source: Ministry of Agriculture, 2007 and Cotton Advisory Board, 2009.

Hectarage of Bt Cotton Hybrid Planted in India, 2002 to 2009

Bt cotton, which confers resistance to important insect pests of cotton, was first adopted in India as hybrids in 2002. There were 54,000 farmers which grew approximately 50,000 hectares of officially approved Bt cotton hybrids for the first time in 2002 which doubled to approximately 100,000 hectares in 2003 (Figure 17). The Bt cotton area increased again four-fold in 2004 to reach half a million hectares. In 2005, the area planted to Bt cotton in India continued to climb reaching 1.3 million hectares, an increase of 160% over 2004. In 2006, the adoption record increases which continued with almost a tripling of the area of Bt cotton to 3.8 million hectares. This tripling in area was the highest percentage year-on-year growth for any country planting biotech crops in the world in 2006. Notably in 2006, India's Bt cotton area (3.8 million hectares) exceeded for the first time, that of China's 3.5 million hectares. In 2007, the Indian cotton sector continued to grow with a record increase of 63% in Bt cotton area from 3.8 to 6.2 million hectares, to become the largest hectarage of Bt cotton in any country in the world. In 2008, the Bt cotton area increased yet again to a record 7.6 million hectares from 6.2 million hectares in 2007. Maintaining double digit growth, the Bt cotton area increased to 8.4 million hectares in 2009, over 7.6 million hectare in the previous year. Despite a very high level of adoption in 2008, 2009 was the fifth consecutive year for India to have the largest year-on-year percentage growth of all biotech cotton growing countries in the world; a 160% increase in 2005, followed by a 192% increase in 2006, a 63% increase in 2007, 23% increase in 2008 and a 11% increase in 2009 (Figure 18). In 2006-07, ISAAA reported that India overtook the USA to become the second largest cotton producing country in the world, after China (USDA/FAS, 2007).

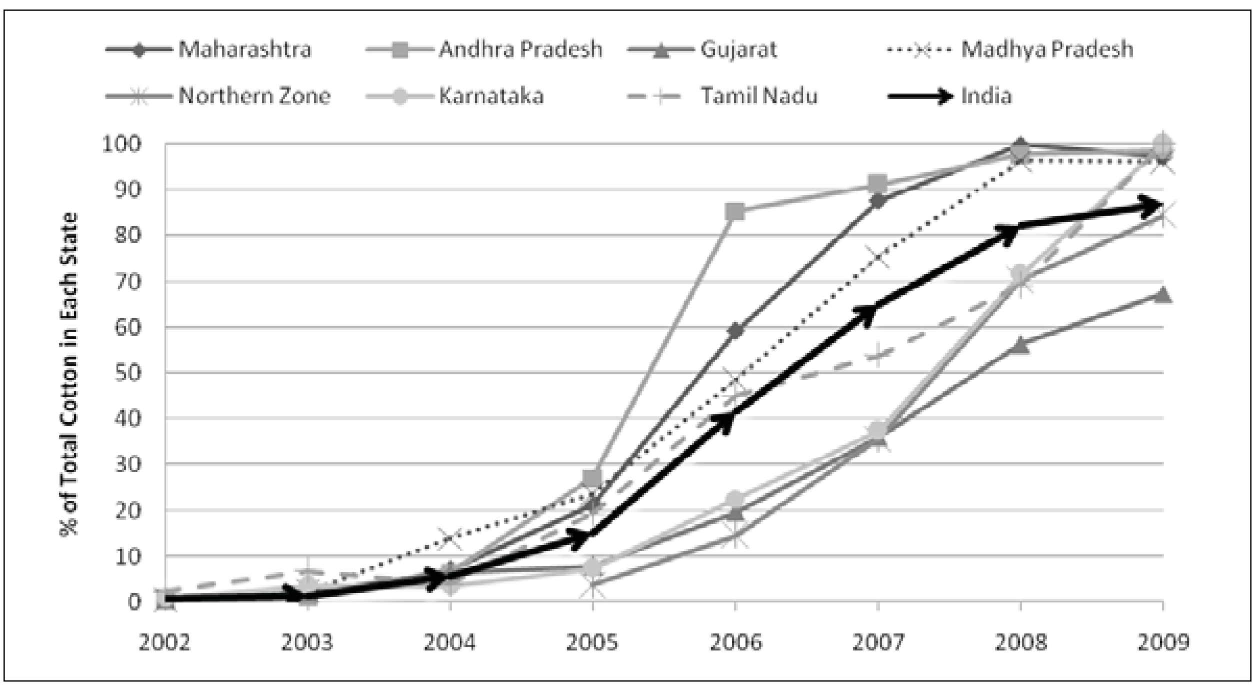
Of the estimated 9.6 million hectares of cotton in India in 2009, 87% or 8.4 million hectares were Bt cotton hybrids – a remarkably high proportion in a fairly short period of eight years equivalent to an unprecedented 168-fold increase from 2002 to 2009. Of the 8.4 million hectares of hybrid Bt cotton grown in India in 2009, 35% was under irrigation and 65% rainfed. A total of 522 Bt cotton hybrids (including a Bt cotton variety) were approved for planting in 2009 compared with 274 Bt cotton hybrids in 2008, 131 in 2007, 62 in 2006, 20 in 2005 and only 4 Bt cotton hybrids in 2004. Over the last eight years, India has greatly diversified deployment of Bt genes and genotypes, which are well-adapted to the different agro-ecological zones to ensure equitable distribution to small and resource-poor cotton farmers. The distribution of Bt cotton in the major growing states from 2002 to 2009 is shown in Table 14. The major states growing Bt cotton in 2009, listed in order of hectarage, were Maharashtra (3.39 million hectares) representing almost half, or 40%, of all Bt cotton in India in 2009, followed by Gujarat (1.68 million hectares or 20%), Andhra Pradesh (1.04 million hectares or 16%), Northern Zone (1.24 million hectares or 15%), Madhya Pradesh (621,000 hectares or 8%), and the balance in Karnataka, Tamil Nadu and other states.

Figure 17. Adoption of Bt Cotton in India for the Eight Year Period, 2002 to 2009



Source: Compiled by ISAAA, 2009.

Figure 18. Percent Adoption of Bt Cotton in India and in Different States Expressed as Percent Adoption within States and Nationally in India, 2002 to 2009



Source: Compiled by ISAAA, 2008.

Table 14. Adoption of Bt Cotton in India, by Major State, from 2002 to 2009 (Thousand Hectares)

State	2002	2003	2004	2005	2006	2007	2008	2009
Maharashtra	25	30	200	607	1,840	2,800	3,130	3,396
Andhra Pradesh	8	10	75	280	830	1,090	1,320	1,049
Gujarat	10	36	122	150	470	908	1,360	1,682
Madhya Pradesh	2	13	80	146	310	500	620	621
Northern Region*	-	-	-	60	215	682	840	1,243
Karnataka	3	4	18	30	85	145	240	273
Tamil Nadu	2	7	5	27	45	70	90	109
Other	-	-	-	-	5	5	5	8
Total	50	100	500	1,300	3,800	6,200	7,605	8,381

Source: Compiled by ISAAA, 2009.

In recent years, there has been an increasing trend to adopt multiple gene (mostly two genes) Bt cotton hybrids by cotton farmers in India (Table 15 and Figure 19). The first two-gene event MON15985, commonly known as Bollgard®II (BG®II) was developed by Mahyco and sourced from Monsanto, featured the two genes *cry1Ac* and *cry2Ab*, and was approved for sale for the first time in 2006 – four years after the approval of the single gene event MON531 Bt cotton hybrids in 2002-03. In the first year 2006-07, the multiple gene Bt cotton hybrids were planted on 0.15 million hectares whilst single gene Bt cotton hybrids occupied 3.65 million hectares equivalent to 96% of all the Bt cotton planted.

Table 15. Adoption of Single and Multiple Bt Cotton in India, 2006 to 2009 (In Millions of Hectares and Percentage)

Number of Genes	2005	2006	2007	2008	2009
Multiple	-	0.15 (4%)	0.46 (8%)	2.04 (27%)	4.82 (57%)
Single	1.3 (100%)	3.65 (96%)	5.74 (92%)	5.56 (73%)	3.58 (43%)
Total	1.3 (100%)	3.80 (100%)	6.20 (100%)	7.60 (100%)	8.40 (100%)

Source: Compiled by ISAAA, 2009.

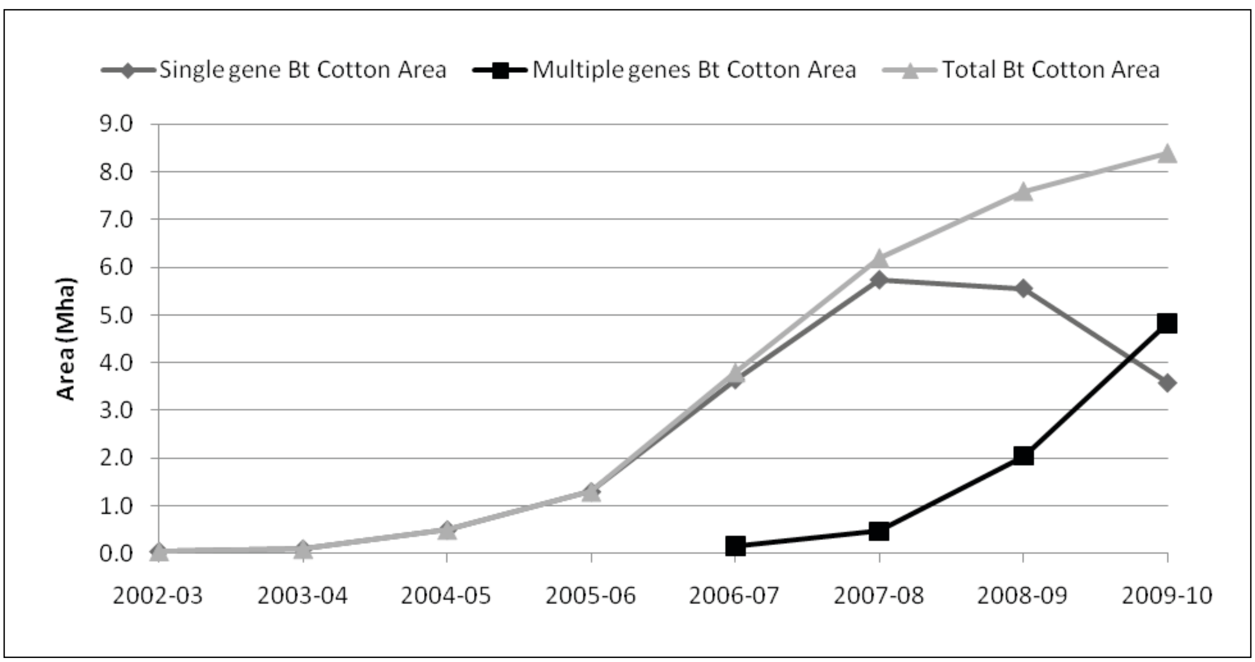
The area under single gene Bt cotton hybrids increased to 5.74 million hectares in 2007 and then registered a decline of 5.56 million hectares in 2008 and 3.58 million hectares in 2009. During the same time, multiple gene Bt cotton area grew rapidly to 0.46 million hectares in 2007 to 2.04 million hectare in 2008. In 2009, the multiple gene Bt cotton hybrids were planted for the first time on more area (57%) than single gene Bt cotton hybrids occupying 4.82 million hectares as compared to 3.58 million (43%) occupied by single gene Bt cotton hybrids. It is projected that the multiple gene Bt cotton hybrids will occupy approximately 90% of total Bt cotton area in 2010.

Farmers prefer multiple genes over a single gene Bt cotton hybrids because multiple gene Bt cotton hybrids provide additional protection to *Spodopetra* (a leaf eating tobacco caterpillar) while it also increases efficacy of protection to both American bollworm, Pink bollworm and Spotted bollworm. It is reported that multiple gene Bt cotton farmers earn higher profit through cost savings associated with fewer sprays for *Spodopetra* control as well as increasing yield by 8-10% over single gene Bt cotton hybrids.

Number of Farmers Growing Bt Cotton Hybrid in India, 2002 to 2009

Based on the latest official data the average cotton holding per farm in India is 1.5 hectares (Table 12) and thus it is estimated that approximately 5.6 million small and resource-poor farmers planted

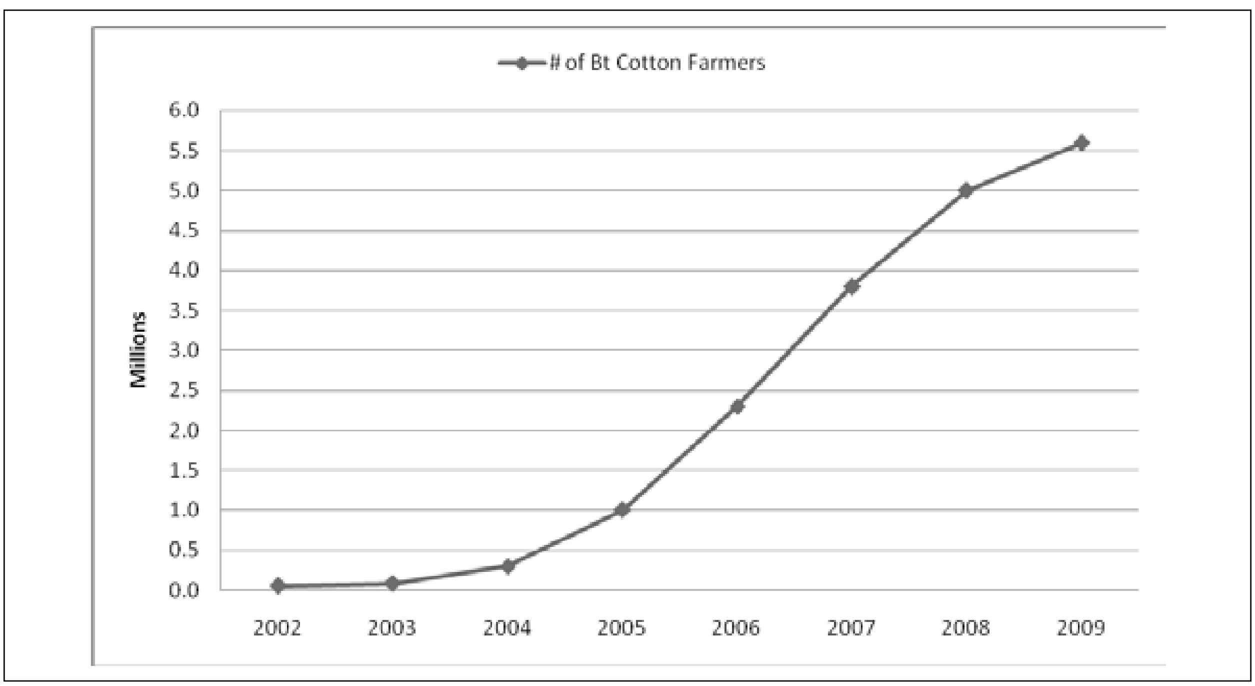
Figure 19. Adoption of Single and Multiple Gene Bt Cotton Hybrids from 2002 to 2009



Source: Compiled by ISAAA, 2009.

Bt cotton hybrids in 2009, up from 5.0 million in 2008 and 3.8 million farmers in 2007 (Figure 20). Thus, remarkably the number of farmers growing Bt cotton hybrids in India has increased from 50,000 in 2002 to 100,000 in 2003, 300,000 small farmers in 2004, to 1 million in 2005, with over a two-fold increase of 2.3 million farmers in 2006, 3.8 million farmers in 2007, 5 million in 2008 and 5.6 million farmers in 2009. This is the largest increase in number of farmers planting biotech crops in any country in 2009. The 5.6 million small and resource-poor farmers who planted and benefited significantly from Bt cotton hybrids in 2009 represented approximately 88% of the total number of 6.4 million farmers who grew cotton in India in 2009. Given that only 90% of the cotton area is planted to hybrid cotton, the percentage adoption for the 8.4 million hybrid hectares alone in 2009 was 94%. This is approximately the same high level of adoption for biotech cotton in the mature biotech cotton markets of the USA and Australia. It is notable that the first indigenous, publicly-bred Bt variety *Bikaneri Nerma* (BN) and hybrid NHH-44Bt (expressing event BNLA-601) were commercialized for the first time in 2009. They are unique because they are the first Bt cotton hybrid and variety to be bred by a group of Indian public sector institutes which include the Central Institute for Cotton Research (CICR), Nagpur and National Research Centre for Plant Biotechnology (NRCPB), New Delhi of the Indian Council of Agricultural Research (ICAR) in partnership with the University of Agricultural Sciences (UAS), Dharwad. NHH-44Bt was planted on approximately 1,000 hectares in three different states including Maharashtra and Gujarat in Central cotton zone and Andhra Pradesh in Southern cotton growing zone, whilst the variety BN Bt was planted on

Figure 20. Number of Small Farmers Adopting Bt Cotton Hybrids in India, 2002 to 2009



Source: Compiled by ISAAA, 2009.

approximately 9,000 hectares. It is likely that the Bt variety BN will be planted in India in 2010 on most of the remaining 10% of cotton hectarage that will not be occupied by hybrids (Kranthi, 2009).

Some of the critics opposed to Bt cotton in India have, without presenting supporting evidence, alleged that Bt cotton has contributed to farmer suicides in India. An important paper (IFPRI, 2008) published by the International Food Policy Research Institute, based in the USA, could not find evidence to support the views of the critics. On the contrary, the paper concludes that:

"In this paper, we provide a comprehensive review of evidence on Bt cotton and farmer suicides, taking into account information from published official and unofficial reports, peer-reviewed journal articles, published studies, media news clips, magazine articles, and radio broadcasts from India, Asia, and international sources from 2002 to 2007. The review is used to evaluate a set of hypotheses on whether or not there has been a resurgence of farmer suicides, and the potential relationship suicide may have with the use of Bt cotton.

We first show that there is no evidence in available data of a "resurgence" of farmer suicides in India in the last five years. Second, we find that Bt cotton technology has been very effective overall in India. However, the context in which Bt cotton was introduced has generated disappointing results in some particular districts and seasons. Third, our analysis clearly shows that Bt cotton is neither a necessary nor a sufficient condition for the occurrence of farmer suicides. In contrast, many other factors have likely played a prominent role" (IFPRI, 2008).

Savings of Insecticides due to Bt Cotton

Traditionally, cotton consumed more insecticides than any other crop in India and was a significant proportion of the total pesticide (insecticides, fungicides and herbicides) market for all crops. For example, of the total pesticide market in India in 1998 valued at US$770 million (Table 16), 30% was for cotton insecticides only, which were equal to 42% of the total insecticide market for all crops in India (Chemical Industry, 2007). Subsequent to the introduction of Bt cotton, cotton consumed only 18% of the total pesticide market, in 2006, valued at US$900 million as compared to a much higher 30% in 1998. Similarly, the market share for cotton insecticides as a percentage of total insecticides declined from 42% in 1998 to 28% in 2006. This saving in insecticides between 1998 and 2006 coincided with the introduction of Bt cotton which occupied 3.8 million hectares equivalent to 42% of the hectarage of the cotton crop in 2006. More specifically, the sharpest decline in insecticides occurred in the bollworm market in cotton, which declined from US$147 million in 1998 to US$65 million in 2006 – a 56% decrease, equivalent to a saving of US$82 million in the use of insecticides to control cotton bollworm in 2006. Thus, insecticide use for control of bollworm dropped by half at the same time when approximately half the cotton area (3.8 million hectares) was benefiting from controlling bollworm with Bt cotton.

Table 16. Value of the Total Pesticide Market in India in 1998 and 2006 Relative to the Value of the Cotton Insecticide Market

Item/Year	1998	2006
Total pesticide market (in million US$)	US$770 million	US$900 million
Cotton insecticides as % of total pesticide market	30%	18%
Cotton insecticides as % of total insecticide market	42%	28%
Value in US$ millions of cotton bollworm market & (savings due to Bt cotton) in 2006 over 1998	US$147 million	US$65 million (Savings of US$82 million, or 56%, compared with 1998)

Source: Chemical Industry, 2007.

Table 17. Consumption of Pesticides in India, 2001 to 2006 (Metric Tons of Technical Grade or Active Ingredient)

Year	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07
Total Pesticide	47,020	48,350	41,020	40,672	39,773	37,959

Source: Central Insecticides Board and Registration Committee, Ministry of Agriculture, 2008.

The trends in decreased use of insecticides on cotton noted by the chemical industry in India (Chemical Industry, 2007), based on the value of confirmed savings from Bt cotton, are similar to the trend noted and supported by the data from the Indian Ministry of Agriculture based on consumption of pesticides (active ingredient in metric tons) during the period 2001 to 2006 (Table 17). Since the introduction of Bt cotton in 2002, the consumption of pesticides as measured in active ingredient, has exhibited a consistent downward trend as adoption of Bt cotton has increased at unprecedented rates to reach 87% of all cotton hectarage in India in 2009. The data in Table 17 confirms a consistent downward trend of pesticide consumption from 48,350 metric tons in 2002, the year Bt cotton was first introduced to 37,959 metric tons in 2006 when 3.8 million hectares occupied 42% of the total hectarage of cotton in India. The decrease in pesticide usage is equivalent to a 22% reduction over only a short period of five years. Pesticide usage statistics for India for 2007, 2008 and 2009 are not yet published but based on the steep decline between 2001 and 2006 the downward trend would be expected to continue as percentage adoption of Bt cotton has steadily increased to reach 87% of all cotton in 2009. It is noteworthy that the decline in pesticide usage between 1998 and 2006 (Table 16) has occurred when the total hectarage of cotton in India has actually increased slightly from 8.7 million hectares in 1998 to 9.2 million hectares in 2006.

In summary, the adoption of Bt cotton in 2002 in India has led to a significant decrease in insecticide usage for the control of cotton bollworm, which in 2006 was estimated at a minimal 20% reduction of approximately 9,000 tons of active ingredient valued at approximately US$80 million in 2006.

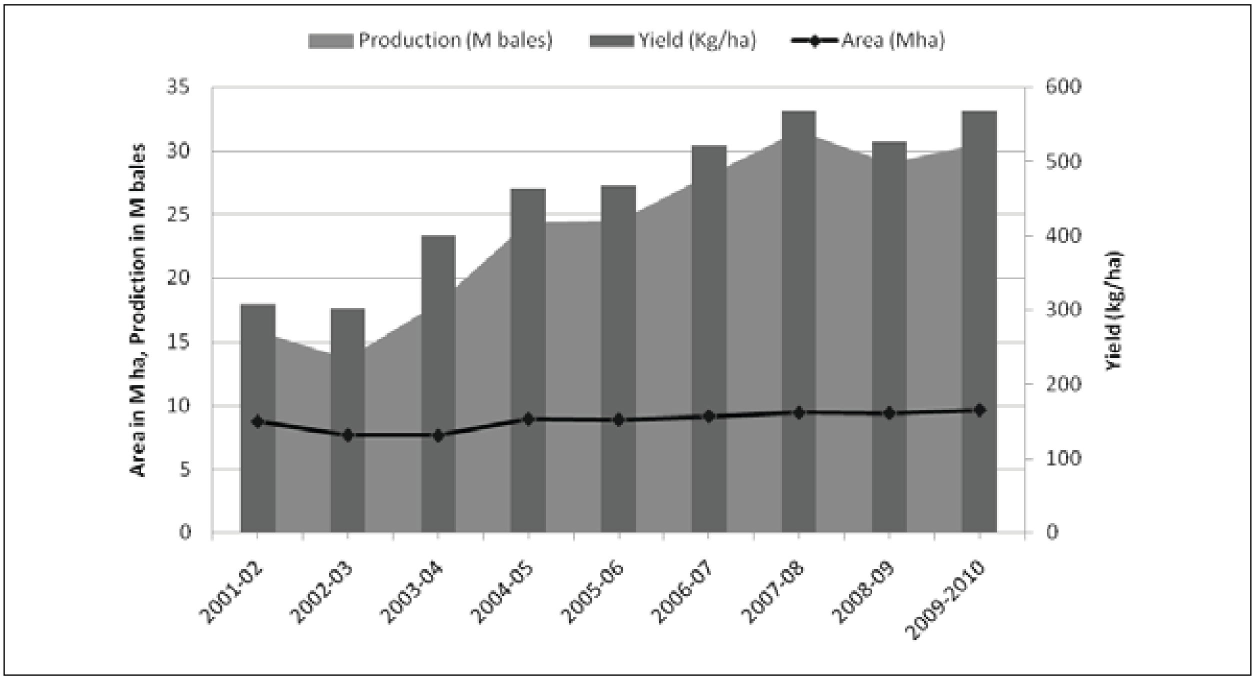
Cotton Production, Yield and Imports/Exports, Since the Introduction of Bt Cotton in 2002

Coincidental with the steep increase in adoption of Bt cotton between 2002 and 2009, the average yield of cotton in India, which used to have one of the lowest yields in the world, increased from 308 kg per hectare in 2001-02, to 526 kg per hectare in 2008-09 and projected to increase to 568 kg per hectare in the 2009-10 season, with 50% or more of the increase in yield, attributed to Bt cotton (Figure 21). Thus, at a national level, Bt cotton is a major factor contributing to higher cotton production which increased from 15.8 million bales in 2001-02, to 24.4 million bales in 2005-06, 28 million bales in 2006-07, and 31.5 million bales in 2007-08, which was a record cotton crop for India (Cotton Advisory Board, 2008). The Cotton Advisory Board projects 30.5 million bales of production in 2009-10 despite the fact that there was a delayed monsoon with erratic rainfall and flooding at the time of boll maturity and cotton picking in the Central and Southern cotton growing zones which contribute over 80% of cotton production in the country. This quantum leap in cotton production since 2002-03 has been triggered by improved seeds and particularly the ever-increasing plantings of improved Bt cotton in the ten cotton-growing states (Cotton Advisory Board, 2009). While the public sector continues to play a dominant role in production and distribution of low-value high volume seeds like cereals, pulses and oilseeds, the private seed sector is focusing on high-value, low-volume segments like vegetables, horticultural and cash crops like cotton. The private seed industry's role in promoting genetically modified (Bt) cotton has been particularly significant. India is now a mega cotton producing country as noted in the Economic Survey of 2006-07. The Annual Economic Survey 2007-08 of the Ministry of Finance also reports an increase in production and productivity of cotton during the Tenth Five Year Plan (2002-2007), which coincides with the introduction of Bt cotton in India in 2002 (Ministry of Finance, 2008).

With the boom in cotton production in the last eight years, India has become transformed from a net importer to a net exporter of cotton. Exports of cotton have registered a sharp increase from a meager 0.05 million bales in 2001-02 to 5.8 million bales in 2006-07 before touching a high of 8.8 million bales in 2007-08. In 2008-09, raw cotton export recorded a modest 3.5 million bales. Cotton industry sources expect the cotton export to rebound to 7.8 million bales in 2009-2010 with imports decreasing to 0.39 million bales (Figure 22).

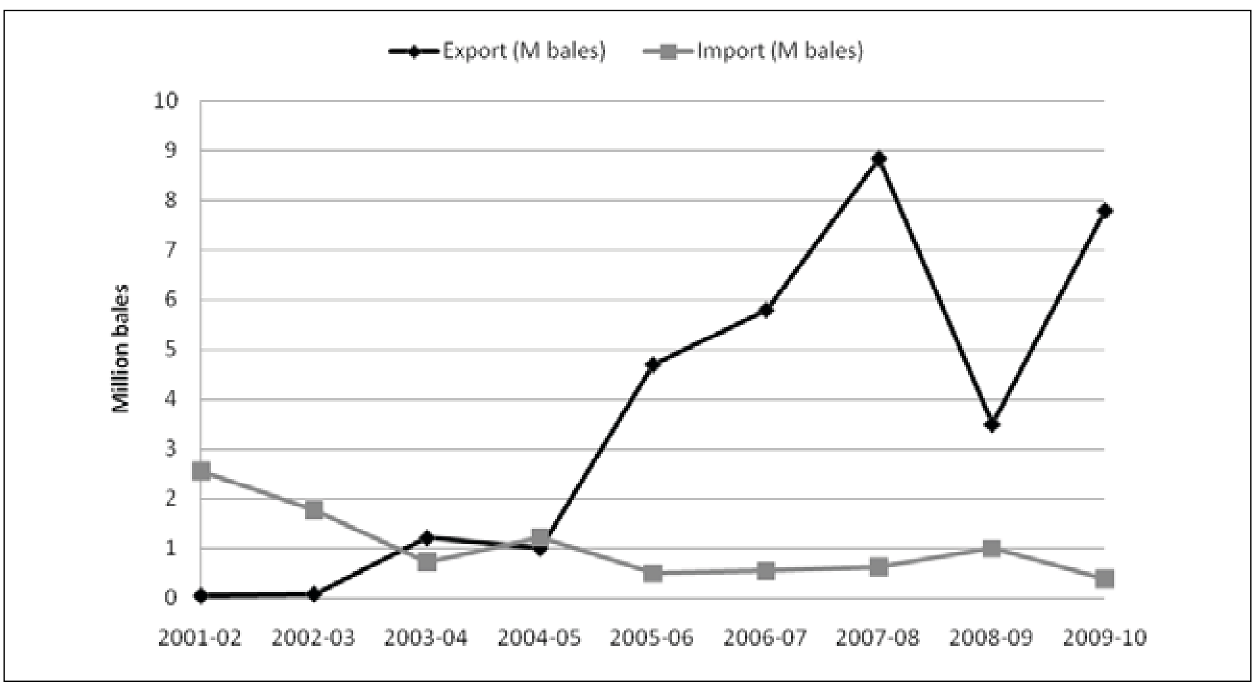
Concurrent with the boom in cotton production, the Indian biotech and seed industry has also been growing at an unprecedented rate with high year-on-year growth because of the high adoption of Bt cotton by Indian farmers. In 2008-09, the Indian biotechnology industry registered an 18% growth in Rupee terms, with record revenue of Rs. 12,137 crore (US$2.7) billion (based on Rupees

Figure 21. Cotton Hectarage, Production and Yield in India, 2001 to 2009



1 bale = 170 kg
Source: Cotton Advisory Board, 2009.

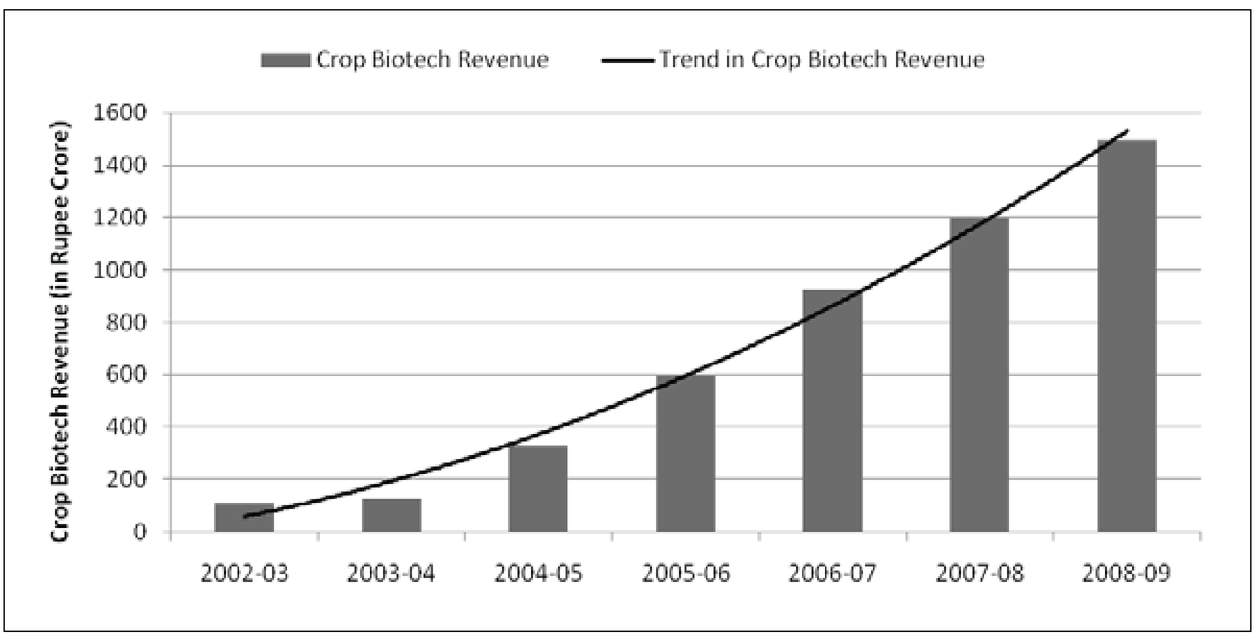
Figure 22. Export and Import of Cotton in India, 2001 to 2009



1 bale = 170 kg
Source: Cotton Corporation of India, 2009.

45 per US$) from 10,234 crore (US$2.3 billion) in 2007-08. According to the survey conducted by BioSpectrum-ABLE (Biospectrum, India, 2009) in 2008-09 (Figure 23), the biotech crop sector grew by a quarter (24%) to Rs. 1,494 crore (US$332 million), registering the second largest growth among various segments of biotech sector in India. Notably, Bt cotton is the only biotech crop product that continues to grow with increasing adoption of Bt cotton hybrids by farmers in India. During the last seven years (2002-2008), Bt cotton sustained growth of the biotech crop segment in the Indian biotech industry. In 2008, the share of the crop biotech segment increased to 12.31% compared to a previous 11.70% of the Indian biotech sector revenue – a trend that has continued since the introduction of Bt cotton hybrids in 2002. More specifically, the biotech crop revenues grew continuously at a double digit rate of 24% in 2008-09, 30% in 2007-08, 54.9% in 2006-07, 95% in 2005-06; it increased fourteen-fold from Rs. 110 crore (US$25 million) in 2002-2003 to Rs. 1,494 crore (US$332 million) in 2008-09. In 2008, the biopharma segment continued to account for the largest share, 64.95%, of the biotech industry revenues followed by 16.99% for bioservices, 12.31% for biotech crop, 3.94% for bioindustrial and the remaining 1.81% for the bioinformatics sector. The survey projects doubling of the Indian biotech industry revenue in the next two years when it is estimated to reach US$5 billion in 2010 compared with US$2.7 billion in 2008 (Based on 45 Rupees per US$).

Figure 23. Crop Biotechnology Industry Market in India (in Rupee Crore), 2002 to 2008



(1 Crore = 10 Million Rupees)
Source: BioSpectrum India, 2009.

Approval of Events and Bt Cotton Hybrids in India

The number of events, as well as the number of Bt cotton hybrids and companies marketing approved hybrids have all increased significantly from 2002, the first year of commercialization of Bt cotton in India. In 2009, the number of Bt cotton hybrids increased by more than two-fold to 522 (including a Bt variety) from 274 hybrids in 2008 – a doubling of the number of hybrids from 131 in 2007. Importantly, this increase in number of hybrids has provided much more choice in 2009 than in previous years to farmers in the North, Central and Southern regions, where specific hybrids have been approved for cultivation in specific regions (Appendix 1 and Figure 24). In 2009, a total of six events were approved for incorporation in a total of 522 hybrids with a fifth event incorporated in both the Bt cotton variety, *Bikaneri Nerma (BN)*, approved in 2008 and the publicly-bred Bt cotton hybrid NHH-44 which was approved for commercial cultivation in 2009. The sixth event MLS-9124 was approved for the first time in 2009 (Table 18).

The first event, MON531, Bollgard®I (BG®I), featuring the *cry1Ac* gene was developed by Maharashtra Hybrid Seeds Company Ltd. (Mahyco), sourced from Monsanto, and approved for sale in 2009, for the eighth consecutive year, in a total of 180 hybrids for use in the North, Central and South zones – this compares with 141 BG®I hybrids in 2008, 96 BG®I hybrids in 2007 and 48 BG®I hybrids in 2006.

Table 18. Commercial Release of Different Bt Cotton Events in India, 2002 to 2009

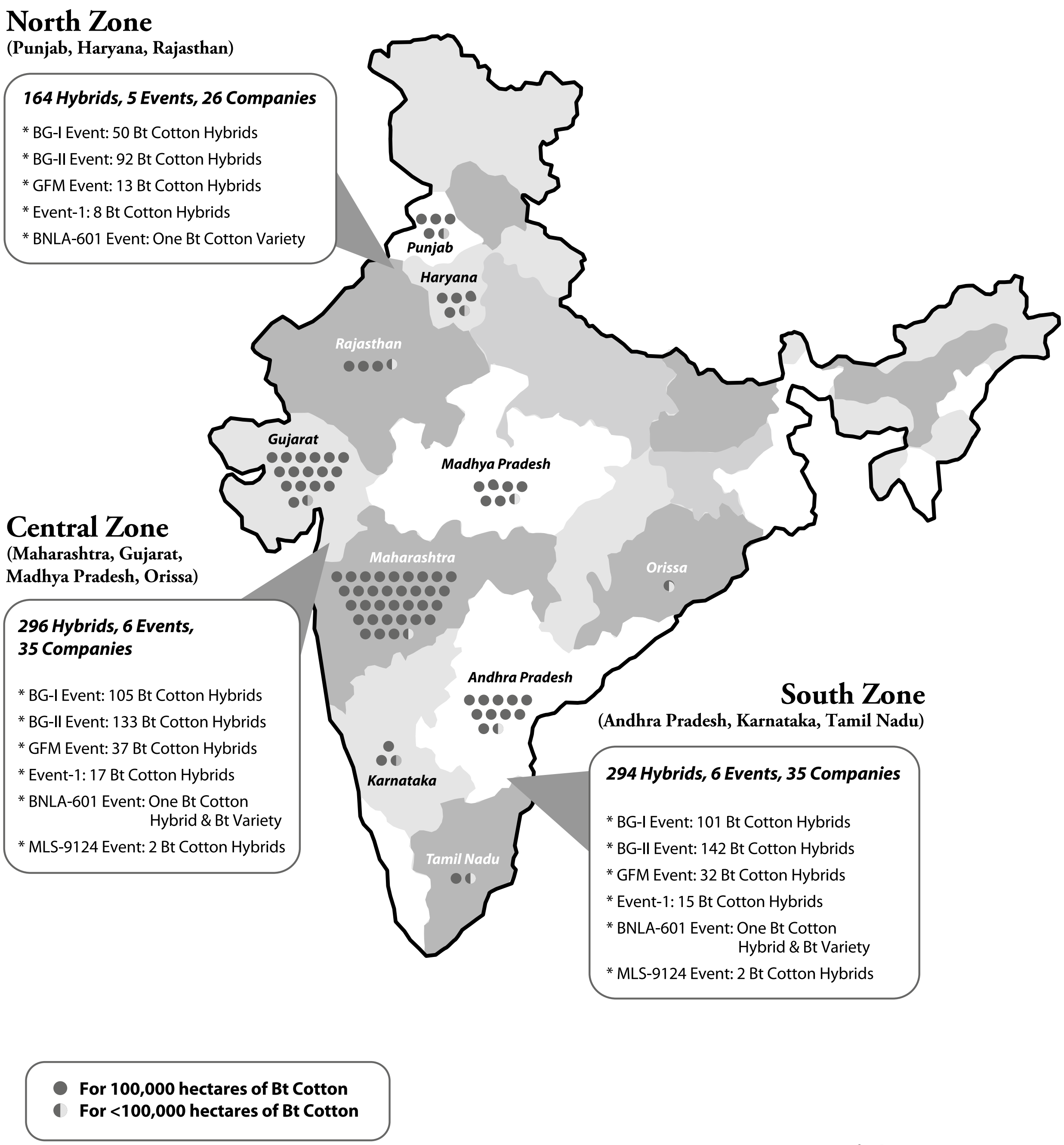
No.	Crop	Event	Developer	Status	Date of Approval
1	Cotton*	MON-531	Mahyco/Monsanto	Commercialized	2002
2	Cotton*	MON-15985	Mahyco/Monsanto	Commercialized	2006
3	Cotton*	Event-1	JK Agri-Genetics	Commercialized	2006
4	Cotton*	GFM Event	Nath Seeds	Commercialized	2006
5	Cotton**	BNLA-601	CICR (ICAR) & UAS, Dharwad	Commercialized	2008
6	Cotton*	MLS-9124	Metahelix Life Sciences	Commercialized	2009

*Bt cotton hybrid; ** Bt cotton variety and Bt cotton hybrid

Source: Compiled by ISAAA, 2009.

The second event, MON15985, Bollgard®II (BG®II) was also developed by Mahyco and sourced from Monsanto, featured the two genes *cry1Ac* and *cry2Ab*, and was approved for sale for the first time in 2006 in a total of seven hybrids for use in the Central and South zones. This event was approved for commercial cultivation for the first time in the Northern zone in 2007 and the number of hybrids

Figure 24. Approval of Events and Bt Cotton Variety & Hybrids in India, 2009



Compiled by ISAAA, 2009.

for sale increased from 7 in 2006, 21 in 2007, 94 in 2008 and further increased significantly to 248 BG®II cotton hybrids in 2009 in the North, Central and South zones.

The third event, known as Event-1 was developed by JK Seeds featuring the *cry1Ac gene*, sourced from IIT Kharagpur, India. The event was approved for sale for the first time in 2006 in a total of four hybrids for use in the North, Central and South zones. Whereas this event was approved in only four hybrids in 2006, in 2008 it quadrupled to 15 hybrids and again doubled to 27 in 2009.

The fourth event is the GFM event which was developed by Nath Seeds, sourced from China, and features the fused genes *cry1Ab* and *cry1Ac*. It was approved for sale for the first time in a total of three hybrids in 2006, one in each of the three regions of India. In 2009, the number of hybrids for sale increased three-fold from 24 to 63 in 3 zones.

In contrast to the above four events, which were all incorporated in cotton hybrids, notably the fifth event known as BNLA-601 was approved for commercial sale in an indigenous publicly-bred cotton variety named *Bikaneri Nerma* (BN) expressing the *cry1Ac* gene. It was approved for commercial release in the North, Central and South cotton growing zones in India during *Kharif*, 2008. In 2009, a publicly-bred Bt cotton hybrid NHH-44 was also released for commercialization based on event BNLA-601 expressing the *cry1Ac* gene. This is the first indigenous Bt cotton event developed by the Central Institute of Cotton Research (CICR) – one of the premier public sector institute of the Indian Council of Agricultural Research (ICAR) – along with University of Agricultural Sciences, Dharwad, Karnataka. The approval of the Bt cotton variety BN will help farmers in varietal growing areas which were previously disadvantaged because they were unable to benefit from the insect resistant Bt cotton hybrids cultivated widely across all three cotton growing zones.

The sixth new event, MLS-9124, was developed indigenously by Metahelix Life Sciences and features a synthetic *cry1C* gene. In 2009, two Bt cotton hybrids namely MH-5125 and MH-5174 expressing the synthetic *cry1C* gene (MLS-9124) were approved for commercial sale for Central and Southern zones.

The commercial deployment of these five events in hybrids and sixth event in both variety and hybrids in India is summarized in Table 19, and their regional distribution is detailed in Table 20. The variety *Bikaneri Nerma* was approved in 2008 and commercialized by CICR, Nagpur and the University of Agricultural Sciences (UAS), Dharwad in the three zones of North, Central and South India. In addition, NHH-44 Bt cotton hybrids was commercialized by CICR, Nagpur and University of Agricultural Sciences (UAS), Dharwad, and approved for planting in Central and South cotton growing zones in 2009.

Table 19. Deployment of Approved Bt Cotton Events/Hybrids/Variety by Region in India in 2009

Event	North (N)	Central (C)	South (S)	North/ Central (N/C)	North/ South (N/S)	Central/ South (C/S)	N/C/S	Total Hybrids
BG-I[1]	34	39	40	6	1	51	9	180
BG-II[2]	63	40	47	3	5	69	21	248
Event-I[3]	7	5	3	0	0	11	1	27
GFM Event[4]	12	19	14	0	0	17	1	63
BNLA-601[5]	0	0	0	0	0	1	1*	2
MLS-9124[6]	0	0	0	0	0	2	0	2
Total	116	103	104	9	6	151	33	522

*Bt cotton variety
[1,2] Mahyco [3] JK Seeds [4] Nath Seeds [5]CICR (ICAR) and [6]Metahelix
Source: Compiled by ISAAA, 2009.

Table 20. Deployment of Approved Bt Cotton Events/Hybrids/Variety by Companies/Institutions in India, 2002 to 2009

Event	2002	2003	2004	2005	2006	2007	2008	2009
NORTH ZONE				6 Hybrids	14 Hybrids	32 Hybrids	62 Hybrids	164 Hybrids
Haryana				1 Event	3 Events	4 Events	4 Events	5 Events
Punjab				3	6	14	15	26
Rajasthan				Companies	Companies	Companies	Companies	Companies
CENTRAL ZONE	3	3	4	12 hybrids	36 Hybrids	84 Hybrids	148 Hybrids	296 Hybrids
Gujarat	Hybrids	Hybrids	Hybrids	1 Event	4 Events	4 Events	4 Events	6 Events
Madhya Pradesh				4	15	23	27	35
Maharashtra				Companies	Companies	Companies	Companies	Companies
SOUTH ZONE	3	3	4	9 Hybrids	31 hybrids	70 Hybrids	149 Hybrids	294 Hybrids
Andhra Pradesh	Hybrids	Hybrids	Hybrids	1 Event	4 Events	4 Events	4 Events	6 Events
Karnataka				3	13	22	27	35
Tamil Nadu				Companies	Companies	Companies	Companies	Companies
Summary								
Total no. of hybrids	3	3	4	20	62	131	274	522*
Total no. of events	1	1	1	1	4	4	4	6
Total no. of companies	1	1	1	3	15	24	30	35

* Some of the 522 hybrids including a variety are being grown in multiple regions (see Figure 24)
Source: Compiled by ISAAA, 2009.

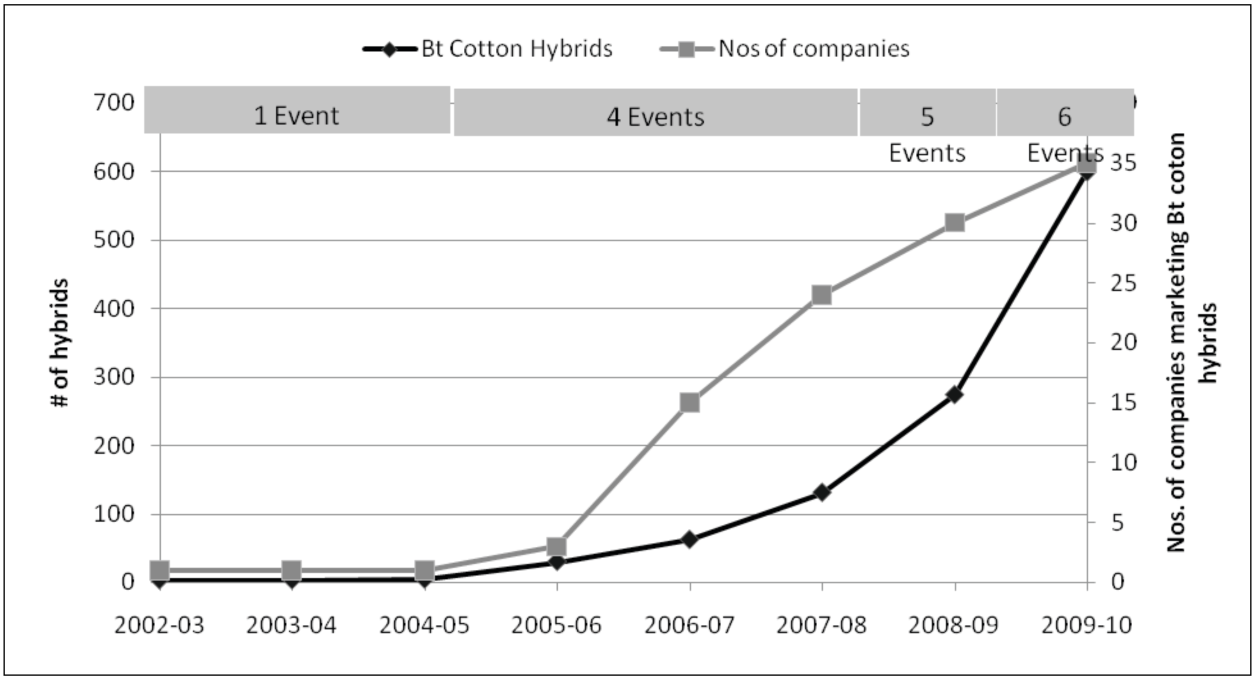
The number of Bt cotton hybrids as well as the number of companies offering Bt cotton hybrids in India has increased dramatically over the last 8 years since the first commercialization in 2002. In 2009, the number of Bt cotton hybrids doubled to 522 (including one variety) from 274 in 2008 and 131 in 2007 with 34 companies and one public sector undertaking marketing those hybrids and variety in three cotton-growing zones in 2009. By contrast in 2008, only 30 companies offered 274 hybrids, up from 24 companies offering 131 hybrids in 2007. The following 34 indigenous seed companies and one public sector institution from India, listed alphabetically, offered the 522 hybrids and one variety for sale in 2009; Ajeet Seeds Ltd., Amar Biotech Ltd., Ankur Seeds Pvt., Bayer Biosciences Ltd., Bioseeds Research India Pvt. Ltd., Ganga Kaveri Seeds Pvt. Ltd., Green Gold Pvt. Ltd., J. K. Agri Genetics Ltd., Kaveri Seeds Pvt. Ltd., Krishidhan Seeds Ltd., Mahyco, Metahelix Life Sciences, Monsanto Holdings Pvt. Ltd., Namdhari Seeds Pvt. Ltd., Nandi Seeds Pvt. Ltd., Nath Seeds Ltd., Navkar Hybrid Seeds Pvt. Ltd., Nuziveedu Seeds Ltd., Palamoor Seeds Pvt. Ltd., Prabhat Agri Biotech Ltd., Pravardhan Seeds Ltd., Rasi Seeds Ltd, RJ Biotech Pvt. Ltd., Safal Seeds and Biotech Ltd., Seed Works India Pvt. Ltd., Solar Agrotech Pvt. Ltd., Super Seeds Pvt. Ltd., Tulasi Seeds Pvt. Ltd., Uniphos Enterprises Ltd., Vibha Agrotech Ltd., Vikki Agrotech, Vikram Seeds Ltd., Yashoda Hybrid Seeds Pvt. Ltd., Zuari Seeds Ltd., CICR (Nagpur) and UAS Dharwad.

The deployment of the four events in 522 hybrids in 2009 is summarized in Table 19 and Table 20, as well as the corresponding distribution of hybrids in 2002, 2003, 2004, 2005, 2006, 2007 and 2008. In 2009, the Genetic Engineering Approval Committee (GEAC) approved 248 new Bt cotton hybrids for commercial cultivation in the 2009 season, in addition to the 274 Bt cotton hybrids approved for sale in 2008, for a total of 522 hybrids. This provided farmers in India's three cotton-growing zones significantly more choice of hybrids for cultivation in 2009. Of the 522 Bt cotton hybrids approved for commercial cultivation, 164 hybrids featuring five events were sold by 26 companies in the Northern zone, 296 hybrids featuring six events were sold by 35 companies in the Central zone, and 294 hybrids featuring six events were sold by 35 companies in the Southern zone (Table 20 and Figure 25).

As described in the earlier section, there has been a substantial increase in the area and number of hybrids with two genes for pest resistance, the BG®II event, in 2009. The BG®II cotton hybrids more than doubled to 248 in 2009 from 94 in 2008 and only 21 hybrids in 2007. This trend is due to the multiple benefits that double genes offered in terms of more effective control of more than one insect pest. For this reason, the BG®II hybrids are preferred by farmers across all three different cotton-growing zones. The BG®II hybrids protect cotton crops from both *Helicoverpa armigera* and *Spodoptera* insects and offer an effective tool in insect resistance management to Indian cotton farmers.

Similarly, the distribution of the 522 hybrids approved for 2009 is summarized in Table 20 as well as 274 hybrids approved for 2008, 131 hybrids approved for 2007, the 62 hybrids approved for 2006,

Figure 25. Release of Bt Cotton Hybrids in India, 2002 to 2009



Source: Compiled by ISAAA, 2009.

the 20 hybrids approved for 2005, the four hybrids offered for sale in 2004 and the three hybrids approved for both 2003 and 2002. In 2002, Mahyco was the first to receive approval for three Bt cotton hybrids, i.e. MECH 12, MECH 162 and MECH 184, for commercial cultivation in the Central and Southern cotton growing zones in India. The rapid deployment of hybrids during the period 2002 to 2008 reaching 522 Bt cotton hybrids in 2009 as well as their respective events in the three regions is summarized in Appendix 1 and illustrated in the map in Figure 24.

The approval and adoption of Bt cotton by the two most populous countries in the world, India (1.1 billion people) and China (1.3 billion people), can greatly influence the approval, adoption and acceptance of biotech crops in other countries throughout the world, particularly in developing countries. It is noteworthy that both countries elected to pursue a similar strategy by first exploring the potential benefits of crop biotechnology with a fiber crop, Bt cotton, which has already generated significant and consistent benefits in China, with the same pattern evident in India, the largest grower of cotton in the world. In 2009, India had more biotech cotton under cultivation (8.4 million hectares) than China (3.8 million hectares) whereas the number of farmers benefiting from Bt cotton was higher in China (7.0 million) than India (5.6 million) because the average cotton holding per farm in China (0.6 hectare) is smaller than in India (1.5 hectare).

Bt Brinjal: An Important Biotech Vegetable Food Crop in India

India's Genetic Engineering Approval Committee (GEAC), the country's biotech regulator, in its 97th meeting held on 14th Oct 2009 recommended the commercial release of Bt Brinjal Event EE-1 developed indigenously by M/s Maharashtra Hybrid Seeds Company Ltd. (Mahyco) in collaboration with the University of Agricultural Sciences (UAS), Dharwad and the Tamil Nadu Agricultural University (TNAU), Coimbatore (Ministry of Environment and Forest, 2009). The recommendation came seven years after the approval of Bt cotton, the country's first biotech crop which was planted by 5.6 million farmers on 87% of total cotton area in 2009. Bt brinjal, which is resistant to the dreaded Fruit and Shoot Borer (FSB), has been under research and development and a stringent regulatory approval process in India since 2000.

Brinjal is a very important common man's vegetable in India. After potato, it ranks as the second highest consumed vegetable in India, along with tomato and onion. A total of 1.4 million small, marginal and resource-poor farmers grow brinjal on 550,000 hectares annually in all the eight vegetable growing zones throughout India. It is an important cash crop for poor farmers, who transplant it from nurseries at different times of the year to produce two or three crops, each of 150 to 180 days' duration. Farmers start harvesting fruits at about 60 days after planting, and continue to harvest for 90 to 120 days, thereby providing a steady supply of food for the family; it also provides a stable income from market sales for most of the year. Brinjal was one of the first vegetable crops adopted by farmers as hybrids, which occupied more than 50% of the brinjal planted area of 550,000 hectares in 2007, the balance being planted with open pollinated varieties (OPVs). Brinjal is marketed in different sizes, shapes and colors to meet consumer preferences.

Of the global production of 32 million tons (1 ton = 1,000 kg) of brinjal produced on 2 million hectares worldwide annually, India produces 8 to 9 million tons, equivalent to one quarter of the global production, which makes India the second largest producer of brinjal in the world, after China. Brinjal is a hardy crop that yields well under stress conditions, including drought. Productivity has increased from 12.6 tons per hectare in 1987-88, to 15.3 tons per hectare in 1991-92, to 16.5 tons per hectare in 2005-06. Although the centre of origin for brinjal is not known for certain, cultivated and related wild species of brinjal in India represent a broad range of genetic diversity which has likely migrated from India, and China, to other countries in South East Asia, Africa, Europe and the Americas.

Brinjal is prone to attack by many insect-pests and diseases; by far the most important of which is the Fruit and Shoot Borer (FSB), for which resistance has not been identified and thus it causes significant losses of up to 60 to 70% in commercial plantings. Damage starts in the nursery, prior to transplanting, continues to harvest and is then carried-over to the next crop of brinjal. FSB damages brinjal in two ways. First, it infests young shoots which limits the ability of plants to produce healthy fruit-bearing shoots, thereby reducing potential yield. Secondly, and more importantly, it bores into fruits, making them unmarketable after harvest – it is this decrease in marketable yield, as opposed to total yield, that is the most important yield loss caused by FSB (Choudhary & Gaur, 2009). Marketable yield refers to the net yield of non-infested undamaged brinjal fruits that a farmer can sell at a premium price. It is the decrease in marketable yield of fruit, as opposed to total yield of fruit that is the most important yield loss caused by fruit and shoot borer (FSB) of brinjal.

Extensive Use of Insecticides

Due to the fact that FSB larvae remain concealed within shoots and fruits, insecticide applications, although numerous, are ineffective. Farmers usually spray twice a week, applying 15 to 40 insecticide sprays, or more, in one season depending on infestation levels. The decision of farmers to spray is influenced more by subjective assessment of visual presence of FSB rather than guided by the more objective science-based methodology of economic threshold levels. This reliance on subjective assessment of visual presence leads to gross over-spraying with insecticides, higher insecticide residues, and unnecessary increase in the farmers' exposure to insecticides (Choudhary & Gaur, 2009). As noted in the Genetic Engineering Approval Committee Expert Committee-II Report on Bt Brinjal Event EE-I (GEAC, 2009), ***"farmers rely exclusively on the application of pesticides to control FSB and to produce blemish-free brinjal fruit. Pesticide use is very intensive for killing the larvae before they bore inside shoots or fruits. Similar surveys conducted by the Bangladesh Agricultural Research Institute in Bangladesh indicated that farmers spray insecticides up to 84 times during a 6-7 month cropping season (BARI, 1995). The approach of pesticide spray schedules that involved calendar spraying whether the pest was present or not has led to increased dependence on pesticides and consequent adverse effects of higher costs of production, environmental pollution, destruction of natural enemies, and development of pesticide resistance in FSB."***

In India for example, for the more productive hybrid brinjal plantings, 54 liters of formulated insecticide per hectare is sprayed, compared with a requirement of only 16 liters when economic thresholds are used to trigger spraying. Similarly, for the less productive open pollinated varieties, 26.7 liters of insecticides per hectare are used, compared with only 4.9 liters per hectare as required by economic thresholds. On average, 4.6 kg of active ingredient of insecticide per hectare per season is applied on brinjal at a cost of Rs. 12,000 per hectare (US$267 per hectare); this is the highest quantity applied to any vegetable crop, with the exception of chili, which consumes 5.13 kg of active ingredient per hectare; okra consumes 3.71 kg of active ingredient per hectare. To illustrate the importance of FSB, of the 15 recommended insecticides for brinjal more than half, or eight are prescribed only for FSB. Typically, farmers indiscriminately apply a cocktail of insecticides on brinjal, including insecticides such as monocrotophos that are restricted or banned for use on vegetable crops by India's Central Insecticides Board and Registration Committee (CIBRC, 2008).

A survey of pesticide residues in vegetable crops taken at the farm gate and markets from 1999 to 2003 confirmed that of the 3,043 samples, two-thirds were found to have pesticide residues, but these were within accepted tolerances, whereas 9% contained residues above the minimum recommended levels as reported in Rajya Sabha – the Upper House of the Parliament of India (Rajya Sabha, 2003). The increasing amount of insecticide residues in vegetables and fruits has been a major concern to consumers who currently have no choice except to buy brinjals with high insecticide residues, but despite the application of many insecticides the brinjal fruits sold in the market are still of inferior quality, infested with larvae of FSB.

As per the report of the large scale field trials (LSTs) of Bt brinjal hybrids conducted by the Indian Institute of Vegetable Research (IIVR) during 2007-08 and 2008-09, on average an amount Rs. 14,701 per hectare (US$327 per hectare) was spent to control FSB in a cropping season. This was in addition to the cost of insecticides used to control other pests including *epilachna* beetle (hadda), red spider mite, whiteflies and jassids (IIVR, 2009).

The Expert Committee-II report on Bt brinjal noted that in spite of the extensive use of chemical pesticides, FSB is difficult to control by the application of pesticides as the larvae are often hidden in the fruit and do not come in contact with the insecticides. The report also noted that the extensive use of chemical pesticides has also led to several problems like resurgence of secondary pests, resistance in pests against pesticides, health hazards and pesticide residues in edible fruit. The Expert Committee-II report observed that the presence of a higher level of residues of monocrotophos in brinjal, clearly demonstrates the indiscriminate use of chemical pesticides in brinjal. As an example, the pesticide residue levels in brinjal as reported by various researchers in India are summarised in Table 21.

The recommendation by GEAC to commercially release Bt brinjal in India emanates from the fact that the current practices of using extensive pesticides is not only harmful to the health and environment but also non-sustainable in future for control of FSB in brinjal crop. GEAC noted that “the adoption of transgenic crops engineered primarily using the cry proteins to prevent damage caused by insect pests has given excellent results in cotton and maize worldwide resulting in significant economic benefits. A similar approach in brinjal is expected to provide substantial benefits to farmers.”

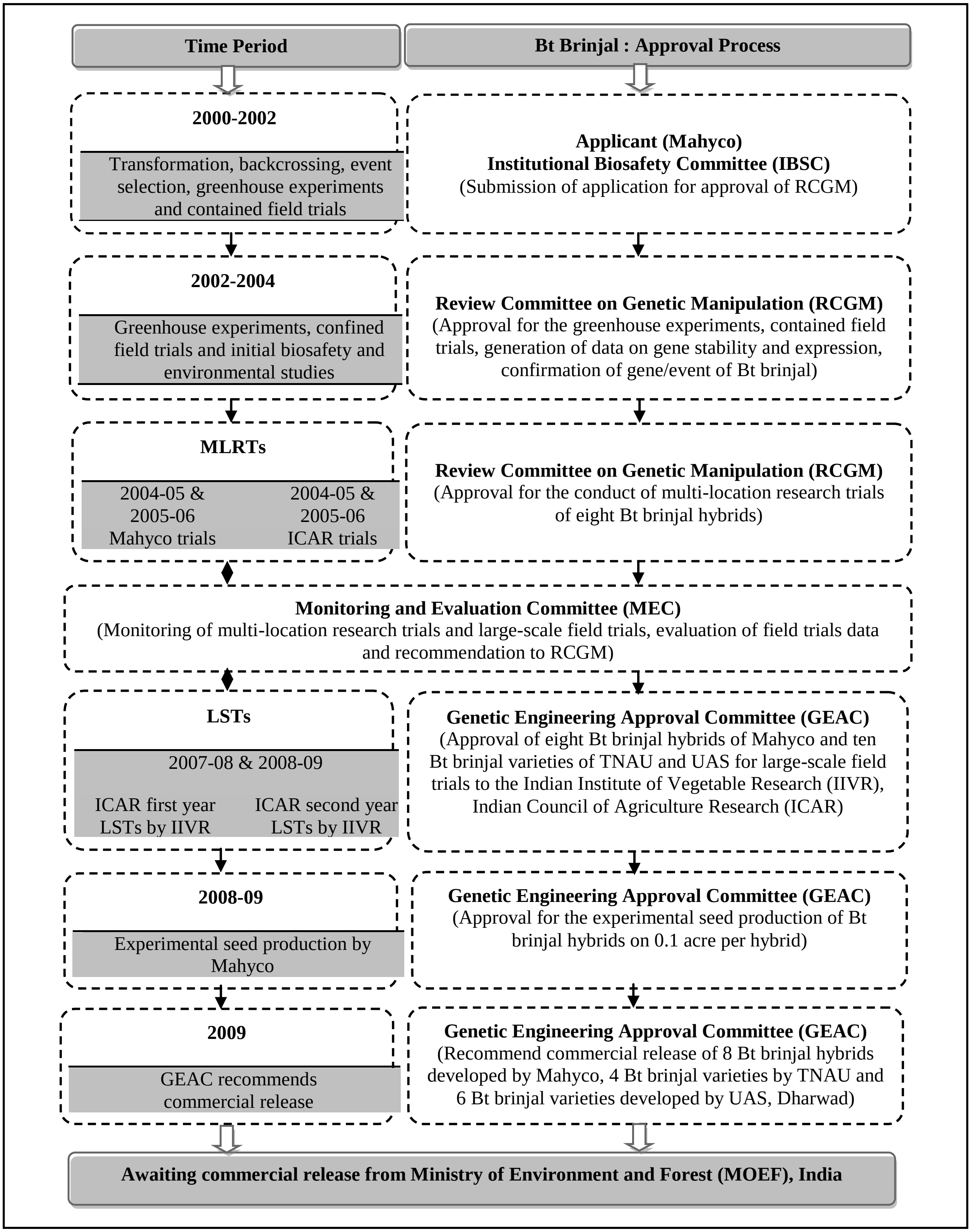
Bt brinjal has been under development by Mahyco in India since 2000. It has undergone a rigorous science-based regulatory approval process in India. Over the last 9 years, Mahyco, the technology developer along with public sector agricultural universities have undertaken various studies and field trials including laboratory experiments, greenhouse and confined field trials, biosafety and food safety studies, multi-location and large scale field trials for agronomic evaluation, socio-economic and environmental impact assessment. In 2008-09, Mahyco received permission from GEAC for experimental seed production of Bt brinjal hybrids. At present, there are 8 Bt brinjal hybrids (MHB-4Bt, MHB-9Bt, MHB-10Bt, MHB-11Bt, MHB-39Bt, MHB-80Bt, MHB-99Bt and MHB-112Bt) developed by Mahyco; 10 open pollinated varieties developed by public sector universities including 4 Bt brinjal varieties (Co2-Bt, MDU1-Bt, KKM1-Bt, PLR1-Bt) by the Tamil Nadu Agricultural University (TNAU), Coimbatore; and 6 Bt brinjal varieties (Malapur local (S)Bt, Manjarigota Bt, Rabkavi local Bt, Kudachi local Bt, Udupigulla Bt, GO112 Bt) by the University of Agricultural Sciences (UAS), Dharwad. All of these 10 varieties and 8 hybrids are awaiting the Government of India's final approval for commercial release (GEAC, 2009). In addition there are 6 open pollinated Bt brinjal varieties developed by the Indian Institute of Vegetable Research (IIVR), Varanasi which have been evaluated under large scale field trials throughout India. India's biotech regulatory, GEAC has already recommended approval of commercial release of Bt brinjal to the Ministry of Environment and Forest in Oct 2009 (MOEF, 2009). In the interim the data generated from 2000 to 2009 has been made available on the GEAC website for public information, scrutiny and comments. A list of important milestones achieved during the development and regulation of Bt brinjal are highlighted in chronological order (Figure 26).

Table 21. Pesticide Residue Levels in Brinjal in India

Insecticide (active ingredient)	MRL (ppm)	Residue level	Reference
Organochlorines	0.25	Above Below	Reddy *et al.* 1998 Rajeswaran *et al.* 2004
Carbosulfan Chlorpyriphos	0.20	Above	Beena-Kumari *et al.* 2004, Patel *et al.* 1999, Arora 2008, Goswami-Giri 2007
Cypermethrin	0.20	Above Below	Beena-Kumari *et al.* 2004, Arora 2008, Duara *et al.* 2003
Endosulfan	2.00	Above	Chandrasekaran *et al.* 1997, Nisha Kumari *et al.* 2005
Fenvalerate	0.20	Below Above	Duara *et al.* 2003 Chandrasekaran *et al.* 1997
Monocrotophos	0.20	Above	Beena-Kumari *et al.* 2004, Ahuja *et al.* 1998, Singh and Mukherjee 1992, Srinivas *et al.* 1996, Goswami-Giri 2007
Quinalphos	0.25	Above	Beena-Kumari *et al.* 2004, Kale *et al.* 1997, Goswami-Giri 2007
Triazophos	0.10	Above Below	Goswami *et al.* 2002 Raj *et al.* 1999

Source: Genetic Engineering Advisory Committee (GEAC), 2009.

Figure 26. Protocol Followed in Chronological Order, for Regulatory Approval of Bt Brinjal in India, 2000 to 2009



Source: Compiled by ISAAA, 2009.

Several food and feed safety assessment studies, including toxicity and allergenicity tests, have been conducted on rats, rabbits, fish, chickens, goats and cows; these studies have confirmed that Bt brinjal is as safe as its non-Bt counterparts. Studies on compositional/nutritional analysis of key components have also been completed and found similar to its non-Bt counterparts. In light of these studies, the Expert Committee-II report concluded that ***"the development and safety assessment of Bt brinjal event EE-1 is in accordance with the prevailing biosafety guidelines and is fully compliant with the conditions stipulated by GEAC, while according approval for large scale trials. The EC-II also noted that the data requirements for safety assessment of GM crops in India are comparable to the internationally accepted norms in different countries and by international agencies and therefore no additional studies need to be prescribed for safety assessment."***

Similarly, environmental impact assessment studies on germination, pollen flow, invasiveness, aggressiveness and weediness, persistence of Bt protein & soil impact, and effect on non-target organisms confirmed that Bt brinjal behaves similarly to its non-Bt counterpart. Based on the data generated from multi-location and large scale field trials, the Expert Committee-II report concluded that ***"introgression of cry1Ac gene has in no way affected outcrossing potential and the weediness characteristics of Bt brinjal. Bt brinjal event EE-1 is highly specific in its action on target organisms and has no adverse impact on non target organisms including beneficial organisms and soil microflora. No accumulation and persistence of Bt protein in the soil takes place and no differences with respect to susceptibility to pests and diseases have been noticed."***

A large number of field trials including multi-location research trials (MLRTs) and large scale field trials (LSTs) were conducted from 2004 to 2008 to assess the efficacy of the intended trait, agronomic performance and socio-economic benefits of Bt brinjal hybrids and varieties in comparison with non-Bt counterparts and non-Bt national best checks. Closely monitored by regulatory authorities, these field trials tested Bt brinjal event EE-1 in more than 50 locations representing major brinjal growing regions for over five years. The MLRTs were conducted separately by Mahyco and ICAR and LSTs under the All India Coordinated Vegetable Improvement Program (AICVIP) of the Indian Institute of Vegetable Research (IIVR), Varanasi – an apex vegetable research institute of the Indian Council of Agricultural Research (ICAR).

The Mahyco MLT field tests in 2004 to 2006 confirmed that the insecticide requirement for Bt brinjal hybrids was on average 80% less than the non-Bt counterpart to control FSB; this translated into a 42% reduction in total insecticides used for control of all insect pests in Bt brinjal versus the control. As a result of the effective control of FSB, Bt brinjal's average marketable yield increased by 100% over its non-Bt counterpart hybrids, 116% over popular conventional hybrids and 166% over popular open pollinated varieties (OPVs) of brinjal. Similarly, ICAR MLRTs at the same period indicated that Bt brinjal hybrids outperformed their non-Bt counterparts and popular hybrids with a 77.24% reduction in insecticides used to control FSB and a 41.79% total reduction in total pesticides. The marketable yield increased by 133.62% over the non-Bt counterparts which was more than double in most cases (Mahyco, 2006; ICAR, 2007; Krishna and Qaim 2007a, 2007b, 2008). The summarized results of MLRTs of Bt brinjal hybrids conducted by Mahyco and ICAR trials, 2004 to 2006 are given in Tables 22 and 23, respectively.

Table 22. Summarized Results of MLRTs with Bt Brinjal Hybrids from Mahyco, 2004 to 2006

Field Trial	Reduction in Insecticide Use		Increase in Fruit Yield Over					
	Against FSB	Against all insect Pests	Non-Bt Counterparts		Popular Hybrids		Popular OPVs	
	%	%	Yield Increase (tons/ha)	%	Yield Increase (tons/ha)	%	Yield Increase (tons/ha)	%
2004-05 (n=9)	80	44	29.4	117	28.4	120	35.9	179
2005-06 (n=6)	79	40	-	76	-	110	-	147
Average	80	42	-	100	-	116	-	166

Source: Mahyco; Krishna and Qaim 2007a, 2007b, 2008.

Table 23. Summarized Results of MLRTs with Bt Brinjal Hybrids from ICAR trials, 2004 to 2006

Field Trial	Reduction in Insecticide Use (%)		Increase in Fruit Yield (%) over	
	Against FSB	Against all insect pests	Non-Bt Counterparts	Popular Hybrids
2004-05	80.00	40.38	154.22	-
2005-06	74.47	43.20	113.02	214.24
Average	77.24	41.79	133.62	-

Source: All India Coordinated Vegetable Improvement Program (AICVIP), 2007.

Based on the data recorded during sets of trials (MLRTs by AICVIP, 2007; LSTs by IIVR, 2009), the Expert Committee-II noted that the efficacy of Bt brinjal hybrids against target pests has been well demonstrated in the assessment of shoot and fruit damage during various field trials (Table 24). The results of the field evaluations indicated that the mean shoot damage was significantly lower in Bt brinjal hybrids (1.51%) as compared to their non-Bt counterparts (7.06%), and checks (13.07%) across locations in all three trial sets. The cumulative fruit damage of Bt brinjal hybrids, their non-Bt counterparts and checks were 8.15%, 26.10% and 25.02%, respectively.

Table 24. Summarized Results of Mean Cumulative Shoot and Fruit Damage in Brinjal, 2004 to 2008

All Trials	Bt Brinjal Hybrids	Non-Bt Counterparts	National Check (Pusa hybrid-6)
Mean Shoot Damage	1.51%	7.06%	13.07%
Mean Cumulative Fruit Damage	8.15%	26.10%	25.02%

Source: AICVIP, 2007; Indian Institute of Vegetable Research (IIVR), 2009.

Importantly, the two-year large scale field trials (LSTs) conducted by the Indian Institute of Vegetable Research (IIVR, 2009) at 21 locations across 10 states over 2007-08 and 2008-09 to assess agronomic performance showed a significantly lower number of FSB larvae on Bt brinjal, 0-20 larvae, as compared to 3.5-80 larvae on the non-Bt counterpart. Agronomic performance data submitted to the regulatory authorities confirmed that Bt brinjal offers the opportunity to simultaneously provide effective control of the most important insect-pests of brinjal. The data also indicated that all three target pests including Fruit and Shoot Borer (*Leucinodes orbonalis*), Fruit Borer (*Helicoverpa armigera*) and Stem Borer (*Euzophera perticella*) are highly susceptible to the Cry1Ac protein level expressed in Bt brinjal hybrids. All three target insect species demonstrated limited variability in their mortality to the Cry1Ac protein as noted in the Expert Committee-II report.

Table 25. Summarized Results of Agronomic Performance of the Two-Year Large-Scale Field Trials (LSTs) of Bt Brinjal Hybrids Conducted by AICVIP /IIVR in India, 2007-08 and 2008-09

Large Scale Field Trials (LSTs)	Mean Marketable Yield (Tons/Ha)			Increase in Marketable Yield over	
	Bt Brinjal Hybrids	Non-Bt Counterparts	National Best Check (Pusa hybrid-6)	Non-Bt Counterparts	National Best Check (Pusa hybrid-6)
2007-08	36.23	28.91	25.15	25%	44%
2008-09	28.27	19.58	19.32	44%	46%
Mean	32.25	24.25	22.24	33%	45%

Source: IIVR, 2009.

The cumulative results of various large scale trials exhibit a significant increase in the marketable yield and saving in insecticide costs, using economic threshold level (ETL)-based sprays. On that basis, the Expert Committee-II concluded that ***"cry1Ac gene provides effective protection to the brinjal crop from the fruit and shoot borer resulting in enhanced economic benefits accrued from higher marketable yield and lower usage of pesticides sprays."*** The results of these studies are detailed in Table 25.

As per data set submitted by the IIVR for evaluation by the Expert Committee-II on Bt brinjal (IIVR, 2009), the GEAC noted that the Bt brinjal hybrids recorded an increase in mean marketable yield by 8 tons per hectare or 33% over the non-Bt counterparts, and by 10 tons per hectare or 45% over the check Pusa Hybrid-6. The mean marketable yield over various locations for Bt hybrids was recorded at 32.25 tons/ha as compared to 24.25 for non-Bt counterparts and 22.24 for the check hybrid (Table 25). It is also noted that the fruit and shoot borer damage exceeded the ETL 0.94 times in Bt hybrids in contrast to 7.44 times in non-Bt counterparts and 7.40 times in the check hybrid (Table 25). As a result, the net saving on the mean cost of sprays (based on ETL) was Rs. 5,200 per hectare (US$115 per hectare) on Bt brinjal hybrids over non-Bt counterparts and Rs. 5,168 over check hybrid. Bt brinjal hybrids recorded the highest mean gross income of Rs. 258,034 per hectare (US$5,734 per hectare) compared to Rs. 193,995 per hectare (US$4,311 per hectare) for non-Bt counterpart and Rs. 177,912 per hectare (US$3,954 per hectare) for the national check hybrid – a 33% and 45% gross income advantage for the Bt brinjal hybrids over the non-Bt counterparts and check hybrids respectively (Based on Rupees 45 per US$) (GEAC, 2009; IIVR, 2009).

Table 26. Mean Economic Performance of Two-Year Large-Scale Field Trials (LSTs) of Bt Brinjal Hybrids Conducted by AICVIP /IIVR in India, 2007-08 and 2008-09

Hybrids	Mean Economic Threshold Level (ETL)	Cost of Cultivation (Rs/Ha)*	Cost of Spray for FSB (Rs/Ha)	Gross Expenditure (Rs/Ha)	Marketable Yield (Tons/Ha)	Gross Income (Rs/Ha)	Net Income (Rs/Ha)
Bt Brinjal Hybrids	0.94	24,325	752	25,077	32.25	258,034	232,957
Non-Bt Counterparts	7.44	24,325	5,952	30,277	24.25	193,995	163,718
Pusa Hybrid-6	7.40	24,325	5,920	30,245	22.24	177,912	147,667

** Cost & Value Estimation: Cost of sucking pest and fungicide sprays (Rs. 3000/ha) inclusive of labour cost. Average fertilizer cost estimated at Rs. 5825/ha inclusive of application costs. Land preparation and transplanting costs were taken as Rs. 2000/ha. Other input costs were estimated as Rs. 4500/ha for irrigation, Rs. 2000/ha for weeding and picking charges for 14 pickings are Rs. 7000/ha. Value of the fruit is estimated as Rs. 8/kg for all tests hybrids for calculation of gross value of harvested crop.*

Source: IIVR, 2009.

The economic data in Table 26 indicates that due to a significant increase in marketable yield and saving on the cost of insecticides, Bt brinjal hybrids will accrue a sizeable profit to brinjal growers in India. The estimated economic benefit due to increased marketable yield in Bt brinjal hybrids is Rs. 64,800 per hectare (US$1,440 per hectare) over non-Bt counterparts and Rs. 80,800 per hectare (US$1,796 per hectare) over the check hybrid. Including savings on cost of insecticides, Bt brinjal hybrid growers will gain net economic benefits of Rs. 69,239 per hectare (US$1,539 per hectare) over non-Bt counterparts and Rs. 85,291 per hectare (US$1,895 per hectare) over the national check-hybrid.

According to the estimates, based on data generated from 2004 to 2008, Bt brinjal hybrids and varieties would help farmers to substantially decrease insecticide use by almost 80%, or more (costing US$40 to US$100 or more per season) to control the key insect pests of brinjal: fruit and shoot borer, fruit borer and stem borer. There will also be a significant increase in marketable yield over non-Bt brinjal hybrids and open pollinated varieties, thereby providing significant advantages for farmers and consumers alike. At the national level, Bt brinjal can thus contribute to food safety and security and sustainability.

Several independent studies estimate that the average small and resource-poor farmer, who cultivates 0.40 hectare of brinjal, would derive significant economic and social benefits by planting Bt brinjal. ABSP-II projections indicate that the potential benefits that Bt brinjal technology offers resource-poor farmers in India are significant and include the following: a 45% reduction in the number of insecticide sprays with positive implications for health, the environment and a significant reduction in production costs; a 117% increase in yield with implications for more affordable vegetables; an estimated US$411 million per annum increase in net benefits to Indian brinjal producers and consumers at the national level (ABSP-II, 2007; James, 2008). These economic benefits could make important contribution to the alleviation of poverty by increasing the income of resource-poor farmers growing brinjal and providing a more affordable source of vegetables for poor consumers. Another study conducted by Tamil Nadu Agricultural University (Ramasamy, 2007) projects similar benefits to the above study by ABSP-II. The Tamil Nadu Agricultural University study on the "Economic and environmental benefits and costs of transgenic crops: *Ex-ante* assessments" projects enormous benefits, welfare and distribution effects of Bt brinjal at the national level. The net estimated benefit of Bt brinjal to Indian farmers and consumers ranges from US$25-142 million per annum assuming only 10% adoption of Bt brinjal in the first year of commercialization.

It is noteworthy that the Bt brinjal event EE-1 has been generously donated by its developer, M/s Maharashtra Hybrid Seeds Company (Mahyco) to public institutes in India, Bangladesh and the Philippines for use in open-pollinated varieties of brinjal in order to meet the specific needs of small resource-poor farmers in India and in neighbouring countries in the region where brinjal is an important crop. The public-private partnership aims to generate affordable seed for resource-poor farmers, which will substantially reduce, by approximately half, the applications of insecticides required, with positive and significant implications for the environment and the health of farmers in India, Bangladesh and the Philippines. This is an excellent working example of a model philanthropic public/private sector partnership that has facilitated the generous donation of a biotechnology application by a private sector company for use by public sector institutes to meet the needs of small resource-poor farmers. The approval of Bt brinjal in India will not only serve the need of small and resource poor farmers of India but also the needs of Bangladesh and the Philippines in evolving a common regulatory framework, and generally facilitate regional harmonization of biotech crops in Asia. It can also serve as a model to facilitate regional harmonization in Sub-Sahara Africa where the need for simplified, responsible and appropriate regulations is even greater than in Asia, and for smaller countries in the Andean region of Latin America. The public private partnership on Bt brinjal between India, Bangladesh and the Philippines has been managed by Cornell University under the USAID biotechnology project, ABSP-II, in which ISAAA helps facilitate the technology transfer and adoption in the Philippines.

Given that biotech crops are not a technology in which society is well informed, ISAAA Brief 38 (Choudhary and Gaur, 2009) "The Development and Regulation of Bt Brinjal in India (*Eggplant/ Aubergine*)" released in early 2009 was designed as a primer for all interest groups with a desire to: firstly, learn about the cultivation of brinjal in India; secondly, to learn about the approval status and attributes of Bt brinjal which provides an option for significantly decreasing the use of insecticides on this important vegetable crop. The subjects covered in ISAAA Brief 38 range from the cultivation of brinjal as a vegetable used in diverse dishes in India and internationally, to the development and approval status of Bt brinjal in India including: regulation, biosafety and food safety assessment, the future prospects for Bt brinjal, and implications for other biotech food crops. ISAAA Brief 38 concludes that the commercialization of Bt brinjal has the potential to benefit up to a total of 1.7 million small farmers in the three countries of India (550,000 hectares farmed by 1.4 million small farmers), Bangladesh (57,747 hectares farmed by approximately 300,000 farmers) and the Philippines (21,000 hectares farmed by 30,000 farmers). The collective area of 630,000 hectares of brinjal represents a quarter of the total vegetable area in these three countries and therefore the potential impact of this project is significant. Brinjal is grown all-year round and supplies 25 calories per serving, and its "meaty" texture makes brinjal a perfect staple for vegetarians. ISAAA Brief 38 was designed to facilitate a more informed and transparent discussion regarding the potential role of biotech food crops, such as Bt brinjal, in contributing to global food security and a more sustainable agriculture.

Impact of Crop Technology in India and Investments in Crop Biotechnology

India is a country with first-hand experience of the life-saving benefits of the Green Revolution in wheat and rice. Yields in both wheat and rice are now plateauing and the conventional technology currently used in wheat and rice and other crops will need to be supplemented to feed a growing population that will increase by 50% to 1.5 billion people by 2050. Accordingly, the Government of India, through the Department of Biotechnology (DBT) in the Ministry of Science and Technology, established six centers of plant biotechnology in 1990 in addition to the existing research institutions of the Indian Council of Agricultural Research (ICAR), Council of Scientific and Industrial Research (CSIR) and different centers/departments of the State Agricultural Universities engaged in R&D of crop biotechnology sector in India. In recent years, the Department of Biotechnology (DBT) has either announced establishment or proposals to establish a series of new institutions, resource centers, biotech parks and incubators and biotech clusters across India to strengthen plant biotechnology research in the country. Table 27 lists DBT's institutional capacity and infrastructure for education, R&D and applied research of crop biotechnology sector in India as of 2009. The increased public sector investments in crop biotechnology in India are complemented by private sector investments from a large number of indigenous Indian seed companies and subsidiaries of multinationals involved in biotech crops.

Although there are no published estimates of the research and development (R&D) expenditures on crop biotechnology in India, the high level of activity in both the public and the private sector indicates that the fast-growing investments are substantial with India ranking third after China and Brazil in developing countries. Crop biotech investments from both the public and private sectors in India have increased significantly in recent years. Public sector investments alone in crop biotechnology were estimated to be about US$1.5 billion over the last five years, or US$300 million per year. Private sector investments are judged to be somewhat less than the public sector at up to US$200 million making the current total of public and private sector investments in crop biotechnology in India at the order of US$500 million per year. Current R&D in crop biotechnology in India is focused on the development of biotech food, feed and fiber crops that can contribute to higher and more stable yields and also enhanced nutrition. Given that rice production in India is vital for food security, much emphasis has been assigned to genomics in rice and the development of improved varieties tolerant to abiotic stresses such as salinity and drought, and biotic stresses such as pests and diseases. Field trials with biotech Bt rice are already underway. Reduction of post-harvest losses, particularly in fruits and vegetables, through delayed ripening genes, is also a major thrust. Reflecting the emphasis on improved crop nutrition, two international collaborative projects involve Golden Rice, and mustard with enhanced levels of beta-carotene plus an initiative to enhance the nutritional value of potatoes with the *ama1* gene. Research in Germany (Stein et al., 2006) predicts a positive impact of Golden Rice 2 in India. Under an optimistic scenario, the burden of disability adjusted life years (DALYs) would be reduced by a significant 59% and by 9% under a pessimistic scenario.

A recent ISAAA publication, "Trust in the Seed" (Choudhary and Gaur, 2008) highlights the important role that improved seeds, including biotech seed, have played in crop production in India. The following are selected modified paragraphs from "Trust in the Seed".

Table 27. DBT's Institutional Capacity and Infrastructure for R&D of Crop Biotech in India, 2009

National Institutions	New National Institutions	Biotech Parks and Incubators	Resource Centers	Biotechnology Clusters
Rajiv Gandhi Centre for Biotechnology, Thiruvananthapuram Established in 1990	UNESCO Regional Centre for Biotechnology Training and Education, Faridabad*	Technology Business Incubators (DST)*	Platform for Translational Research on Transgenic Crops (PTTC) at ICRISAT, Hyderabad*	Agri-food Biotech Cluster, Punjab Knowledge City, Mohali*
National Centre for Cell Sciences (NCCS), Pune Established in 1996	National Agri-food Biotechnology Institute (NABI), Mohali*	ICICI Knowledge Park, Hyderabad*	Genomics and proteomics technology platforms at Delhi University and IARI*	National Capital Region Biotechnology Cluster, Faridabad**
National Institute of Plant Genome Research (NIPGR), New Delhi Established in 1997	Food Bioprocessing Unit, Mohali*	S&T Park, Bangalore*	Detection facilities of genetically modified food and food products (CDFD, Hyderabad); (NBPGR, New Delhi); (ITRC, Lucknow); (NIN, Hyderabad); and (CFTRI, Mysore)*	Biotechnology Cluster, University of Agricultural Sciences, Bangalore**
Centre for DNA Fingerprinting and Diagnostics (CDFD), Hyderabad Established in 1998	National Institute of Abiotic Stress Management, Baramati* (A new institute of ICAR)	TICEL Park, Chennai*	National Containment-cum-Quarantine Facility for Transgenic Planting Material, NBPGR, New Delhi (DBT)*	Biotechnology Cluster, University of Hyderabad, Hyderabad**
Institute of Bioresources and Sustainable Development (IBSD), Imphal Established in 2001	National Institute of Agricultural Biotechnology** (A new institute of ICAR)	Agri-food Biotech Park, Mohali*	National Certification Facility for Tissue Culture Plants (at several existing institutions)*	
Institute of Life Sciences (ILS), Bhuvaneshwar Established in 2002	National Biotic Stress Institute** (A new institute of ICAR)	Biotechnology Incubation Centre, Genome Valley, Hyderabad*	Biomolecular Characterization Centre, Bangalore**	
	Centre of Bioinformatics in Agriculture** (A new institute of ICAR)	Agri-Incubator, University of Agricultural Sciences, Dharwad and Tamil Nadu Agricultural University, Coimbatore*		
		Agri Business Incubator, (ICRISAT), Hyderabad (An initiative of DST)*		

*New initiative, **Proposed   Source: DBT, 2009; Natesh & Bhan, 2009.

"Improved seeds have been a key contributing factor to quantum increases in crop productivity and production in India during the last 50 years. Three significant developments in improved seed and crop technologies have changed the face of Indian crop production and contributed to food security, and the alleviation of poverty and hunger.

The first major development was the green revolution in the 1960s and 1970s which resulted in unprecedented increases in food production from the high yielding, open-pollinated varieties (OPVs) of semi-dwarf wheat and semi-dwarf rice which literally saved millions from hunger in India. Dr. Norman Borlaug was awarded the Nobel Peace Prize in 1970 for developing the semi-dwarf wheats, which were credited with saving up to 1 billion lives in Asia, the majority in India. Dr. Borlaug's counterpart in India was Dr. M. S. Swaminathan recipient of the first World Food Prize in 1987. A tribute featuring the life and achievements of Dr. Norman Borlaug (1914-2009) as the first founding patron of ISAAA and a Nobel Peace Laureate is included with this Brief.

The second development was more modest and associated with the introduction of hybrid seeds, which replaced OPVs in the 1980s and 1990s, primarily in selected vegetable crops, such as tomato, capsicum, brinjal, okra, chili, cabbage and in field crops such as maize, sorghum, pearl millet, and cotton. Whereas hybrid seeds need to be replaced by farmers every year, they offer an attractive incentive to farmers because of the significant yield gains from hybrid vigor and moreover they provide an important technology platform for enhancing productivity in a sustainable manner for the longer term.

The third major development was in 2002, which featured the application of biotechnology to crops which led to the approval and commercialization of the first biotech crop in India featuring the Bt gene in hybrid cotton which confers resistance to the critically important lepidopteran insect pest, cotton bollworm. The Bt cotton experience in India is a remarkable story, which has clearly demonstrated the enormous impact that can be achieved by adopting biotech crops. In the short span of eight years, 2002 to 2009, cotton yields and production doubled, transforming India from an importer to an exporter of cotton. These gains in crop production are unprecedented which is why 5.6 million small farmers in India in 2009 elected to plant 8.4 million hectares of Bt cotton which represented 87% of the total national area of cotton, 9.6 million hectares, which is the largest area of cotton in any country in the world.

Importantly, one common element in all of the three above developments in improved seed was the willingness and indeed the eagerness, of small resource-poor farmers in India to embrace, change and adopt these new technologies, in order to quickly overcome production constraints and to increase their income to sustain their livelihoods and escape poverty. Thus, Indian farmers have not only been receptive but proactive in the adoption of all the new technologies, as and when they were made available to them even though the pace of introduction of new technologies has been slow in agriculture compared to any other sector because of onerous regulation requirements. These regulatory constraints have been exacerbated by procedural delays precipitated by activists who are well resourced and mobilized in national campaigns to unnecessarily delay the adoption of biotech crops which are subject to a very rigorous science-based regulation system. Despite the intensive actions of activists, Bt cotton has achieved unparalleled success in India simply due to the multiple and significant benefits it consistently delivers to farmers and reflected in the unprecedented 168-fold increase in Bt cotton hectarage between 2002 and 2009. The vote of confidence of farmers in Bt cotton is also reflected in the "litmus-test" for "Trust" which confirms that more than 9 out of 10 farmers who planted Bt cotton in 2005 also elected to plant Bt cotton in 2006 and the figure was even higher in 2007, 2008 and 2009, and projected to continuously increase in the future. This is a very high level of repeat adoption for any crop technology by industry standards and reflects the level of conviction in the technology by small resource-poor farmers who have elected to make the additional investment in Bt cotton because of the superior returns and benefits it offers over conventional hybrid cotton and even more over, open-pollinated varieties.

Not surprisingly, the remarkable success of Bt cotton in India and the support of farmers for the technology, has led to widespread strong political support to emulate the success of Bt cotton in other food crops. Whilst India has already approved the initial field testing of Bt rice, with drought and saline tolerant rice under development, it was Bt brinjal, (eggplant or aubergine) which was recommended for commercial release by the biotech regulator, GEAC, in Oct 2009. It is now awaiting formal approval for commercial release from the Ministry of Environment and Forest (MOEF), Government of India. Bt brinjal is of special significance because it is the most probable first biotech food crop to be approved for commercialization in India.

Biotech Crops Under Development in India

Biotech crops in development by the public sector include the following 15 crops: banana, cabbage, cassava, cauliflower, chickpea, cotton, eggplant, mustard/rapeseed, papaya, pigeon pea, potato, rice (including basmati), tomato, watermelon and wheat. In addition, the private sector in India has the following nine biotech crops under development: cabbage, cauliflower, cotton, maize, mustard/rapeseed, okra, pigeon pea, rice, and tomato. There are now 12 biotech crops in field trials in India and these are listed alphabetically in Table 28. In India, an estimated 12 million farmers grow over 7.5 million hectares of maize – India is the fifth largest maize country in the world after the USA, China, Brazil and Mexico. Clearance was given recently by the Indian Government for field trials of Bt maize and Bt/HT maize which, subject to regulatory approval could be deployed commercially within 5 years.

Table 28. Status of Field Trials of Biotech/GM Crops in India, 2009

Crop	Organization	Transgene/Trait	Event
Brinjal	IARI, New Delhi	*cry1Aabc/IR*	-
	Sungro Seeds, New Delhi	*cry1Ac/IR*	*EE-1*
	Mahyco, Jalna	*cry1Ac/IR*	*EE-1*
	TNAU, Coimbatore	*cry1Ac/IR*	*EE-1*
	UAS, Dharwad	*cry1Ac/IR*	*EE-1*
	IIVR, Varanasi	*cry1Ac/IR*	*EE-1*
	Bejo Sheetal, Jalna	*cry1Fa1/IR*	*Event-142*
Cabbage	Nunhems, Gurgaon	*cry1Ba* and *cry1Ca*/IR	-
	Sungro Seeds, New Delhi	*cry1Ac*/IR	-
Cauliflower	Sungro Seeds, New Delhi	*cry1Ac*/IR	*CFE-4*
	Nunhems, Gurgaon	*cry1Ba* and *cry1Ca*/IR	-
Cotton	Mahyco, Jalna	*cry1Ac* and *cry2Ab*/IR & HT	*MON 15985 and MON 88913*
	Dow Agro Sciences, Mumbai	*cry1Ac* and *cry1F*/IR	*Event 3006-210-23 and Event 281-24-236*
	JK Agri-Genetics, Hyderabad	*cry1Ac* and *cry1Ec*/IR	*Event 1 and Event 24*
	Metahelix, Bangalore	*cry1C*/IR	*Event 9124*
	CICR, Nagpur and UAS, Dharwad	*cry1Ac*/IR	*BN Bt event (BNLA-601)*
Groundnut	ICRISAT, Hyderabad	Rice *chit* and *DREB*/FR, DST	-
Maize	Monsanto, Mumbai	*cry2Ab2* & *cryA.105* and *CP4EPSPS*/IR&HT	Mon89034 and NK603
	Pioneer/Dupont, Hyderabad	*cry1F* and *CP4EPSPS*/IR&HT	*TC1507, NK603*
	Dow Agro Sciences, Mumbai	*cry1F*/IR	*TC1507*
Mustard	Delhi University, New Delhi	bar, barnase,barstar/AP	-
Okra	Mahyco, Mumbai	*cry1Ac*/IR	-
	Sungro Seeds, Delhi	*cry1Ac*/IR	
	Bejo Sheetal, Jalna	*cry1Ac*/IR	
	Arya Seeds, Gurgaon	*CP-AV1*/IR	
Potato	CPRI, Shimla	*RB, GA20 Oxidase 1 gene*/DR	-
	NIPGR, Delhi	*ama1*/NE	
Rice	IARI, New Delhi	*cry1Aabc, DREB, GR-1 & GR-2 (Golden Rice)*/NE	-
	TNAU, Coimbatore	*chi11*/FR	
	MSSRF, Chennai	*MnSOD*/DST	
	DRR, Hyderabad	*cry1Ac*/IR	
	Mahyco, Mumbai	*cry1Ac, cry2Ab*/IR	
	Bayer CropScience, Hyderabad	*cry1Ab* and *cry1Ca*/IR	
	Avesthagen	*NAD9*/NE	
Sorghum	NRCS, Hyderabad	*cry 1B*/IR	*Event 4 and Event 19*

Table 28. Status of Field Trials of Biotech/GM Crops in India, 2009

Crop	Organization	Transgene/Trait	Event
Tomato	IARI, New Delhi Mahyco, Mumbai Avesthagen	*antisense replicase, ACC Synthase gene, osmotin, DREB*/IR, DR, FR, NE, DST *cry1Ac*/IR *NAD9*/NE	- - -

Legend: AP: Agronomic Performance, BR: Bacterial Resistance, DR: Disease Resistance, DST: Drought and Salinity Tolerance, FR: Fungal resistance, IR: Insect Resistance, HT: Herbicide Tolerance, NE: Nutritional Enhancement.
Abbreviation: TNAU- Tamil Nadu Agricultural University; IIVR- Indian Institute of Vegetable Research; UAS-University of Agricultural Sciences; CICR-Central Institute of Cotton Research; ICRISAT-International Crop Research Institute for Semi-Arid Tropics; CPRI-Central Potato Research Institute; NIPGR-National Institute of Plant Genome Research; IARI-Indian Agricultural Research Institute; MSSRF-MS Swaminathan Research Foundation; DRR-Directorate of Rice Research; NRCS-National Research Center on Sorghum.

Source: Indian GMO Research Information System (IGMORIS), 2009, Compiled by ISAAA, 2009.

It is clear that India will be in a position to commercialize several biotech food crops in the near term, thus an awareness initiative to inform the public of the attributes of biotech crops is both timely and important. A survey by the Indian Institute of Management (IIM, 2007) addressed the issues of consumer awareness, opinion, acceptance and willingness to pay for GM foods in the Indian market place. The survey, conducted by (IIM) Ahmadabad in collaboration with Ohio State University, revealed that 70% of India's middle class is prepared to consume genetically modified food. The study also revealed that on average, consumers were willing to pay 19.5% and 16.1% premiums for Golden Rice and GM edible oil, respectively. The study suggested that consumer education societies, government ministries, and food companies create awareness about GM foods amongst Indian consumers.

In summary, India's increased public and private sector investments including government support for crop biotechnology is progressive. There were several key developments in India during 2009 that merit inclusion in this Brief. Nine events/developments are summarized in the paragraphs below:

Significant Developments in Crop Biotechnology in India in 2009

1). India's biotech regulator GEAC recommends commercial release of Bt brinjal

India's Genetic Engineering Approval Committee (GEAC), the country's biotech regulator, in its meeting held on 14th Oct 2009 recommended the commercial release of Bt brinjal in the country. The recommendation came seven years after the approval of Bt cotton, the country's first transgenic crop. Bt brinjal, which is resistant to the dreaded fruit and shoot borer (FSB), has been under research and development and stringent regulatory approval process since 2000.

Brinjal – "the King of Vegetable" is the second largest consumed vegetable in India after potato. As an important cash crop, 1.4 million small and marginal farmers grow brinjal on 550,000 hectare throughout India. Brinjal is prone to many insect pests of which Fruit and Shoot Borer (FSB) causes significant losses of up to 60-70% in commercial plantings. Farmers spray twice a week applying 40 insecticides sprays or more in a season to attempt to control this insect pest which escapes repeated insecticides sprays, as it bores inside shoots and fruits causing heavy losses to farmers. As a result, brinjal fruits sold in the market contain high pesticide residues and are of inferior quality, infested with larvae of FSB. Bt brinjal offers promising solution to the serious problem faced by farmers and consumers.

GEAC has submitted the recommendation to Mr. Jairam Ramesh, Minister of State (Independent Charge) for Environment and Forest (MOEF), Government of India. Minister Ramesh said in a press release that the ministry will make the decision after consultation with scientists, farmers, consumer groups and NGOs scheduled in January/February 2010 or "after all stakeholders are satisfied that they have been heard to their satisfaction." The objective of the consultation, Minister Ramesh noted, is to "arrive at careful, considered decision in the public and national interest."

Press Statement by Mr. Jairam Ramesh, Minister of State for Environment and Forest (MOEF), Government of India dated 15th Oct, 2009 available at:
http://moef.nic.in/downloads/public-information/Press_Bt%20Brinjal.pdf
Decision on Bt Brinjal after satisfactory consultations with all stakeholders: Jairam Ramesh, the Press Information Bureau (PIB), Government of India available at:
http://pib.nic.in/release/release.asp?relid=53217

2). India's GEAC approves commercialization of a publicly-bred Bt cotton variety and hybrid

Indian small and marginal cotton farmers planted a modest area of approximately 10,000 hectares of an Indian publicly-bred Bt cotton variety, named Bikaneri Nerma (BN) Bt and NHH-44 Bt cotton hybrid for the first time in 2009. Around 9,000 hectares of BN Bt cotton varieties and 1,000 hectares of NHH-44 Bt cotton hybrids were planted in different states including Maharashtra, Gujarat and Andhra Pradesh. Both BN Bt variety and NHH-44 Bt cotton hybrid express the cry1Ac gene, BNLA-601 event developed indigenously by the Central Institute for Cotton Research (CICR) Nagpur and National Research Centre for Plant Biotechnology (NRCPB), New Delhi of the Indian Council of Agricultural Research (ICAR) in partnership with the University of Agricultural Sciences (UAS), Dharwad, Karnataka.

In 2008, India's apex biotech regulatory body – the GEAC approved the commercial release of the indigenous BN Bt cotton variety expressing the *cry1Ac* gene, event BNLA-601 in the North, Central and South Cotton Growing Zones in India during *Kharif season* 2008. The GEAC also permitted commercial release of NHH-44 Bt cotton hybrid BNLA-601 event for the Central and South zones in 2009.

The decision during the 84th GEAC meeting held on 5th May 2008 available at: http://www.envfor.nic.in/divisions/csurv/geac/decision-may-84.pdf and 93rd GEAC meeting held on 13th May 2009 available at: http://www.envfor.nic.in/divisions/csurv/geac/decision-may-93.pdf

3). India approves new Bt cotton event

In 2009, the GEAC approved the commercialization of a new Bt cotton event MLS-9124. The new event expresses a truncated, synthetic *cry1C* gene developed indigenously by Metahelix Life Sciences Pvt Ltd, Bangalore. Two Bt cotton hybrids 5174 Bt and 5125 Bt expressing synthetic *cry1C* gene, which is highly effective in its control against *Spodoptera litura* were approved for planting in Central and South zones in 2009. It is important to note that there has been approval of six Bt cotton events developed by both public and private sector institutions in the last eight years from 2002 to 2009 in order to provide a choice to cotton farmers and delay resistance development among the bollworm populations.

The decision during the 93rd GEAC meeting held on 13th May 2009 available at:
http://www.envfor.nic.in/divisions/csurv/geac/decision-may-93.pdf

4). India boosts import of transgenic plant material for R&D on biotech crops

A new research study *Import and Commercialization of Transgenic Crops: An Indian Perspective* published in the recent issue of Asian Biotechnology and Development Review (ABDR) reveals a surge in the import of transgenic materials for R&D of transgenic crops in India. Between 1997 and 2008, a total of 79 consignments of transgenic plant materials have been imported from different countries through the National Bureau of Plant Genetic Resources (NBPGR). NBPGR is a national agency for import and quarantine processing of transgenic plant materials for various public and private research institutions engaged in R&D of transgenic crops.

The imported crops included cabbage, Indian mustard, rapeseed, chickpea, soybean, tomato, tobacco, rice, potato, wheat and corn. Out of these imported transgenic crops, the highest number of imports was for cotton followed by maize and rice. The predominant trait in these imported crops is for resistance to lepidopteran insects followed by herbicide tolerance. The highest number of transgenes were introduced for rice including *AmA1* gene and ferritin genes for improved nutrition, *cry1Ac, cry1C, cry2A, cry19C* and *GFM-cry1A* genes for resistance against lepidopteran insects, *cry1Ab* gene for resistance to stem borer, *cp4epsps* gene for herbicide tolerance, *Xa21* gene for resistance to bacterial leaf blight, *PR* genes for resistance to sheath borer, *bar* gene for resistance to glufosinate ammonium herbicide, *HAS, ScFv* & *AFP-AG* genes for nematode resistance, and the genes for phytoene synthase, phytoene desaturase, and lycopene cyclase involved in the synthesis of β-carotene in the endosperm of Golden Rice.

The study examined the pattern of import in a range of crops for different traits over the last decade and attempts to understand the gap between the pace at which the transgenic crops are being imported by public and private sectors and their actual commercialization. The study concluded that harnessing optimum benefits of transgenic crops while sustaining our valuable biodiversity hinges on systematic development, import and commercialization of transgenic crops along with strong public and private sector collaboration. It also addressed the concerns regarding potential impacts of transgenic crops on environment and human health and proposed collaboration between public and private sectors to adequately address the biosafety issues.

For more information on import and quarantine procedures for transgenic material visit the National Bureau of Plant Genetic Resources (NBPGR) at: http://www.nbpgr.ernet.in and access full copy of the article from the Asian Biotechnology and Development Review (ABDR, 2009) website at: http://www.ris.org.in/article6_v11n2.pdf

5). India approves export of Bt cotton hybrid seed to Pakistan

In 2009, India's Genetic Engineering Approval Committee (GEAC) has approved the export of Bt cotton hybrid seeds for multi-location trials in neighboring Pakistan. Pakistan is the fourth largest cotton-producing country in the world and ranks after the Bt cotton growing countries of China, India and USA. Pakistan has approximately 3 million hectares of cotton and produces about 13 million bales of cotton annually, compared with 29 million bales in India in 2008.

The Genetic Engineering Approval Committee (GEAC) approved a request from Hyderabad-based Bayer Bio Sciences and Delhi-based Monsanto Holdings Pvt. Ltd. to export Bt cotton hybrid seeds expressing multiple genes *cry1Ac* and *cry2Ab* (event MON 15985) to Karachi based Bayer Crop Science Pvt. Ltd. and Lahore based Monsanto Pakistan Agritech Pvt. Ltd., respectively. The intended purpose of the export is for conducting multi-locational field trials in different agro climatic zones in Pakistan. The export, however, is subject to rules stipulated by the Pakistan National Biosafety Committee and approval from the National Biodiversity Authority (NBA), Chennai, India.

The decision during the 93rd GEAC meeting held on 15th May 2009 is available at:
http://www.envfor.nic.in/divisions/csurv/geac/decision-may-93.pdf

6). India streamlines regulatory system for safety assessment of GM plants

In 2009, the Genetic Engineering Approval Committee (GEAC) of the Ministry of Environment and Forest (MOEF) in collaboration with the Department of Biotechnology (DBT) introduced a new regulatory system for conducting field trials to address the food, feed and environmental safety and completion of specific information and data requirements for the safety assessment of GM plants. The new system simplified the field trial requirements and replaced the old and cumbersome procedure of confined, multi-location and large scale field trials with a simplified structure:

i). Studies to be completed before Biosafety Research Level I (BRL-I) trials are undertaken
ii). Field studies that should be completed during BRL-I and/or Biosafety Research Level II (BRL-II) trials
iii). Non-field studies that should be completed in parallel to BRL-I and BRL-II.

A new set of guidelines, standard operating procedures (SOPs) and protocols for safety assessment of genetically engineered plants and foods derived from genetically engineered plants were introduced to support the new regulatory system on safety assessment of GM Crops. These include:

i). Guidelines for the conduct of field trials of regulated, genetically engineered plants in India and Standard Operating Procedures (SOPs)
ii). Protocol for safety assessment of genetically engineered plants
iii). ICMR guidelines for the safety of foods derived from genetically engineered plants in India

The new system is a step in the direction of implementing a rigorous and sound science-based approval system for genetically modified crops and foods in India. The new system benefits from inter-ministerial expertise on biotechnology, including the Department of Biotechnology, Ministry of Environment and Forest, Ministry of Agriculture and Ministry of Health and Family Welfare.

Source: The guidance for information/data generation and documentation for safety assessement of regulated, GE plants and a set of new guidelines for GE plants and foods derived from the GE plants is available at the Indian GMOs Research Information System (IGMORIS): http://www.igmoris.nic.in/

7). India's GEAC initiates an event-based approval mechanism

Taking into consideration recommendations for streamlining the current regulatory approval process for GM crops, an "Event Based Approval Mechanism" was adopted with respect to Bt cotton hybrids expressing approved events in India's Genetic Engineering Approval Committee meeting held on 2nd April 2008.

In 2009, the Ministry of Environment and Forest (MoEF) notified clients of a new procedure for commercial release of Bt cotton hybrids expressing approved events called "Event Based Approval Mechanism (EBAM)." This mechanism will be applicable to new cotton hybrids expressing four approved events including MON531 (*cry1Ac* gene) and MON15985 (*cry1Ac* and *cry2Ab* genes) of Mahyco-Monsanto, Event-1 (*cry1Ac* gene) of JK Agri-Genetics and GFM Event (*cry 1 Ab + cry Ac* genes) of Nath Seeds.

The approval mechanism which is initially applicable to approved cotton events will speed up the introduction of new GM crops to the country without compromising biosafety and environmental safety. In 2009, 248 new Bt cotton hybrids expressing four events were approved under the new event based approval mechanism.

More information about the "New Procedure for Commercial Release of Bt Cotton Hybrids Expressing Approved Events" is available at: http://www.envfor.nic.in/divisions/csurv/geac/New%20procedure%20under%20EABM.pdf

8). India boosts R&D of GM vegetables

India has been making R&D progress on the development of genetically modified (GM) vegetables and is likely to release GM vegetables in the next three years for commercial production. The Minister of State for Agriculture, Consumer Affairs, Food and Public Distribution, Prof. K.V. Thomas informed the Lok Sabha, the lower house of the Parliament of India, that the production of GM vegetables has not yet been commercialized in the country but research and development work is in progress.

In recent years, India experienced a tremendous success with doubling cotton production after the commercialization of Bt cotton hybrids in 2002. India retained its ranking as the fourth largest adopter of biotech crops in the world in 2009 with Bt cotton hybrids occupying 8.4 million hectares equivalent to 87% of the total cotton area in 2009. A record 5.6 million small and resource-poor farmers planted Bt cotton in 2009. India Bt cotton increased its Bt cotton area 168-fold in the eight year period 2002 to 2009. Considering the short period of eight years for Bt cotton in India with the corresponding global increase in adoption of 79-fold over a longer period of 14 years, 1996 to 2009, the adoption rate in India is approximately four times as fast as the global increase.

The Indian Council of Agricultural Research (ICAR) and Department of Biotechnology (DBT) approved several projects for developing GM varieties in tomato, brinjal and cauliflower. The transgenic lines are in various stages of development at different institutes and will be released for cultivation after clearance by the Review Committee on Genetic Manipulation (RCGM) and Genetic Engineering Approval Committee (GEAC). He also informed the house that the target for the next three years has been fixed primarily to release and popularize the GM varieties in some of the major vegetable crops.

More information on "Research on genetically modified vegetables in progress" is available at Lok Sabha, the Parliament of India at: http://pib.nic.in/release/release.asp?relid=50364

9). Food Safety and Standard Authority begins operation

The Food Safety and Standards Authority of India (FSSAI) was established as a statutory body under the Food Safety and Standards Act, 2006 began operations in 2009. The FSSAI was set up as a specialized regulatory agency for laying down science based standards for items of food and regulating manufacturing, processing, distribution, sale and import of food so as to ensure safe and wholesome food for human consumption.

From 2009, all the laws and official orders relating to whole food and processed food will fall under the ambit of the Food Safety and Standards Authority of India. These include Vegetables Oil Products (Control) Order, 1998; Edible Oils Packaging (Regulation) Order, 1998; the Solvent Extracted Oil, Deoiled Meal and Edible Flour (Control) Order, 1967; Prevention of Food Adulteration Act, 1954 (PFA); Fruit Products Order, 1955 (FPO); Meat Food Products Order, 1973 (MFPO) and Milk and Milk Product Order, 1992 (MMPO).

In 2009, the Food Safety and Standards Authority of India constituted a scientific committee and established scientific panels for providing scientific opinions to the Food Authority. These scientific panels include; the scientific panel on functional foods, nutraceuticals, dietetic products and other similar products; scientific panel on method of sampling and analysis; scientific panel on food additives, flavourings, processing aids and materials in contact with food; scientific panel on contaminants in the food chain; scientific panel on biological hazards; scientific panel on pesticides and antibiotic residues; scientific panel on labelling and claims/advertisements and the scientific panel on genetically modified organisms and foods.

For detailed information about the various provisions governing food article please refer to the Food Safety and Standard Authority (FSSA) available at: http://www.fssai.gov.in/

Benefits from Bt Cotton in India

The global study of benefits generated by biotech crops conducted by Brookes and Barfoot (2009, forthcoming), estimates that India enhanced farm income from Bt cotton by US$5.1 billion in the period 2002 to 2008 and US$1.8 billion in 2008 alone.

A sample of eleven economic studies on the impact of Bt cotton, all conducted by public sector institutes over the period 1998 to 2009, covering both pre and post-commercialization of Bt cotton are referenced chronologically in Table 29. The first three studies were based on two sets of data to estimate the overall economic advantage of cotton including a field trial data set for 1998/99 to 2000/01 from the Department of Biotechnology analyzed by Naik (2001) and the second set was an ICAR field trial data set for 2001-2002 analyzed and published by ICAR (2002) and Qaim (2006). The other eight studies/surveys were conducted on large numbers of Bt cotton farmers' fields between 2002 to 2007, by different public sector institutions listed in Table 20. The studies have consistently confirmed 50 to 110% increase in profits from Bt cotton, equivalent to a range of US$76 to US$250 per hectare. These profits have accrued to small and resource-poor cotton farmers in the various cotton growing states of India. The yield increases ranged usually from 30 to 60% and the reduction in number of insecticide sprays averaged around 50%. It is noteworthy that the benefits recorded in pre-commercialization field trials are consistent with the actual experience of farmers commercializing Bt cotton during the eight year period 2002 to 2009.

Pre-commercialization Bt cotton data analysed by Naik (2001) indicated that the overall economic advantage of Bt cotton in 1998/99 ranged from US$76 to US$236 per hectare, equivalent to an average 77% gain, compared with conventional cotton. Naik reported a 38% yield increase and 75% reduction in numbers of insecticides spray on Bt cotton over non-Bt counterparts.

The ICAR (2002) data set from large scale field trials in 2001 reported that the economic advantages for three Bt cotton hybrids (MECH-12, MECH-162 and MECH-184) tested under the All India Coordinated Cotton Improvement Project (AICCIP) from 1998/99 to 2000/01 was relatively high due to severe pest infestations confirming efficacy of Bt technology for targeted insect pests. The overall economic advantages of the three Bt hybrids ranged from US$96 to US$210 per hectare – a 29% to 86% increase compared to conventional cotton. Qaim (2006) analyzed multi-location field trials data generated by Mahyco and showed similar economic benefits – a 50% reduction in number of sprays, 34% yield increase resulting in a net profit of US$118 per hectare. The magnitude of the economic advantages reported by Qaim 2006 was of the same order of magnitude as the 1998/99 data set analyzed by Naik (2001), and ICAR field trials data (2002). These pre-commercialization studies confirmed that Bt cotton resulted in a major economic advantage to cotton farmers by substantially increasing yield, reducing insecticide sprays and reduction in labour costs.

The first on-farm study by Bennett et al. (2006) confirmed that the principal gain from Bt cotton in India was the significant yield gains estimated at 45% in 2002, and 63% in 2001, for an average of 54% over the two years. Taking into account the decrease in application of insecticides for bollworm control, which translates into a saving of 2.5 sprays, and the increased cost of Bt cotton seed, Brookes and Barfoot (2008) estimated that the net economic benefits for Bt cotton farmers in India were US$139 per hectare in 2002, US$324 per hectare in 2003, US$171 per hectare in 2004, and US$260

Table 29. Eleven Studies Conducted by Public Institutes on the Benefits of Bt Cotton in India for the Years, 1998 to 2009

Publication	[1]Naik 2001	[2]ICAR field trials 2002	[3]Qaim 2006	[4]Bennet 2006	[5]IIMA 2006	[6]ICAR FLD 2006	[7]Andhra University 2006	[8]CESS 2007	[9]Subramanian & Qaim 2009	[10]Sadashivappa & Qaim 2009	[11]Qaim *et. al* 2009
Period studied	1998-99 & 00-01	2001	2001-2002	2002 & 2003	2004	2005	2006	2004-05	2004-05	2006-07	1998-06
Yield increase	38%	60-90%	34%	45-63%	31%	30.9%	46%	32%	30-40%	43%	37%
Reduction in no. of spray	4 to 1 (75%)	5-6 to 1 spray (70%)	6.8 to 4.2 (50%)	3 to 1	39%	–	55%	25%	50%	21%	41%
Increased profit	77%	68%	69%	50% or more gross margins	88%	–	110%	83%	–	70%	89%
Average increase in profit/hectare	$76 to $236/ hectare	$96 to $210/ hectare	$118/ hectare	–	$250/ hectare	–	$223/ hectare	$225/ hectare	$156/ hectare or more	$148 /hectare or more	$131/ hectare or more

Sources:

1. Naik G. 2001. "An analysis of socio-economic impact of Bt technology on Indian cotton farmers," Centre for Management in Agriculture, IIMA, India.
2. Indian Council for Agricultural Research (ICAR), 2002. "Report on 2001 IPM trial cost benefit analysis," ICAR, New Delhi, India.
3. Qaim M. 2006. "Adoption of Bt cotton and impact variability: Insights from India", Review of Agricultural Economics. 28: 48-58.
4. Bennett R. et al. 2006. "Farm-level economic performance of genetically modified cotton in Maharastra, India," Review of Agricultural Economics, 28: 59-71.
5. Gandhi V and Namboodiri, NV. 2006. "The adoption and economics of Bt cotton in India: Preliminary results from a study", IIM Ahmedabad working paper no. 2006-09-04, pp 1-27. Sept 2006.
6. Front line demonstrations on cotton 2005-06. Mini Mission II, Technology Mission on Cotton, Indian Council for Agricultural Research (ICAR), New Delhi, India.
7. Ramgopal N. 2006. Economics of Bt cotton vis-à-vis Traditional cotton varieties (Study in Andhra Pradesh)," Agro-Economic Research Center, Andhra University, A.P.
8. Dev SM and NC Rao. 2007. "Socio-economic impact of Bt cotton", CESS Monographs, Centre for Economic and Social Studies (CESS), Hyderabad, A.P.
9. Subramanian A and M Qaim. 2009. Village-wide Effects of Agricultural Biotechnology: The Case of Bt Cotton in India, World Development. 37 (1): 256–267.
10. Sadashivappa P and M Qaim. 2009. Bt Cotton in India: Development of Benefits and the Role of Government Seed Price Interventions, AgBioForum. 12(2): 1-12.
11. Qaim M, A Subramanian and P Sadashivappa. 2009. Commercialized GM crops and yield, Correspondence, Nature Biotechnology. 27 (9) (Sept 2009).

per hectare in 2005, for a four year average of approximately US$225 per hectare. The benefits at the farmer level translated to a national gain of US$2.0 billion in 2007 and accumulatively US$3.2 billion for the period 2002 to 2007. Other studies reported a similar range of benefits, acknowledging that benefits will vary from year to year due to varying levels of bollworm infestations. The study by Gandhi and Namboodiri (2006), reported a yield gain of 31%, a significant reduction in the number of pesticide sprays by 39%, and an 88% increase in profit or an increase of US$250 per hectare for the 2004 cotton growing season.

A Front Line Demonstration (FLD) study on cotton for 2005-06 released by the Indian Council of Agricultural Research (ICAR, 2006) reconfirms a net 30.9% increase in seed yield of Bt cotton hybrids over non-Bt hybrids and a 66.3% increase over open-pollinated cotton varieties (OPV). Data in the study covered 1,200 demonstration and farmers' plots in 11 cotton-growing states in India. In the demonstration plots, the Bt cotton hybrids proved to be highly productive with an average yield of 2,329 kg/ha of seed cotton compared to the non-Bt cotton hybrids (1,742 kg/ha) and varieties (1,340 kg/ha). Similarly, the average yield of Bt cotton hybrids was higher in farmers' plots at 1,783 kg/ha compared to non-Bt cotton hybrids (1,362 kg/ha) and OPV in farmers' field (1,072 kg/ha).

A study in 2005 by University of Andhra (2006) concluded that Bt cotton farmers earned three times more than non-Bt cotton farmers in Guntur district and eight times more in Warangal district of Andhra Pradesh, India. The Government of Andhra Pradesh commissioned the study three years ago to examine the advantages, disadvantages, cost of cultivation and net return to Bt cotton as compared to other cotton varieties in selected districts. The study confirmed that the average Bt farmer had a 46% higher yield and applied 55% less pesticides than the non-Bt cotton farmer in Guntur district. Bt cotton farmers in Warangal district applied 16% less pesticides and reaped 47% more cotton as compared to non-Bt farmers. Farmers noted that Bt cotton allowed earlier picking due to less pest susceptibility, and the boll color was superior.

A 2007 study "Socioeconomic impact of Bt cotton", conducted by the Centre for Economic and Social Studies (CESS), Hyderabad concluded that the Bt cotton technology was superior to the conventional cotton hybrids in terms of yield and net returns. The study was carried out in four districts; Warangal, Nalgonda, Guntur and Kurnool in Andhra Pradesh representing the four agro-climatic zones in 2004-2005 and 2005-2006 and sponsored by the Andhra Pradesh Netherlands Biotechnology Programme (APNBP) now known as Agri Biotechnology Foundation – a part of Seventh Framework Programme of the European Union. Whereas the absolute cost of production for Bt cotton was 17% higher, the study reported that the expenditures on insecticides decreased by 18% (from 12 sprays on non-Bt cotton to 9 sprays) yield increased by 32% resulting in the overall cost of cotton per quintal decreasing by 11%. Thus, as a result of higher yield and reduced pesticide sprays, Bt cotton farmers improved their net income by 83% over non-Bt cotton. The study confirmed that Bt cotton generated 21% higher labour employment than non-Bt cotton of which female laborers were the major beneficiaries among casual laborers. The study concluded that small farmers elected to plant Bt cotton, rather than conventional because it was more profitable and allowed them and their families to enjoy improved living standards.

A recent paper "Village-wide effects of agricultural biotechnology: The case of Bt cotton in India", featured a case study by Subramanian et al. (2009). The study analyzed the economy-wide effects of Bt cotton for rural households in semi-arid India. The study showed that Bt cotton technology increased yield between 30-40% and reduced insecticide quantities by about 50% on average, thus generating an additional income of US$156 per hectare or more. More specifically, Bt cotton was associated with a substantial overall generation of rural employment with important gender implications. They concluded by noting that Bt technology generated more employment for females than males, ***"The aggregation of total wage income showed that females earned much more from Bt cotton than males. This was due to the fact that cotton harvesting is largely carried out by hired female laborers, whose employment opportunities and returns to labor improve remarkably. Pest control, on the other hand, is often the responsibility of male family members, so that Bt technology reduced their employment in cotton production. On average, the saved family labor could be reemployed efficiently in alternative agricultural and non-agricultural activities, so that the overall returns to labor increased, including for males."*** Similarly, studies published by Sadashivappa et. al. (2009) (which analyzed Bt technology performance over the first five years of adoption, using panel data with three rounds of observations) concluded that on average, Bt adopting farmers realized pesticide reductions of roughly 40%, and yield advantages of 30-40% resulting in a higher net profit of 70% or US$148 per hectare, or more.

Moreover, the recent studies by Qaim et al. (2009) analyzed the socio-economic effects of Bt cotton in India and demonstrated spillover effects of Bt cotton benefits for rural households in semi-arid states – Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu. The pre and post commercialization farm surveys conducted by Qaim et al, revealed that farmers adopting Bt cotton used 41% less pesticides and obtained 37% higher yields, resulting in an 89% or US$135 per hectare gain in cotton profits. In spite of seasonal and regional variation, these advantages have been sustainable over time. These direct benefits of Bt cotton technology have also been reported by other farm surveys conducted by public sector institutions during the period 1998 to 2006. For the first time in a systematic survey, Qaim et al. (2009), demonstrated the indirect benefits of Bt technology in India. For instance, higher cotton yields provided more employment opportunities for agricultural laborers and a boost to rural transport and trading businesses. Income gains among farmers and farm workers resulted in more demand for food and non-food items, inducing growth and household income increases in other sectors locally. Their research noted that each dollar of direct benefits was associated with over US$0.80 cents of additional indirect benefits in the local economy. In terms of income distribution, all types of households benefited, including those below the poverty line. Sixty percent of the gains accrued to the extremely and moderately poor. Bt cotton also generated increased net employment, with important gender implications. Compared to conventional cotton, Bt increased aggregated returns to labor by 42%, whereas the returns for hired female agricultural workers increased by 55%. This is largely due to additional labor employed for picking cotton, which is primarily a female activity in India. As is known, women's income has a particularly positive effect for child nutrition and welfare. These studies concluded that ***"In this case, at least, there is strong evidence that the trait in this crop is already contributing to poverty reduction in the subcontinent."***

The only published impact studies of Bt cotton in 2008/09 was conducted by IMRB International (IMRB, 2009) which focused on the agronomic and economic benefits. The only published study specifically on the social impact of Bt cotton was conducted by Indicus Analytics in 2007 (Indicus, 2007).

The IMRB study "Samiksha-09" sampled 4863 farmers selected from 400 villages from 27 districts in six States and interviewed 4,860 farmers representing both BG-I®, BG-II® and non-Bt cotton farmers based on 2008 cotton cultivation. The IMRB study compared the economic benefits of BG-I® and BG-II® cotton hybrids versus non-Bt cotton hybrids. The study reported a 38% incremental yield for BG-I® hybrids and 46% incremental yield with BG-II® cotton hybrids over conventional cotton hybrids in 2008. Similarly, the study reported higher saving on the cost of pesticide sprays of Rs. 1,635 per hectare (US$36) for BG-II® hybrids and Rs. 909 (US$20) for BG-I® cotton hybrids over conventional cotton. As a result, BG-II® cotton farmers earned Rs. 23,374 per hectare (US$520) and Rs. 17,082 (US$378) for BG-I® cotton farmers over conventional cotton farmers. It is noteworthy that on average BG-II® cotton farmers earned an additional net income of Rs. 6,292 (US$140) over BG-I® cotton farmers. This is consistent with the trend for farmers to increasingly adopt BG-II® cotton hybrids over BG-I® cotton hybrids in 2008 and 2009 and it is expected that BG-II® cotton hybrids will replace BG-I® cotton hybrids in the near term. On a cost benefit analysis, the study showed that BG-II® cotton hybrids offered 194% return on investment compared with 158% for BG-I® cotton hybrids and only 93% for non-Bt cotton hybrids. The study also revealed that 90% and 91% of BG-I® and BG-II® cotton farmers, respectively, were satisfied with the performance of Bt cotton technology cutting irrespective of whether they were large, medium, or small and marginal farmers. The IMRB estimates for the 2008 season were higher than estimates for the previous years (2002 to 2007) due to higher prices of cotton, the higher value of the Indian Rupee versus the US dollar. The IMRB study estimated that in 2008 Bt cotton technology helped farmers to increase cotton production nationally by 72 million quintals of seed cotton (42 million bales of lint), reduced pesticide usages by Rs. 1,813 crore (US$403 million) and earned additional income of Rs. 16,215 crore (US$3.6 billion).

The latest parallel study to the IMRB studies, conducted by Indicus Analytics (Indicus, 2007) focused on Bt cotton in India in 2006 – it was the first study to focus entirely on the social impact as opposed to the economic impact. The study involved 9,300 households growing Bt cotton and non-Bt cotton in 465 villages. The study reported that villages growing Bt cotton had more social benefits than villages growing non-Bt cotton. More specifically, compared with non-Bt cotton villages, Bt cotton villages had more access to permanent markets (44% versus 35%), and banking facilities (34% versus 28%). Bt cotton farmers also benefit more from visits of government and private sector extension workers and are more likely to adopt recommended practices such as improved rotation, and change in the use of the first generation Bt cotton hybrids for improved second generation Bt cotton hybrids. Notably, there was also a consistent difference between Bt cotton households and non-Bt cotton households in terms of access and utilization of various services. More specifically compared with non-Bt cotton household, women in Bt cotton households had a higher usage of antenatal check ups, more and higher use of professionals to assist with births at home. Similarly, children from Bt cotton households had a higher proportion, which had benefitted from vaccination (67% versus 62%) and they were more likely to be enrolled in school. It is noteworthy that the socio-economic advantages enjoyed by Bt cotton households are already evident despite the fact that the first Bt cotton was only adopted in 2002. Thus, the economic benefits associated with Bt cotton is already starting to have a welfare impact that provides a better quality of life for Bt cotton farmers and their families in India.

The 2008 ISAAA Report (James, 2008) projected that the adoption rate of Bt cotton in India in 2009 would reach more than 80%, whereas the actual level in 2009 was 87%. Given the significant and multiple agronomic, economic and welfare benefits that farmers derive from Bt cotton in India, the adoption of approved Bt cotton hybrids and varieties in India is expected to continue to increase modestly in 2010 since the current level of adoption at 87% is close to optimal. Despite the unprecedented high adoption of Bt cotton by 5.6 million farmers, the majority of whom have first-hand experience of up to eight years of the significant benefits it offers, and the consistent high performance of Bt cotton compared with conventional, anti-biotech groups still continue to vigorously campaign against biotech in India, using all means to try and discredit the technology, including filing public interest writ petitions in the Supreme Court contesting the biosafety of biotech products.

Political Support for Biotech Crops in India

There is strong and growing political support for Bt cotton in India and in turn for other biotech crops. This is due to the remarkable progress that has been achieved in a relatively short period of eight years, with yields doubling and multiple material and welfare benefits evident to farmers, the textile industry, exports, and at the national level. This progress has been recognized by leading politicians and policy makers who have become advocates of biotechnology because of the multiple benefits it offers. A sample of the public statements of leading Indian politicians follows.

The Prime Minister of India Dr. Manmohan Singh. While inaugurating the 97th Indian Science Congress in Thiruvanthapuran, Kerala on 3 January, 2010,

Dr. Manmohan Singh, the Prime Minister of India lauded the resounding success of Bt cotton in India and emphasized the need for developments in biotechnology for greatly improving the yield of major crops in India. His speech was of particular significance because the congress is the apex body for science and technology in India and has focused on "Science and Technology Challenges of 21st Century-National Perspective". He said ***"Developments in biotechnology present us the prospect of greatly improving yields in our major crops by increasing resistance to pests and also to moisture stress. Bt Cotton has been well accepted in the country and has made a great difference to the production of cotton. The technology of genetic modification is also being extended to food crops though this raises legitimate questions of safety. These must be given full weightage, with appropriate regulatory control based on strictly scientific criteria. Subject to these caveats, we should pursue all possible leads that biotechnology provides that might increase our food security as we go through climate related stress"*** (Singh, 2010).

Prof. M. S. Swaminathan, Member of Parliament, Rajya Sabha (Upper House), the Parliament of India and Chairman, MSSRF

Prof. M. S. Swaminathan in his article "GM: Food for Thought" published in the Asian Age, Delhi, 26th August 2009:

"The world population has crossed six billion and is predicted to double in the next 50 years. Ensuring an adequate food supply for this booming population is a major challenge in the years to come. GM foods promise to meet this need in a number of ways..... GM foods have the potential to solve many of the world's hunger and malnutrition problems, and to help protect and preserve the environment by increasing yield and reducing reliance upon chemical pesticides" (Swaminathan, 2009).

Mr. Sharad Pawar, the Minister of Agriculture and Consumer Affairs

Opening Remarks by Agriculture Minister Mr. Sharad Pawar at Economic Editor's Conference on 4th Nov 2009 at New Delhi:

"Agricultural Research & Education has also played a crucial role in the growth of the agriculture and allied sectors. Major achievements include development of 96 varieties/hybrids of crops including a Bt gene containing cotton variety Bikaneri Narma. Department of Agriculture Research and Education has also developed cost effective amelioration technologies for waterlogged, salt affected and acid soils. In order to address the issues of impact of climate change on agriculture, a National Institute of Abiotic Stress Management has been established" (Pawar, 2009).

Presentation at the National Seminar on "Seed and Crop Technologies for Doubling Agricultural Production", organized by the National Seed Association of India (NSAI) from 8-9 August, 2008, New Delhi:

"With limited natural resources available to improve agricultural production, genetically engineered crops developed by applying biotechnological tools, are being looked upon as a promising alternative which can benefit farmers, manufacturers as well as consumers" (Pawar, 2008a).

Mr. Prithviraj Chavan, the Union Minister of Science & Technology and Earth Sciences

In an exclusive interview with BiotechNews, an official news portal of the Department of Biotechnology (DBT), India's Union Minister of Science & Technology Mr. Prithviraj Chavan describes Bt brinjal a safe breakthrough. DBT's BiotechNews features a cover story on "Bt brinjal: A Pioneering Push" in the Dec 2009 issue.

"I am sure that development of Bt brinjal, the first biotech vegetable crop, is appropriate and timely. I understand that it has been tested rigorously over the last nine years and has been found substantially equivalent to its non-Bt counterparts, except for an additional gene-cry1Ac which expresses Cry protein effective only against very specific target insect, in this case Fruit and Shoot Borer (FSB). GEAC has evaluated Bt brinjal for its efficacy and safety as per the protocols and procedures prescribed under the Ministry of Environment and Forest's Environment Protection Act 1986 and Rules 1989 as well as DBT's own biosafety norms."

Highlighting the rigorous testing that has preceded the GEAC nod to Bt brinjal Mr. Chavan says ***"All these studies have concluded that Bt brinjal causes no adverse effects when consumed by humans, animals, non-target organisms and beneficial insects. In fact, Bt protein was not even detectable in cooked brinjal fruit."*** Finally, lauding the role of Bt technology in agriculture, he said ***"The main advantage of this technology is that it reduces the use of chemical pest control making the technology safe for the environment as well as human consumption".***

Minister of State for Environment and Forests Mr Jairam Ramesh - Replying to a question "Introduction of Bt brinjal" in the Rajya Sabha (Upper House) of the Parliament of India on 23 Nov 2009, he stated that ***"The cumulative results of more than 50 field trials conducted to assess the safety, efficacy and agronomic performance of Bt brinjal demonstrate that Cry1Ac protein in Bt brinjal provides effective protection from the Fruit and Shoot Borer, a major pest in brinjal crop; resulting in enhanced economic benefits to the farmers and traders accrued from higher marketable yield and lower usage of pesticide sprays"*** (Ramesh, 2009).

India's Minister of State for Agriculture Mr. K V Thomas while delivering concluding remarks during the Multi-stakeholder Workshop "Ensuring food security and agricultural sustainability through advances in agri-biotechnology" organized by TERI University held on 13th Nov 2009, New Delhi:

"The GM technology cannot be avoided," Minister of State for Agriculture Mr. K V Thomas said, adding India cannot oppose the use of technology if it wants to increase yields and manage the present agricultural crisis. ***"The country needs to take scientific and practical steps to improve productivity and bring down cost of production. The GM technology is one way to achieve this",*** he noted (Thomas, 2009).

Dr. P. Chidambaram, the Former Minister of Finance

Former Finance Minister P. Chidambaram has called for emulation of the cotton production success story, through the use of genetically modified Bt cotton, in the area of food crops to make the country self sufficient in its food needs. ***"It is important to apply biotechnology in agriculture. What has been done with Bt cotton must be done with food grains,"*** Chidambaram said at the opening of the seventh edition of Bangalore's annual biotechnology event Bio-2007 on 7-9 June 2007 at Bangalore (Chidambaram, 2007).

Concerns over the safety of genetically modified products ***"must be faced at an intellectual level by scientists. It cannot be brushed aside by emotion and political arguments," he said. While the biotechnology sector is growing in India fuelled by the growth of the bio-pharma and bio-services sectors, the real need is for the growth of agri-biotech,"*** Chidambaram said referring to the stagnant production of rice and wheat.

"Bt cotton has made India a cotton exporting country. We thought of ourselves as exporters of wheat and rice, but today we import wheat. No country as large as India can survive on imports for its food needs," the Finance Minister pointed out. ***The production figures for rice and wheat are far below the world average and yield gaps vary dramatically across different states,"*** he said. ***"The success achieved in cotton must be used to make the country self sufficient in rice, wheat, pulse and oil seed production."***

Farmer Experience

In 2009, 5.6 million farmers planted Bt cotton over 8.4 million hectares in India. Majority of these farmers are small, marginal and resource poor. Their livelihood depends on success and failure of cotton crop. In this section, we have summarized experiences of many farmers from different cotton growing states particularly women farmers who have been planting Bt cotton hybrids for the last couple of years and have recently switched to double-gene based Bt cotton hybrids. Experiences of these farmers have been captured as follow:

Experiences of three Bt cotton farmers including two women farmers from Maharashtra:

Mrs. Mirabai Bhaskarrao Gorde grows Bt cotton on 7 acres of her farm land and lives with her family in Village Hatola, Taluka-Darvha of Yavatmal District in Maharashtra State.

"During the last four years, I have been planting Bt cotton in our field and thanks to it, we have got good results in yield. This has helped to improve our financial stability. From the income earned from cultivating Bt cotton on my seven acres, we could set up an irrigation facility including installing a motor pump to irrigate our land. Since the last two years we have been planting advanced Bt cotton (BG-II®) hybrid seeds which gave us around 3-4 more quintals per acre. This extra income and savings due to reduced pesticide sprays helped me to support the family income allowing us to start a grain flour mill and purchase a minidor vehicle for my eldest son which has enabled him to settle down in life. All this – higher yield, more savings has been possible only because of advanced Bt cotton hybrid and has helped us significantly to improve our lives."

Mrs. Radhabai Gyandeo Thomre is a marginal farmer having 5 acres of land which is primarily rain-fed and lives with her family in Village-Pimpalgaon Pandhari, Aurangabad district of Maharashtra.

"Since last two years, I have been planting BG-II® Bt cotton hybrids on my 5 acres land. This new Bt cotton offers effective protection against all bollworms and particularly pink bollworm and Spodoptera which helps us a great deal. Effective control of pink bollworm has helped us to lead better quality life. It has also made picking easy and harvesting much simpler and faster. More yield of 2-3 quintals per acre over old Bt cotton hybrids and hence, a better and higher price for my produce that has helped me earn higher profits.

New Bt cotton hybrids has improved my socio-economic condition as now I am able to send my daughter to a school. My sons have been enrolled for higher education in Aurangabad City. And we have also installed a new pipeline for our fields. I would suggest all my farmer friends to use Bt technology as it has not only improved the lives of my family members, but has also revolutionized the socio economic condition of the entire village. In my village itself, many people have built concrete houses, purchased two wheelers among other luxuries."

Mr. Bhaskar Daulat Kale grows Bt cotton on his 6 acres farm land and lives happily in his Village Mera Khurd, District Buldana of Maharashtra.

"My name is Bhaskar Daulat Kale resident of Mera Khurd. I am a born farmer with 6 acres of land which is now irrigated by virtue of Bt cotton. I used to plant a crop of cotton & soy-bean. In 2008, I had sown 3 acres of Bt cotton in my field and I am pleased to share that I had got 14 quintals per acre, for 42 quintals in total. The quality of cotton was extremely good and sold my cotton crop at a highest market rate of Rs. 2800 per quintal, thus earning Rs. 117,600 from my 3 acre Bt cotton plots. This has helped me to install lift irrigation in my field and used balance money for the wedding of my relatives. This year, I have again sown Surpass Bt Cotton Dhanno BG-II® hybrids under irrigation in my field. The condition of crop is extremely good and I have used all crop protection measures on my cotton crop. I am expecting more yield this year than last year. I am extremely thankful to the Bt cotton which helped me in enhancing my financial & social status. Now my confidence level has increased in cotton cultivation. I am very thankful to Bt cotton particularly in improving my social status."

Experience of a Bt cotton woman farmer from Madhya Pradesh

Woman farmer **Mrs. Geetabai Kherde** cultivates Bt cotton hybrids and lives with her family in Pandhana Village, Khandwa District of Madhya Pradesh.

"I have been cultivating Bt cotton since 2004 and I have been getting excellent cotton yield. With the higher income earned with Bt cotton, I was able to enrol my children in better schools, build a pucca home, and marry off my daughter and son. Then in 2007, I got to know of BG-II® Bt cotton hybrids and started using it. With it, I got higher yields as compared to conventional Bt cotton hybrids. With the higher additional income earned, I used it to purchase many necessities for my home. Additionally, I also invested in a well and installed a pipeline. After using advanced Bt cotton hybrids, I did not have to use a single pesticide spray to take care of pests. I suggested all fellow farmers to cultivate cotton using only BG-II® Bt cotton seeds to get higher yields, more savings due to reduced pesticide sprays and higher income."

Experience of two Bt cotton women farmers from Andhra Pradesh

Woman farmer **Mrs. Duggirala Koteswaramma** is the group leader of Development for Women and Children in Rural Areas (DWCRA) Self-Employment group in the Village-Kolagatla, Durgi Mandal of Guntur District, Andhra Pradesh.

"We have been cultivating cotton for the last 25 years and have been cultivating Bt cotton for many years now. This year we cultivated 10 acres with BG-II® Bt cotton. During the non-Bt hybrid days, the yields were very poor and input costs were very high. But with the

introduction of Bt cotton, the insecticides cost has gone down tremendously and yields are very high. Bt cotton delivers encouraging and consistent results. With the benefits from Bt cotton cultivation, I could send my children to good school and purchase a motor bike for my son. I am proud to share that my son is now studying B.Tech."

Mrs. Aakkapalli Ramadevi, is a woman cotton farmer from Thimmampeta Village, Duggondi Mandal of Warangal District, Andhra Pradesh, India. She is a typical small and resource-poor farmer who owns only 3 acres of land (1.3 hectares) in her village. Prior to the introduction of Bt cotton she said that:

"My entire family had to stay in the farm and we had to spend 50% of the yield on pesticides alone. The yields were very low and used to incur losses, so we were perpetually losing money. Our family suffered a great deal and I had to go for labor work. My children also worked in the farm. We always looked forward to the rice distributed by government public distribution system. To sum it up, we were very badly off and not able to afford anything properly. Initially, I used to hate Bt cotton because there were NGOs who protested very loudly against Bt cotton. NGOs were pulling out any trials planted in the farms. Despite the protest, the good effects of the technology were very visible and I noticed it. I decided to experiment with it since I observed that it was able to control pests and reduce spraying considerably. I could also see the benefits being reaped by fellow farmers and the profits that were coming with the usage of Bt cotton. I somehow managed to convince my husband and told him that it was worth a try. Due to financial reasons I couldn't get into agriculture but in 2005-06, I got into it with determination and planted Bt cotton in three acres. First and foremost, our yield increased drastically. We got a profit of Rupees 10,000-15,000 per acre. The work in the farm decreased a lot bringing comfort. Because I also work as a daily wage-worker for 10-12 days in a month, I am able to also earn additional Rs. 500-600 per month. Now I am able to send my boy to school and actually spend some additional money on his new education per year. Finally, cotton cultivation has actually turned profitable."

Experience of a Bt cotton women farmer from Karnataka

Mrs. Chandamma Biradar is a Bt cotton farmer from Tokapur Village, Shahpur Taluka in Gulbarga District of Karnataka.

"I have been growing cotton from the past 6-7 years. In the past, we were spraying a lot of insecticides to avoid the losses due to insect bollworms. Later when Bt technology was introduced in cotton hybrids and I started using Bt cotton hybrids. When we observed a higher attack of spodoptera pests, I have been advised to switch over to advanced Bt cotton

hybrids. Thereafter, we have been living a good life. Since the past 2 years, I have realized good profits with BG-II® Bt cotton hybrids by virtue of which I could construct our new house & marry off my children. I feel Bt cotton technology has saved lives of many poor cotton farmers. So I hope we will have many more hybrids with Bt technology and also new technologies in other crops too."

Experience of two Bt cotton farmers from Punjab

Mr. Balkaran Singh is a Bt cotton farmer from Gagrana village, Mansa district of Punjab.

"I have 10 acres on which I cultivate Bt cotton. As a result of the higher yields, more savings from reduced pesticide sprays and earnings I have renovated my home. I have resumed my studies and also support the education of my younger brother in Chandigarh at Rs. 10,000 per month. I have also bought an Enfield Bullet motorcycle of which I proudly correct those around me, "Its not a motorcycle. It's a Bullet!" For the last few years, I have been getting higher yields of 14 quintals per acre from BG-II® Bt cotton seeds vs. only 7 quintals per acre with conventional seeds, which have helped me earn a higher income of Rs. 35,000 per acre. In addition, I also save Rs. 5000 per acre on pesticide using less insecticide to fight the cotton bollworm."

Mr. Gulab Singh is a cotton farmer and a village *'Sarpanch* a local people representative of Gurusar Jodha village of Muktsar district, Punjab.

"I have a total of 15 acres of land, where 12 acres is under BG®II cotton and 3 acres under BG®I cotton hybrids. BG®II cotton hybrids gave me incremental yield of 1.5 quintals per acre as compared to BG®I cotton hybrids. With BG®I, I went for 2 sprays to control Spodoptera pest, while in BG®II, I did not use a single spray for Spodoptera. I also earned an incremental income of Rs. 4,200 per acre in BG®II cotton and an additional Rs. 1,400 per acre reduction in cost of sprays. Thereby, I earned higher income of Rs. 5,600 per acre due to adoption of BG®II cotton hybrids. Punjab farmers are thankful to Bt cotton technology that helped us to increase yields, reduced pesticides and earned higher incomcle. Pre-Bt cotton days, we used to spray 18-20 sprays for control of bollworm. This resulted in an expenditure of Rs. 8,000-10,000 per acre. We used to incur loss from cotton crop. Now with Bt cotton, we are earning more income and as a result I bought a new Farmtrac Tractor recently" (Singh, 2008).

Experience of a Bt cotton woman farmer from Tamil Nadu

Woman farmer **Mrs. D. Susila** lives with her family in Sokkanathapuram Village of Perambalur District in Tamil Nadu.

"In 2009, I cultivated Bt cotton in one acre and BG-II® Bt cotton hybrids in another acre. I spent up to Rs. 1,800 per acre to control pest in Bt cotton field, and this amount was saved with BG-II® seeds as it was able to effectively address the pest attack. Moreover, I also got higher yield with BG-II® Bt cotton of 10 quintals per acre as compared earlier. The higher profits earned due to Bt cotton cultivation has helped me to set up my son's business, Susi Offset Printers. Today, I am living a better life and my family is happy and content."

Experiences of two cotton farmers from Gujarat:

Mr. Baldev Patel cultivates Bt cotton on his 4 acres farm located at Kurali village, Vadodara District of Gujarat.

"I have four acres on which I cultivate Bollgard Bt cotton. I feel proud in having built a new pucca home worth Rs. 3.5 lakh for my family and have also taken 8 acres of land on lease. I have sent my daughter to Mount Abu Convent for better education with annual fees of Rs. 50,000 and investing in life insurance policies for my family. I have reaped higher yields of 15 quintals per acre with BG-II® Bt cotton hybrids as against only 7 quintals per acre with conventional seeds. As a result, I earn higher income of Rs. 27,500 per acre and savings on pesticides of Rs. 4,000 per acre, thus enabling my family to lead a better life."

Mr. Yogeshbhai Chimanbhai Patel cultivates cotton in his farm located at Dhawat village, Karjan Taluka of Vadodara district, Gujarat.

"I have been growing cotton for the past few years but it was only after the introduction of Bt cotton that my yields have doubled. I used to harvest 6-7 quintals per acre which was almost doubled to 11-12 quintals per acre after I planted Bt cotton hybrids from 2002 onwards. With BG®II technology, cotton yields have further increased up to 12-15 quintals per acre. In addition, I get approximately 50% of pesticide savings, as of now I do not have to spend much on bollworm control, which used to be my major input cost. Bt cotton helped me to get higher yields, pesticide savings, better insect control and earn higher income, which has enabled me to purchase new four acres of land. I have also built a tube well in my farm and purchased a new tractor. I have earned the respect of my fellow farmers and I also became the Chairman of the Jai Kisan Cooperative Society last year."

CANADA

In 2009, Canada retained its fifth place in world ranking having been narrowly displaced from its traditional fourth place in world ranking by India in 2008. Growth in biotech crop area continued in Canada in 2009 with a net gain of approximately 700,000 hectares, equivalent to a 9% year-over-year growth, with a total biotech crop area of 8.2 million hectares for the four biotech crops of canola, maize, soybean and sugarbeet. Of the four biotech crops the largest increase was 500,000 hectares for canola and almost 150,000 hectares for soybean.

CANADA

Population: 32.9 million

GDP: US$1,330 billion

GDP per Capita: US$40,330

Agriculture as % GDP: 2.6%

Agricultural GDP: US$34.9 billion

% employed in agriculture: 3%

Arable Land (AL): 49.9 million hectares

Ratio of AL/Population*: 6.0

Major crops:
- Wheat
- Barley
- Maize
- Rapeseed
- Potato

Commercialized Biotech Crops:
- HT Canola
- HT Soybean
- HT/Bt/HT-Bt Maize
- HT Sugarbeet

Total area under biotech crops and (%) increase in 2009:
7.6 Million Hectares (+9%)

Farm income gain from biotech, 1996-2008: US$2.1 billion

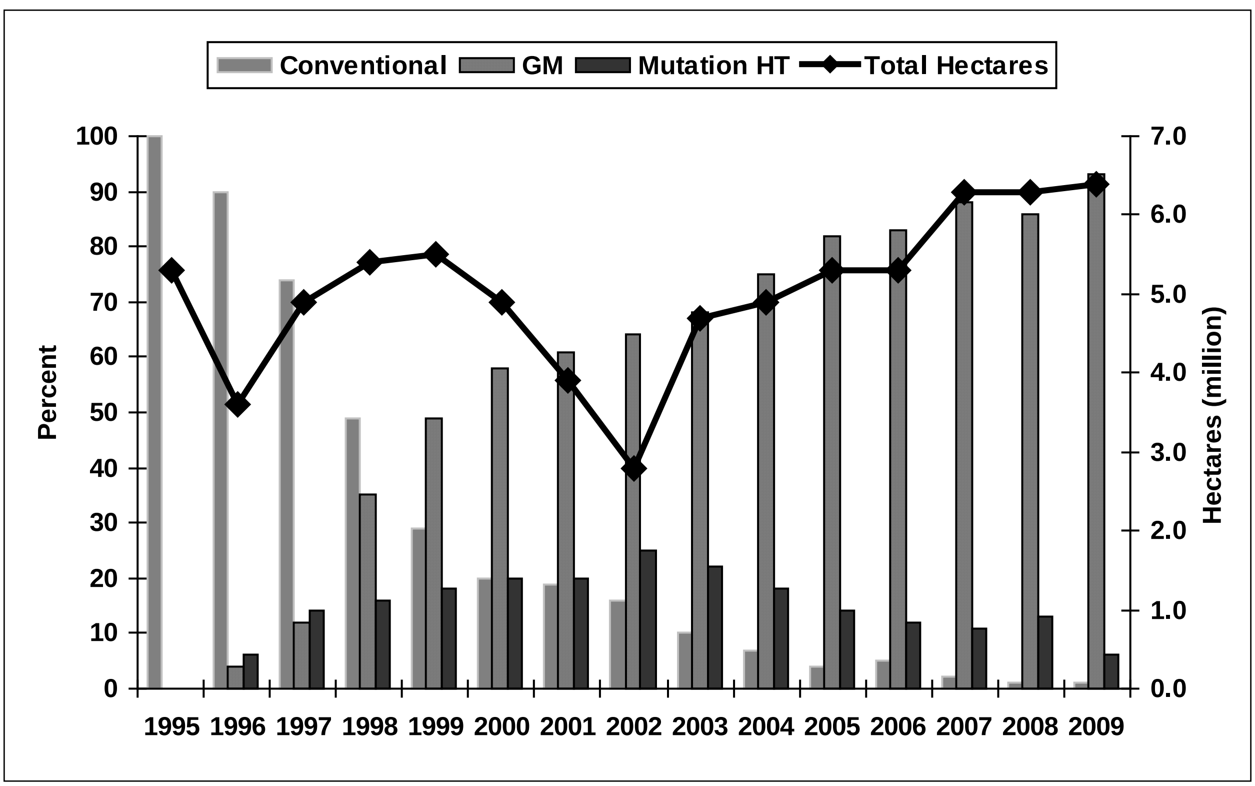
*Ratio: % global arable land / % global population

Canada is a member of the group of six "founder biotech crop countries", having commercialized herbicide tolerant canola in 1996, the first year of commercialization of biotech crops. In 2009, Canada retained its fifth place in world ranking, having been narrowly displaced from its traditional fourth place in world ranking by India in 2008. Growth in biotech crop area continued in Canada in 2009 with a net gain of approximately 700,000 hectares, equivalent to a 9% year-over-year growth, with a total biotech crop area of 8.2 million hectares for the four biotech crops of canola, maize, soybean and sugarbeet. The largest biotech crop area by far, is herbicide tolerant canola, most of which is grown in the west where adoption rates are very high. The total land area planted to canola in Canada in 2009 was 6.4 million hectares. In 2009, the national adoption rate for biotech canola was 93%, significantly higher by 7% compared with 86% in both 2008 and 2007, and up from 84% in 2006 and 82% in 2005 (Figure 27). In 2009, biotech herbicide tolerant canola was grown on approximately 6.0 million hectares, 10% more than the 5.5 million hectares of biotech canola grown in 2008; this compares with 5.1 million hectares in 2007 and 4.5 million hectares of biotech canola in 2006. Thus, in Canada there has been an impressive, steady and significant increase both in the total land area planted to canola and in the percentage planted to herbicide tolerant biotech canola, which has now reached a high national adoption rate of 93%, with only 1% devoted to conventional canola; the balance of 6% canola hectarage was planted to mutation-derived herbicide tolerant canola. Thus, the significant 7% increase in adoption of biotech canola from 86% in 2008 to 93% in 2009, resulted in the biotech canola area increasing by approximately 0.5 million hectares, equivalent to approximately 10% growth between 2008 and 2009.

Of past and present biotech canola events grown in Canada, the following were approved by the EU for import of seed for processing, meal and oil: events MSIRFI, MSIRF2, Topas 19/2, T45, MS8RF3, and GT73. The only event approved in 2009 was T45 which was discontinued before EU approval was granted.

In Ontario and Quebec, the major provinces for maize and soybean hectarage, the total plantings of maize in 2009 were 1.23 million hectares, up slightly by 2% from 1.2 million hectares in 2008. Notably, the total plantings of soybean were up significantly by 17% at 1.4 million hectares compared with only 1.2 million hectares in 2008. The 2009 total plantings of sugarbeet were the

Figure 27. Percentage of Conventional, Biotech and Mutation based Herbicide tolerance (HT) Canola Planted in Canada, 1996-2009 (Million Hectares), 1995-2009



Source: Based on Canola Council of Canada data, Personal Communication, 2009.

same as 2008 at approximately 18,000 hectares of which 96% was herbicide tolerant. In 2009, the area of biotech maize, 1.221 million hectares was up slightly from the 1,190,000 hectares in 2008 and the 1,170,000 hectares in 2007. Canada is one of only seven countries (the others are the USA, Argentina, the Philippines, South Africa, Honduras and Chile) which grow maize with double stacked traits for herbicide tolerance and Bt for insect resistance. Similarly except for the USA, Canada is the only country to grow a triple stack with one gene for European corn borer, a second for root worm control and a third for herbicide tolerance. Of the biotech maize in Canada in 2009, 46% had a single gene compared with 68% in 2008, 32% had 2 stacked genes compared with 27% in 2008, and 22% had triple stacked genes compared with only 5% in 2008. This growth in double and triple stacked genes versus single genes is typical of the shift in favor of stacked genes compared with single genes that has occurred in all seven countries that deploy stacked genes in maize. Whereas the total of biotech maize hectarage in Canada, measured in hectares, was 1.2 million hectares in 2009, the hectarage, measured in "trait hectares" was 76% higher at 2,107 million "trait" hectares. This compares with only a 35% higher increase at 1.6 million hectares in 2008 reflecting the increasing shift in favor of double and triple genes in 2009 versus 2008. In 2009, the biotech soybean hectarage was 995,000 hectares, a significant 13% higher than the 880,000 hectares in 2008.

The continued growth of biotech crops in Canada in 2009 occurred with significantly higher total plantings of soybean (1.4 million hectares), slightly higher plantings of maize (1.2 million hectares) and similar plantings of canola (6.4 million hectares). Biotech RR®sugarbeet was planted in Canada in 2009, for the second time after being launched in 2008. It is estimated that in 2009, 96% (up from 59% in 2008) of the sugarbeet in Canada and equivalent to approximately 15,000 hectares were RR®sugarbeet. This was the second year of planting in Ontario in Eastern Canada, (with the beets transported and processed in the USA) and the first year of production in Western Canada where they were processed in Canada.

According to the Canola Council of Canada (2008) revised projections suggest that approximately 2% of the Canada canola production will be used for biofuel by 2012. Canada is a major producer of wheat and several of the current principal wheat varieties have been developed through mutagenesis – there is increased interest in biotech wheat. Maize with higher levels of lysine is undergoing field tests. The RR®alfalfa from the USA has been approved for import to Canada.

Benefits from Biotech Crops in Canada

Canada is estimated to have enhanced farm income from biotech canola, maize and soybean of US$2.1 billion in the period 1996 to 2008 and the benefits for 2008 alone is estimated at US$0.4 billion (Brookes and Barfoot, 2010, forthcoming).

Currently, a new study is underway in Canada on the benefits from biotech canola – the study was not completed in time for the results to be included in this Brief. The most recent detailed benefit study of biotech canola, conducted by the Canola Council of Canada in 2007 is summarized below. Biotech canola was by far the largest hectarage of biotech crops in Canada in 2007 representing approximately 75% of the total biotech crop area of 7 million hectares. The detailed study (Canola Council of Canada, 2007) involved 650 growers; 325 growing conventional and 325 growing herbicide tolerant biotech canola. The study covered the period 1997 to 2000 and the major benefits were the following:

- More cost effective weed management was the most important advantage attributed by farmers to herbicide tolerant canola with herbicide cost 40% lower for biotech canola (saving of 1,500 MT of herbicide in 2000) compared with conventional canola.
- A 10% yield advantage for biotech canola over conventional and a dockage was only 3.87% for biotech canola compared with 5.14% for conventional.
- Less tillage and summer fallow required for biotech canola which required less labor and tractor fuel (saving of 31.2 million liters in 2000 alone) and facilitated conservation of soil structure and moisture and easy “over the top” spraying for weeds after crop establishment.
- Increased grower revenue of US$14.36 per hectare and a profit of US$26.23 per hectare for biotech canola over conventional.
- At a national level the direct value to growers from 1997 to 2000 was in the range of US$144 to US$249 million.
- The indirect value to industry of biotech canola was up to US$215 million for the same period 1997 to 2000.
- The total direct and indirect value to industry and growers for the period 1997 to 2000 was US$464 million.
- Extrapolating from the period 1997 to 2000 when 8,090 hectares of biotech canola were grown for a gain of US$464 million and the additional 19,809 hectares grown during the period 2001 to 2007, the total direct and indirect value to industry and growers for the period 1997 to 2007 is of the order of US$1.6 billion.

Farmer Experience

Jim Pallister is a canola farmer from Canada. He says:

“The biotech varieties deliver excellent yields and are a good marketable quality product. Our yields have increased with this production method, which is partly due to very clean crops, better seed bed and soil and superior plant breeding” (Pallister, 2006).

CHINA

By far, the most important biotech crop development in China in 2009 was the approval on 27 November 2009 of biotech Bt rice and biotech phytase maize. The developments have momentous implications for China, Asia and the world, because rice is the most important food crop in the world and maize is the most important feed crop in the world. Bt rice can benefit the 110 million rice households in China totaling 440 million beneficiaries, assuming four per family. With 250 million rice households in Asia the number of potential beneficiaries is a momentous 1 billion. Maize is grown by 100 million maize households (400 million potential beneficiaries) in China. Phytase maize can increase the efficiency of meat production, an important new and growing need, as China becomes more prosperous and consumes more meat. China has 500 million pigs (50% of global swine herd) and 13 billion chickens, ducks and other poultry that need feed. In 2009, 7.0 million small and resource-poor farmers in China continued to benefit from planting 3.7 million hectares of Bt cotton, which was equivalent to 68% of the national cotton crop of 5.4 million hectares; the Bt cotton area, at 3.7 million hectares is slightly lower than 2008 at 3.8 million hectares, due to a small decrease in total plantings of cotton in China but percentage adoption of Bt cotton remained the same at 68% in 2009 and 2008. Research in northern China indicates that there maybe up to another 10 million beneficiary farmers cultivating 22 million hectares of crops other than cotton, which also host cotton bollworm, but where infestations have decreased up to ten-fold. In Guangdong province, the principal province for papaya, approximately 90% of the papaya was planted with biotech papaya resistant to papaya ring spot virus. In addition, plantations of Bt poplar continued to be grown on approximately 450 hectares, approximately 10% more than 2008. The Chinese Government's assignment of high priority to agriculture, and more specifically crop biotechnology, championed by Premier Wen Jiabao, is resulting in handsome returns for China both in terms of strategically important new crops like biotech rice and maize and reflects academic excellence in crop biotechnology. Agricultural science is China's fastest-growing research field, with China's share of global publications in agricultural science growing from 1.5% in 1999 to 5% in 2008. In 1999, China spent only 0.23% of its agricultural GDP on agricultural R & D, but this increased to 0.8% in 2008 and is now close to the 1% recommended by the World Bank for developing countries. The new target for the Chinese Government is to increase total grain production to 540 million tons by 2020 and to double Chinese farmers' 2008 income by 2020 with biotech crops expected to make an important contribution.

China approves biotech rice and maize in landmark decision on 27 November 2009

In November 2009, China completed its approval of a troika of key biotech crops – fiber (Bt cotton already approved in 1997), feed (phytase maize) and food (Bt rice).The ISAAA 2008 Brief, predicted ***"a new wave of adoption of biotech crops… providing a seamless interface with the first wave of adoption, resulting in continued and broad-based strong growth in global hectarage."*** This prediction became reality on 27 November 2009, when China's Ministry of Agriculture (MOA) granted no less than three biosafety certificates on the same day. Two certificates were issued for biotech rice, one for a rice variety (Huahui-1) a restorer line, and the other for a hybrid rice line (Bt Shanyou-63), both of which expressed *cry1Ab/cry1Ac* and developed at Huazhong Agricultural University (Crop Biotech Update, 2009). The approval of Bt rice is extremely important because rice is the most important food crop in the world that feeds 3 billion people or almost half of humanity; furthermore and importantly, rice is also the most important food crop of the poor. The third certificate was for biotech phytase maize; this is also very important because maize is the most important animal feed crop in the world. The phytase maize was developed by the Chinese Academy of Agricultural Sciences (CAAS) and licensed to Origin Agritech Limited after 7 years of study at CAAS. **The three certificates of approval have momentous positive implications for biotech crops in China, Asia and the whole world.** It is important to note that the MOA conducted a very careful due diligence study, prior to issuing the three certificates for full commercialization in about 2 to 3 years, pending completion of the standard registration field trials which applies to all new conventional and biotech crops. It is noteworthy that China has now completed approval of a

CHINA

Population: 1,331.4 billion

GDP: US$3,206 billion

GDP per Capita: US$ 2,430

Agriculture as % GDP: 11.1%

Agricultural GDP: US$355.9 billion

% employed in agriculture: 41%

Arable Land (AL): 143.4 million hectares

Ratio of AL/Population*: 0.45

Major crops:
- Rice, paddy
- Sugarcane
- Sweet potato
- Maize
- Vegetables
- Cotton

Commercialized Biotech Crops:
- Bt Cotton
- Bt Poplar
- PRSV Papaya
- VR Sweet Pepper
- DR, VR Tomato

Total area under biotech crops and (%) increase in 2009:
3.7 Million Hectares (-3%)

Increased farm income for 1997-2008: US$7.6 billion

*Ratio: % global arable land / % global population

troika of the key biotech crops in an appropriate chronology – first was FIBER (cotton), followed by FEED (maize) and FOOD (rice). The potential benefits of these 3 crops for China are enormous and summarized below.

- **Bt cotton.** China has successfully planted Bt cotton since 1997 and now, 7 million small farmers in China are already increasing their income by approximately US$220 per hectare (equivalent to approximately US$1 billion nationally) due, on average, to a 10% increase in yield, a 60% reduction in insecticides, both of which contribute to a more sustainable agriculture and the prosperity of small poor farmers. China is the largest producer of cotton in the world, with 68% of its 5.4 million hectares successfully planted with Bt cotton in 2009.

- **Bt rice** offers the potential to generate benefits of US$4 billion annually from an average yield increase of 8%, and an 80% decrease in insecticides, equivalent to 17 kg per hectare on China's major staple food crop, rice, which occupies 30 million hectares (Huang et al. 2005). It is estimated that 75% of all rice in China is infested with the rice-borer pest, which Bt rice controls. China is the biggest producer of rice in the world (178 million tons of paddy) with 110 million rice households (a total of 440 million people based on 4 per family) who could benefit directly as farmers from this technology, as well as China's 1.3 billion rice consumers. Bt rice will increase productivity of more affordable rice at the very time when China needs new technology to maintain self-sufficiency and increase food production to overcome drought, salinity, pests and other yield constraints associated with climate change and dropping water tables. Crops that use water efficiently and the development of drought tolerant crops is top priority for China.

- **Phytase maize.** China, after the USA, is the second largest grower of maize in the world (30 million hectares grown by 100 million households); it is principally used for animal feed. Achieving self-sufficiency in maize and meeting the increased demand for more meat in a more prosperous China, is an enormous challenge. For example, China's swine herd, the biggest in the world, increased 100-fold from 5 million in 1968 to over 500 million today. Phytase maize will allow pigs to digest more phosphorus, resulting in faster growth/more efficient meat production, and coincidentally result in a reduction of phosphate pollution from animal waste into soil and extensive bodies of water and aquifers. Maize is also used as feed for China's huge number of domesticated avian species – 13 billion chickens, ducks and other poultry, up from 12.3 million in 1968. Phytase maize will allow animal feed producers to eliminate the need to purchase phytase with savings in equipment, labor and added convenience. The significance of this maize approval is that China is the second largest grower of maize in the world with 30 million hectares (USA is the largest at 35 million hectares). As wealth is rapidly being created in China more meat is being consumed which in turn requires significantly more animal feed of which maize is a principal source. China imports 5 million tons annually at a foreign exchange cost of US$1 billion. Phytase maize is China's first approved feed crop, The only country in Asia that has approved and already growing biotech maize is the Philippines where it was first deployed in 2003; Bt maize, herbicide tolerant (HT) maize and the stacked Bt/HT product were grown on approximately 0.5 million hectares in the Philippines in 2009.

In China, it is important to note that all three approved biotech crops, Bt cotton, Bt rice and phytase maize, were all developed with public resources by Chinese public sector institutions. The significant advantages that these products offer China also apply to other developing countries, particularly in Asia (but also elsewhere in the world), which have similar crop production constraints. Other Asian countries which could benefit from biotech maize include India (8 million hectares), Indonesia (3 million hectares), Thailand, Vietnam and Pakistan, all with approximately 1 million hectares each of maize. Asia grows and consumes 90% of the production from the world's 150 million hectares of rice, and Bt rice can have enormous impact in Asia. Not only can Bt rice contribute to an increase productivity and self-sufficiency but it can also make a substantive contribution to the alleviation of poverty of poor small farmers who represent 50% of the world's poor. Similarly, there are up to 50 million hectares of maize in Asia that could benefit from biotech maize. China's exertion of global leadership in approving biotech rice and maize in 2009 will likely result in a positive influence on acceptance and speed of adoption of biotech food and feed crops in Asia, and more generally globally, particularly in developing countries. This approval is exemplary for other countries in pursuit of "self-sufficiency" (optimizing productivity and production of home-grown food) as opposed to "food security", (enough food for all) – the distinction is important and the two goals are not mutually exclusive. China can serve as a model for other developing countries, particularly in Asia, which could have substantive implications for:

- a more timely and efficient approval process for biotech crops in developing countries;
- new modes of South-South technology transfer and sharing, including public/public and public/private sector partnerships;
- more orderly international trade in rice and reduction in probability of recurrence of 2008-type price hikes, which were devastating for the poor; and
- shift of more authority and responsibility to developing countries to optimize "self-sufficiency" and provide more incentive for their involvement to deliver their share of the 2015 Millennium Development Goals.

Finally, Bt rice and phytase maize should be seen as only the first of many agronomic and quality biotech traits to be integrated into improved biotech crops, with significant enhanced yield and quality, which can contribute to the doubling of food, feed and fiber production on less resources, particularly water and nitrogen, by 2050. The approval by China of the first major biotech food crop, Bt rice, can be the unique global catalyst for both the public and private sectors from developing and industrial countries to work together in a global initiative toward the noble goal of "food for all and self-sufficiency" in a more just society. The issuance of three biosafety certificates for rice and maize reflects China's clear intent to practice what it preaches and to approve for commercialization its home-grown biotech fiber, feed and food crops (biotech papaya – a fruit/food crop that has been successfully cultivated commercially since 2006/07) that offer significant economic and environmental benefits, and perhaps more importantly, allows China to be least dependent on others for food, feed and fiber – a strategic issue for China.

Like the USA, Argentina, and Canada, China is a member of the group of six "founder biotech crop countries", having first commercialized biotech crops in 1996, the first year of global commercialization. The national area planted to cotton in China in 2009, at 5.41 million hectares was slightly lower than that planted in 2008, 5.67 million hectares, and a parallel decrease has been recorded for the area of Bt cotton. The areas planted to Bt cotton in 2009 and 2008 were approximately the same at 3.7 and 3.8 million hectares respectively, with the percentage adoption unchanged at 68% for 2008 and 2009. The size of farms in China is very small. In a recent survey of cotton farms, the average size of farm, as determined by the area of cultivable land, was 0.8 hectare and the average size of a cotton holding was 0.6 hectare. Currently, 64 varieties of Bt cotton are grown in China. An estimated 7.0 million small and resource-poor farmers grew Bt cotton in China in 2009, compared with 7.1 million in 2008. However, an important paper in Science (Wu et al. 2008) suggested that the potential number of small farmers benefiting indirectly from Bt cotton in China might be up to 10 million more. Following the extensive planting of Bt cotton in six northern provinces of China, during the period 1997 to 2006, Wu et al. (2008) reported that cotton bollworm populations decreased markedly (by up to ten-fold) in other crops that also host the cotton bollworm – these include maize, peanut, sesame, legumes, wheat, sorghum, vegetables and melons. Whereas cotton occupies only about 3 million hectares and farmed by an estimated 5 million farmers in the six northern provinces of China, host crops of cotton bollworm occupy 7 times the area at 22 million hectares and are farmed by more than 10 million subsistence farmers.

The comprehensive study by Wu et al. (2008) involved the six provinces of Hebei, Shandong, Jiangsu, Shanxi, Henan and Anhui. The number of cotton bollworm larvae in maize, peanuts, soybeans and vegetables dropped dramatically by approximately 90% from around 3,000 in 1997 to 300% in 2006. Importantly, the study concludes that Bt cotton not only provides control for the damaging cotton bollworm on cotton but results in the suppression of cotton bollworm on several other important host crops that occupy more than seven times the area of Bt cotton. The dramatic reduction by 90% in the level of cotton bollworm in host crops other than cotton has implications for insecticide savings, which may translate to a significant decrease in the need for insecticide sprays on these host crops, other than cotton cultivated by approximately 10 million farmers. This important finding may mean that the number of farmers that could benefit directly and indirectly from Bt cotton in northern

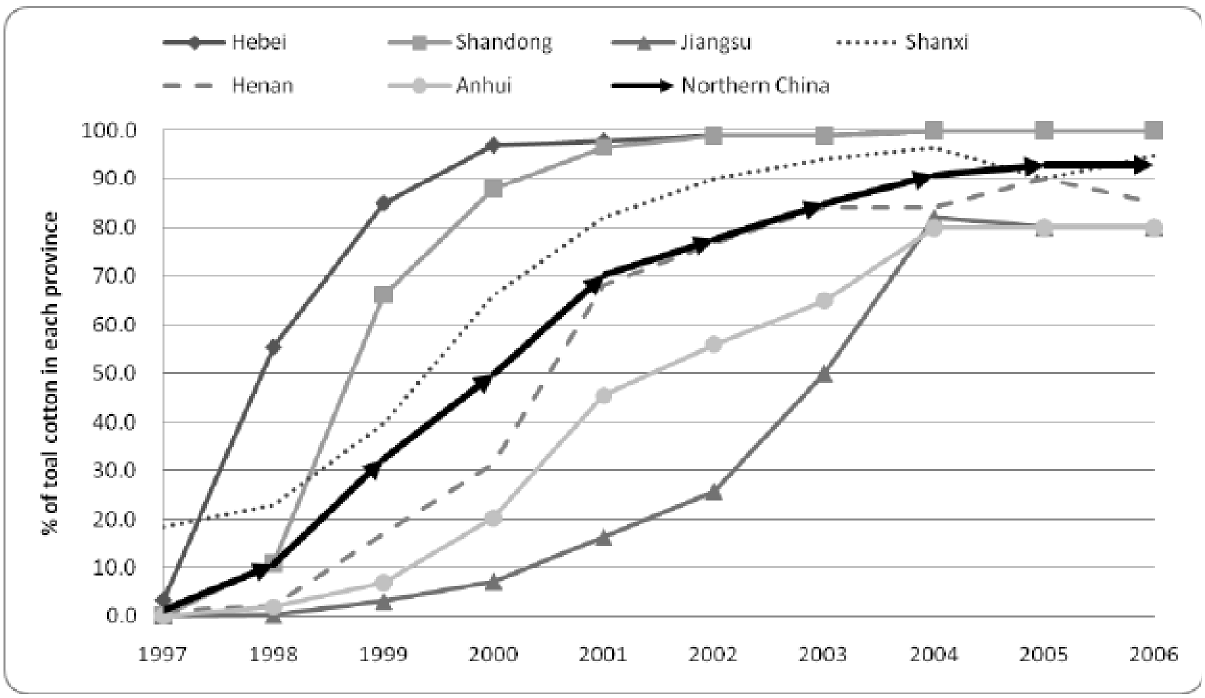
China, may number an additional 10 million, compared with the 5 million that benefit from Bt cotton directly in the six northern provinces of China. Thus, past estimates of the benefits associated with Bt cotton in China in terms of the number of beneficiary farmers, and economic, agronomic and environmental benefits may have been grossly underestimated because the benefits to farmers cultivating crops other than cotton that host cotton bollworm were not known and have not been considered. Coincidentally, as a result of the decrease in use of broad spectrum sprays for the control of cotton bollworm in cotton in northern China, myrids, which were previously a secondary insect pest of relatively low economic importance have not surprisingly become relatively more important. This demonstrates the need and importance for a broad integrated pest management strategy for the control of insect pets featuring both biotechnology and other means of control.

The field data from China's Ministry of Agriculture used in the same study by Wu et al. (2008) also clearly demonstrated the unusually high and rapid adoption of Bt cotton in each of the six provinces of northern China during the period 1997 to 2006 (Figure 28). It is noteworthy that adoption of Bt cotton was fastest in the two provinces of Hebei and Shangdong reaching over 95% in the short span of 5 years and 100% in 8 years. The adoption rates in the provinces of Jiangsu, Shanxi, Henan and Anhui were almost as fast reaching 80 to 90% in 8 years or less (Figure 28). In northern China, as a region, more than 66% adoption of Bt cotton was reached in only 5 years. These adoption rates are remarkably high by any standard and reflect the vote of confidence of farmers in Bt cotton, which has delivered multiple and significant economic, agronomic and socio-economic benefits consistently from 1997, the first year of commercialization, to the present.

One of the important indicators that reflect farmers' confidence in any new technology, including Bt cotton, is the extent to which farmers repeat the planting of Bt cotton in the following season. In 2006 and 2007, of 240 cotton growing households surveyed in 12 villages in three provinces – Hebei, Henan and Shandong, by the Center for Chinese Agricultural Policy of the Chinese Academy of Sciences, it is notable that every single family that reported growing Bt cotton in 2006 also elected to grow Bt cotton in 2007. Thus, the repeat index for farmers growing Bt cotton in 2006 and 2007 in three provinces in China was 100%. Interestingly, of the 240 farmers surveyed, a few farmers in one village also grew one variety of non-Bt cotton in 2006 that they also grew in 2007. This reflects the fact that farmers invariably want to compare the performance of old and improved technologies side-by-side in their own fields. The same happened during the introduction of hybrid maize in the corn belt in the USA – farmers planted the best performing varieties next to the new hybrids until they were satisfied that hybrids consistently out-performed their old varieties, and it took several years before hybrid maize was fully adopted.

The level of Bt cotton adoption in China seems to have plateaued at around 68%. This plateauing may be in part due to the fact that the large cotton areas in the province of Xing Xang are subject to much less pest pressure than eastern provinces such as Hubei where pest pressure is high and where

Figure 28. Adoption of Bt Cotton in Each Province of Northern China, as Percentage, 1997 to 2006



Source: Wu et al. 2008, Data in Annex from China's Ministry of Agriculture.

adoption rates are well above the national average. It is estimated that about 10 to 15% of the cotton area in Xing Xang was planted with Bt cotton.

No additional information was available in 2009 regarding a report from the Chinese Academy of Agricultural Sciences (CAAS) that new Bt cotton hybrids could yield up to 25% more than the current Bt cotton varieties. If confirmed, this could spur a renewed wave of increased adoption that would significantly exceed current adoption rates of around two-thirds of national cotton hectarage. Whereas hybrids are expected to become more prevalent in the near-term, no additional information is available at this time. New Bt cotton hybrids could boost farmer income making China the second country after India to profit from Bt cotton hybrids which, unlike varieties, offer an incentive for developers of the hybrids which have a built-in value-capture system not found in varieties. Use of non-conventional hybrids is already widespread (70% adoption) in the Yangtze River Valley but less prevalent in the Yellow River Valley. These non-conventional Bt hybrids are bred by crossing two varieties, rather than the normal inbred lines, which optimize hybrid vigor. The use of these non-conventional Bt hybrids provides slightly higher yields and can pave the way for new hybrids with higher yield potential. China, with its track record of having already developed successful Bt cotton varieties that compete with products developed by the private sector, has gained a rich experience in crop biotechnology, which has served China well in the development of biotech crops like Bt rice and Phytase maize, and for others in the future.

In September 2006, China's National Biosafety Committee recommended for commercialization a locally developed biotech papaya resistant to papaya ringspot virus (PRSV) (Table 30). The technology features the viral replicase gene and was developed by South China Agricultural University; the papaya biotech variety is highly resistant to all the local strains of PRSV. This approval and eventual commercialization in China was a significant development in that papaya is a fruit/food crop, which is widely consumed throughout the country. The main province for papaya production in China is the province of Guangdong. In 2009, the total papaya hectarage in Guangdong province was approximately 5,000 hectares (similar to 2008) of which approximately 4,500 hectares, or 90% was biotech papaya, compared with 88% in 2008 and 70% adoption, equivalent to 3,550 hectares in 2007. Thus, the percentage adoption of biotech papaya increased from 70 to 90% between 2007 and 2009.

Table 30. Approval and Commercialization of Biotech Crops in China

Crop	Year of Approval
Cotton	1997
Petunia	1997
Tomato	1998
Sweet Pepper	1998
Poplar Trees	2003
Papaya	2006
Rice (Bt)	2009 (27 November)
Maize (Phytase)	2009 (27 November)

Source: Compiled by Clive James, 2009.

Bt poplars (*Populus nigra*) have also been approved for commercialization in China. The first Bt poplars were developed and commercialized in 2003 by the Research Institute of Forestry in Beijing, which is part of the Chinese Academy of Forestry. It is estimated that by the year 2015, China will need 330-340 million cubic meters of timber, of which approximately half, or 140-150 million cubic meters, will have to be produced in China, with the balance imported. In order to meet this challenging goal, the development of improved tree plantations in China was accelerated. Some fast-growing trees, such as poplar, eucalyptus, larch, and Chinese fir, were carefully selected and widely planted in China. During the past 20 years, a total of 7.04 million hectares of selected poplar clones were planted in China for commercial production; this represents 19% of total tree plantations in China. However, it was observed that these monoclonal plantations were susceptible to insect pests which caused severe infestations resulting in significant damage, estimated at millions of US dollars annually. In order to develop poplars that were more tolerant to insect attack, GM/biotech poplars were generated in China. More specifically, *Populus nigra* clones (12, 172 and 153) were developed with *cry1Aa* and a hybrid white poplar clone 741 was transformed with a fusion of *cry1Aa* and *API* (coding for a proteinase inhibitor from *Sagittaria sagittifolia*). Under rigorous testing, these Bt poplar clones have exhibited a high level of resistance to leaf pests, resulting in a substantial 90% reduction in leaf damage. The two clones were first commercialized in 2003, and by 2009, 447 hectares had already been planted in northern China, up from 400 hectares in 2008; about 90% of the 447 hectares were planted with Bt *Populus nigra* clones, and the balance of 10% with clone 741 with *cry1Aa* and *API*. A new clone under development, a hybrid white poplar clone 84K, transformed with the *Bt886Cry3Aa* resistance gene, has already undergone testing in nurseries and the preliminary results are promising. Clone 84K with the *Bt886Cry3Aa* is tolerant to the economically important Asian longhorn beetle, which attacks the trunks of poplars and can cause significant damage (Lu M-Z, 2009, Personal Communication).

There is a growing number of collaborative initiatives between Chinese institutions and foreign companies and institutions. For example, the China National Seed Group (China Seed) and Monsanto have agreed to extend their respective investments in their joint venture company, CNSGC-DEKALB Seed Company Ltd. (CNDK) – the agreement is pending approval by the Chinese Government. CNDK was formed in 2001 to market maize hybrids in China, the second largest market for maize hybrids in the world, after the USA. In November 2009, Monsanto announced the establishment of its Biotechnology Research Center in Zhongguancun, Bejing that will allow the company to strengthen its links with Chinese Research Institutions in plant biotechnology and genomics. In November 2008, Bayer Crop Science signed an MOU with the Chinese Academy of Agricultural Sciences (CAAS) for joint development and global marketing of new agricultural products which will strengthen and expand the seed and traits business of both parties in China.

RR2Yield™ Soybean Approval in China

The decision by China on 5 September 2008 to approve for import the new **RR2Yield™** soybean was a major development with significant implications (McWilliams, 2008). China, the most populous country in the world is also the largest consumer of edible soybean in the world. China spent US$4 billion importing US soybean in 2007 which accounted for 38% of all US soybean exports. Prior to the Chinese approval, **RR2Yield™** soybean had already been approved as safe for food, feed in the USA, Canada, Mexico, Taiwan, Japan, the Philippines, Australia and New Zealand which collectively import 30% of all US soy exports. The new approval from China means that over two thirds (68%) of the US soybean export markets have already been cleared with China representing more than half (38% out of 68%). **RR2Yield™** has demonstrated a yield advantage over the first generation RR®soybean, which was released in 1996, of 7 to 11%. The initial launch for **RR2Yield™** soybean was in 2009 on approximately 0.5 million hectares in the USA and Canada, to be followed by a planned large scale launch of 2 to 3 million hectares in 2010. It is projected that **RR2Yield™**, which will cost more than the current RR®soybean could increase net benefits to farmers by US$85 to US$135 per hectare, based on a price of US$12 per bushel.

Political Will and Support for Biotech Crops

It is evident that after the 27 November 2009 approvals of both biotech rice and maize, that Chinese policymakers view agricultural biotechnology as a strategic element for increasing productivity and self-sufficiency, improving national food security and ensuring competitiveness in the international market place. There is little doubt that China will now become one of the world leaders in crop biotechnology since Chinese policymakers have concluded that there are unacceptable risks of being dependent on imported technologies for food security. In addition to cotton which is already deployed and the approved Bt rice and phytase maize, China has an impressive portfolio of other biotech crops being field-tested, including wheat, potato, tomato, soybean, cabbage, peanut, melon, papaya, sweet pepper, chili, rapeseed, and tobacco.

It is instructive to trace the increasing political will, support and confidence in biotech crops prior to the 27 November 2009 approval of Bt rice and phytase maize. In June 2008, **Chinese Premier Wen Jiabao** addressed the Chinese Academy of Science and stated that, ***"To solve the food problem, we have to rely on big science and technology measures, rely on biotechnology, rely on GM."*** This was a remarkably strong support for biotech crops from China's cabinet and Premier Wen Jiabao, who urged authorities to ***"waste no time to implement the program and understand the urgency and importance of the program."*** In July 2008, Premier Wen Jiabao, in his capacity as Chairman of the State Council, announced that the cabinet had approved a significant increase in budget for GM crops of 4 to 5 billion Yuan, equivalent to US$584 million to US$730 million in the coming years. As of 2006, China had approved 211 field trials for a total of 20 crops. In September 2008, **Xue Dayuan, chief scientist on biodiversity,** noted that the new US$3.5 billion R&D initiative announced by Premier Wen Jiabao ***"will spur the commercialization of GM varieties"*** (Stone, 2008). It is noteworthy that funding for the program is resourced in a novel way from local governments and indigenous agbiotech companies. A significant component in the new initiative is a public awareness program to educate the public about biotech crops. The aim of the program is to ***"obtain genes with great potential commercial value whose intellectual property rights belong to China, and to develop high quality, high yield, and pest resistant genetically modified new species"*** (Shuping, 2008; Stone, 2008). Thus, biotech crops in China are assigned the highest level of political support. Premier Wen's and the cabinet's very supportive comments on biotech crops had direct implications for biotech rice in China and is viewed in a very positive light by Dr. Dafang Huang, former director of the biotechnology institute in the Chinese Academy for Agricultural Sciences and by Dr. Jikun Huang, senior economist at the Chinese Academy of Science. Dr. Jikun Huang commented that, ***"The plan's approval is a very positive signal to the future of research and commercialization to more GMO crops."*** Dr. Jikun Huang has been involved in the development of biotech crops in China, since the genesis of biotech crops in China and has projected benefits of US$4 billion per year from Bt rice – this projection is based on extensive pre-production field trials conducted to determine the benefits of biotech rice. The approval of biotech rice by China on 27 November 2009 has enormous implications for all the rice growing countries of Asia which represent 90% of global production, with more than 110 million households growing rice in China alone, and more than a quarter billion (250 million) rice households in Asia, the majority of which represent the poorest people in the world. In the context of decreasing agricultural land, rapidly dropping water tables and increased demand for food grains, China has set challenging targets to produce 500 million tons of grains by 2010 and 540 million by 2020 whereas demand in 2008 is already at 518 million tons (Shuping, 2008).

Indications that China was considering commercialization of biotech rice in the near term were attributed to comments made by the Vice Minister of Agriculture Niu Dun, and reported by the China Daily on 25 August 2009. More specifically Nui Dun said "***China has worked on research of transgenic rice and is strongly considering its commercialization."*** Government officials observed that the GM/biotech rice being considered for approval was more resistant to pests and more tasty and indicated that final approval to sell GM rice was close. Observers in China opined that a change in attitude regarding the approval of biotech rice began last year when the State Council approved a major R and D project on GM crops, meats and other products worth 20 billion yuan (US$3 billion at 6.8 yuan per US$). Government officials said that ***"By 2020, China could be a leader in GM foods, cloning, large-scale transgenic technology and new breed promotion. Rice and corn are the items nearest commercialization."*** Given that rice is a crucial staple in Asia and throughout the Pacific area, officials said ***"Increased production would make a massive difference."***

Over the last 30 years, China's national rice production has almost doubled from 304 million tons in 1978 to 528 million tons in 2008. China's population is expected to grow to 1.6 billion by 2020, when it is estimated that 630 million tons of rice will be needed. China has embraced biotechnology and more specifically highlighted biotech crops in a well planned innovative scientific strategy that offers the best promise for doubling food, feed and fiber production sustainably in China by 2050. Dr. Cao Mengliang, a researcher on molecular rice at China's National Hybrid Rice R&D Centre, said that ***"In China, the safety of transgenic food is not only a scientific issue, but one with economic and political importance. Studies of the safety of the technology have been completed. Discussions about whether to open it up to the market are now in the final stages.***

Now, the safety certificate is the last thing needed before commercialized production. The technology will mainly focus on insect resistance, pesticide implications and disease control and upon improvements to quality and taste" (China Daily, 2009).

Observers monitoring the situation in biotech/GM rice in China predict that following the 27 November 2009 approval, biotech rice will be welcomed by farmers because of its potential to increase yield, reduced need for pesticides and labor, and thus its potential to generate increased return which can contribute to a better quality of life for the 110 million rice households in China who are some of the poorest people in the world. Thus biotech crops are entirely consistent with the policy of the Chinese Government which has assigned the highest priority to poverty alleviation and increased prosperity for the rural population of China which represents approximately two-thirds of China's 1.3 billion people.

The Chinese Government's assignment of high priority to agriculture, and more specifically crop biotechnology, championed by Premier Wen Jiabao, is resulting in handsome returns for China both in terms of strategically important new crops like biotech rice and maize and reflects the growing academic excellence of China in biotech crops. A November 2009 Report (Adams, 2009) noted that agricultural science is China's fastest-growing research field. From 1999 to 2008 growth in agricultural science papers outpaced growth in all other topics. From 2004 to 2008, agricultural researchers published four times more scientific papers compared with the period 1999 to 2003. China's share of global publications in agricultural science grew from 1.5% in 1999 to 5% in 2008. Professor Lin Min, Director of the Chinese Academy of Agricultural Sciences' Biotechnology Research Center, opined that China's agricultural ascent in agricultural science is due to ***"rich research resources, constant governmental investment and support, and an expanding pool of world-class talents."*** In 1999, China spent only 0.23% of its agricultural GDP on agricultural R & D but this increased to 0.8% in 2008 and is now close to the 1% recommended by the World Bank for developing countries (Lin, 2009). Allocation by the Chinese Government of substantial agricultural research resources, have been the key to driving the rapid growth especially in biotechnology: "***Otherwise you could only conduct model research rather than application research. The return of an increasing number of overseas-trained and world-class Chinese agricultural scientists is also helping and they are lured back by China's rapid economic development and attractive job offers and at the same time, China's home-grown agricultural researchers are also catching up quickly,***" said Lin (2009).

Elsewhere in Asia, outside China, there are also significant R&D investments on biotech rice featuring agronomic and quality traits. For example, a team at the University of Tokyo, Japan has developed biotech rice that can tolerate iron deficiency, which is a very prevalent constraint in the rice growing countries of Asia (Takanori et al. 2008). Deployment of a rice tolerant to iron deficiency is one of many biotechnology applications, including pest and disease resistance and pro-Vitamin A enhanced Golden Rice (expected to be available in Asia in 2012) that could contribute to higher productivity and improved nutritional quality of rice. Rice is not only the most important food crop in the world but is also the most important food crop of the poor in the world. This is particularly true in Asia where 90% of the world's rice is produced and consumed and where rice has a very important cultural role. In Asia, rice is the staple of 600 million extremely poor rural people, mostly subsistence farmers and the rural landless who are completely dependent on agriculture for their livelihood. Hence, biotech rice with improved attributes can make an enormous contribution to the alleviation of poverty and hunger in Asia but also in Latin America and Africa where rice is also important, particularly for the poorer in rural communities.

China is very much cognizant of the need for biosafety management in order to ensure protection of the environment and consumers, and this was the major consideration in the approval of Bt rice in November 2009. Given the paramount importance of rice as the principal food crop in China, approximately 20% of the government's investment in crop biotechnology has been devoted to rice. This was equivalent to an annual investment of US$24 million at official exchange rates, or US$120 million per year at a purchasing power parity rate of five, which undoubtedly makes China's investment in rice biotechnology, by far, the largest in the world. Three insect resistant hybrid rice varieties, two featuring the Bt gene and the other with the *CpTi trypsin* gene, entered pre-production field trials in 2001, plus a rice variety carrying the *Xa21* gene that confers resistance to the important bacterial blight disease of rice. Annual and extensive large-scale pre-production trials of these new biotech hybrids of rice, starting in 2001, confirmed yield increases of approximately 2 to 6%, plus a saving of 17 kg per hectare in pesticides, with positive health implications, along with a labor saving of 8 days per hectare, resulting in an overall increase in net income per hectare of US$80 to US$100. It is projected that with full adoption, the new biotech rice hybrids could result in a national benefit to China of US$4 billion; insect borers, which can be controlled by Bt, are prevalent on up to 75% of approximately 30 million hectares of rice in China (Jikun Huang, 2009. Personal Communication).

Whereas ISAAA has no knowledge of biotech rice being approved in any other country except China, the previous administration in Iran did temporarily officially released a Bt rice in 2004 to coincide with the celebration of the International Rice Year. The biotech rice, a high quality rice named "Tarom molaii", was estimated to have been cultivated on 2,000 hectares in 2004 and was grown successfully on 4,000 hectares by more than 500 farmers in 2005, because it yielded significantly more than its conventional counterpart. The National Biosafety Council of Iran is now apparently reviewing the dossier on biotech rice as part of the process of approving and commercialization of rice in Iran.

Even though the global price of rice has modulated to US$, approximately US$550 per ton in recent months the unprecedented increase in the price of rice to US$1,000 a ton in April 2008 (a significant 2.5-fold increase over the 2006 price of US$300 a ton), spurred unparalleled political support for biotech crops and provided an important incentive for the expedited adoption of biotech rice because of its potential to significantly increase productivity per hectare leading to increase in supply and in turn to modulate rice prices.

With the approval of biotech rice in November 2009, this leaves wheat, as the only one of the three major world staples: maize, rice and wheat, to be denied the significant advantages offered by biotechnology. The adoption of biotech rice and maize in Asia will, in due course, greatly facilitate and expedite the approval and adoption of biotech wheat. The first biotech wheat to be approved in China in about 5 years may be virus resistant (yellow mosaic virus), which is being field tested. A "sprout tolerant" wheat is also being developed in China. Wheat with improved resistance to *Fusarium* and thus lower levels of mycotoxin is also under development as well as quality traits and for the longer term, improved drought resistance.

The near-term food and feed needs of China, and more broadly Asia, are not limited to the major crop rice, but also apply to maize for feed, and also, more and better quality wheat for food. China's priority-trait needs include disease and insect resistance, herbicide tolerance as well as quality traits. China has an impressive stable of its own home-grown biotech crops with various traits which can be complemented with products developed by the public and private sectors from the global crop biotech market. China has estimated potential benefits from biotech cotton and rice at US$5 billion per year and can complement these gains by applying biotechnology to the other staples of maize and wheat, and up to a dozen other crops in the near, medium and long term. At the opening ceremony of the International High-level Forum on Biotechnology held in Beijing in September 2005, the Minister of Science and Technology Xu Guanhua commented that, ***"Biotechnology could become the fastest growing industry in China in the next 15 years"*** and that, ***"Biotechnology will be put high on the country's mid- and long-term scientific and technological development strategy."*** He further predicted that eventually the advancement in R&D would lead to a bio-economy boom (China Daily, 2005). China currently has 200 government funded biotechnology laboratories and 500 companies active in biotechnology.

In summary, there is little doubt, now that China has approved both biotech rice and maize, the country will seek to further enhance its role as a world leader in crop biotechnology. The 2008 statements of Premier Wen Jiabao backed by a substantial commitment of an additional US$3.5 billion over the next 15 years to crop biotechnology is evidence of very strong political will at the cabinet level for crop biotechnology in China. In October 2008, Wen Jiabo (2008) reinforced his support for biotech crops when he stated that, ***"I strongly advocate making great efforts to pursue transgenic engineering. The recent food shortages around the world have further strengthened my belief."*** The substantial economic, environmental, and social benefits from Bt cotton have provided China with its first-hand experience of biotech crops. It is almost certain that the rich experience with Bt cotton served China well in its consideration and approval of biotech rice and maize in November 2009.

China considers food safety and self-sufficiency top priorities and importantly, as basic human rights. China is committed to transform agriculture from a traditional to a modern agriculture with high priority assigned to crop biotechnology. China has consistently maintained a grain self-sufficiency of 95% or more in recent years, and has made a significant contribution to the alleviation of poverty (People's Daily, 2009). In 2008, total grain production in China reached 525 million tons, compared with only 113 million tons in 1949. In 2007, per capita rural income was 4,140 Yuan (US$608), five times what it was in 1978. The number of rural poor has declined from 250 million in 1978 to 15 million today. China, with the exception of India, is one of very few developing countries which has increased investments in agriculture significantly and as a result reaped handsome benefits. The Chinese Government increased its investments in agriculture by 30% in 2007, by 38% in 2008 and is expected to have increased it by another 20% in 2009. Maize yield increased from 1.18 tons in 1961 to 5.61 tons per hectare in 2007, rice from 2.0 to 6.3 tons and wheat from 0.6 tons to 4.6 tons per hectare, in the same period. The new target for the Chinese Government is to increase total grain production to 540 million tons by 2020 and to double Chinese farmers' 2008 income by 2020 (Xinhua, 2009a). These are challenging and formidable targets but past experience and perseverance in successfully attaining equally formidable goals would indicate that for China, they are feasible. The major challenge is to increase crop productivity significantly in the face of water scarcity, loss of fertile land and slowing agricultural productivity constrained by the law of diminishing returns, slowing gains from successful past technologies. Despite all these formidable challenges, China is also boldly investing in more collaborative programs designed to assist other developing countries in agriculture with a more pragmatic **"do as I do"** philosophy and not the "**do as I say**" philosophy practiced by most other development donors. China is currently setting up 20 agricultural technology demonstration centers in the developing world and plans to double the number of Chinese agricultural experts assigned to agricultural development projects in Asia, Africa and Latin America.

Benefits from Biotech Crops in China

Bt cotton – In 2009, Bt cotton was planted by 7.0 million small and resource-poor farmers on 3.7 million hectares, which is 68% of the 5.4 million hectares of all cotton planted in China. Based on studies conducted by the Center for Chinese Agricultural Policy (CCAP), it was concluded that, on average at the farm level, Bt cotton increases yield by 9.6%, reduces insecticide use by 60%, with positive implications for both the environment and the farmers' health, and generates a substantial US$220 per hectare increase in income which makes a significant contribution to their livelihood as the income of many cotton farmers can be as low as around US$1 per day (Huang, 2008, Personal Communication). At the national level, it is estimated that increased income from Bt cotton will be approximately US$1 billion per year by 2010. It is estimated that China has enhanced its farm income from biotech cotton by US$7.6 billion in the period 1997 to 2008 and by US$0.9 billion in 2008 alone (Brookes and Barfoot, forthcoming 2010).

Biotech rice – The biotech hybrid rice is resistant to specific pests (insect borers). The product, based on CCAP's study, increased yield by about 8%, reduced insecticide application by nearly 80% or 17 kg per hectare. At a national level, it is projected that biotech rice could deliver benefits in the order of US$4 billion per year in the future, plus environmental benefits that will contribute to a more sustainable agriculture and the alleviation of poverty for small and resource-poor farmers (Huang, Personal Communication).

Farmer Experience

Niu Qingjun is a typical Chinese cotton farmer in Shandong province in China, one of the largest cotton growing provinces in the country. Niu is 42 years old, is married with two children and 80% of the family income comes from cotton, which represents the livelihood of the whole family. Niu has been growing Bt cotton since 1998. The total size of his farm is 0.61 hectare and cotton is the only crop that he grows on his farm. Niu's experience with Bt cotton is captured in the following comments. ***"We could not even plant cotton if there is no insect resistant cotton (Bt cotton). We could not control bollworm infestation before planting insect resistant cotton, even if spraying 40 times insecticide in 1997."*** Niu harvested 2,680 kg of seed cotton in 2007; given that the price of seed cotton is 6.8 RMB/kg, he would approximately make a profit of 14,000 RMB or US$1,886 (not including labor inputs). Niu only sprayed insecticide 12 times in 2007, approximately half the number of sprays he used on conventional cotton prior to the introduction of Bt cotton (Qingjun, 2007).

PARAGUAY

In 2009, Paraguay grew a total of 2.5 million hectares of soybean, of which 2.25 million hectares (90% adoption) were biotech herbicide tolerant soybean; this compares with 2.66 million hectares of biotech soybean in 2008 out of a total of 2.8 million hectares. The decrease in 2009 was due to significantly less total plantings of soybean, and uncertainties associated with the drought and the economic recession.

Paraguay is the world's number four exporter of soybeans and grew biotech soybean unofficially for several years until it approved four herbicide tolerant soybean varieties in 2004. In 2009, Paraguay was expected to grow a total of 2.5 million hectares of soybean of which 2.25 million hectares (90% adoption) was biotech herbicide tolerant soybean; this compares with 2.66 million hectares of biotech soybean in 2008 out of a total of 2.8 million hectares. The decrease in 2009 was mainly due to significantly less total plantings of soybean, and uncertainties associated with the drought and the economic recession. Paraguay is one of the 11 countries that have successfully grown biotech soybeans; the ten countries, listed in order of biotech soybean hectarage are the USA, Argentina, Brazil, Paraguay, Canada, Bolivia, Uruguay, South Africa, Mexico, Chile and Costa Rica.

Biotech maize and cotton have not been officially approved to-date in Paraguay but its neighboring countries Argentina and Brazil are growing both biotech crops successfully. Paraguay was expected to grow approximately 600,000 hectares of maize in 2009, the same as 2008 and up from 450,000 hectares in 2007. There is almost certainly a potential for utilizing biotech maize for economic, environmental and social benefits because its neighbor Argentina is already benefiting from Bt and herbicide tolerant maize, as well as the stacked product. Paraguay was also expected to grow 50,000 hectares of cotton in 2009, which could also benefit significantly from the biotech traits used in cotton in the neighboring countries of Argentina and Brazil.

PARAGUAY

Population: 6.5 million

GDP: US$14 billion

GDP per Capita: US$2,140

Agriculture as % GDP: 23%

Agricultural GDP: US$3.74 billion

% employed in agriculture: 26.7%

Arable Land (AL): 4.3 million hectares

Ratio of AL/Population*: 3.0

Major crops:
- Cassava
- Soybean
- Sugarcane
- Maize
- Wheat

Commercialized Biotech Crop: HT Soybean

Total area under biotech crops and (%) increase in 2009:
2.2 Million Hectares (-19%)

Farm income gain from biotech, 2004-2007: US$500 million

*Ratio: % global arable land / % global population

Benefits from Biotech Crop in Paraguay

Paraguay is estimated to have enhanced farm income from biotech soybean by US$503 million in the period 2004 to 2008 and the benefits for 2008 alone is estimated at US$59 million (Brookes and Barfoot, 2010, forthcoming).

SOUTH AFRICA

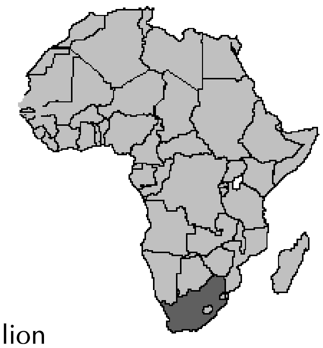
The planting of biotech crops for the 2009/2010 season was well underway when this Brief went to press and the area occupied by biotech crops in 2009 continued to increase. The estimated total biotech crop area in 2009 was 2.1 million hectares, up from 1.8 million hectares in 2008 and equivalent to a year-over-year growth rate of 16.1%. Growth in 2009 was mainly attributed to an increase in biotech maize area from 1.617 to 1.878 million hectares, with the adoption rate increasing from 62% in 2008 to 78% of total maize area in 2009. Approximately 8.0 million hectares (7,984,000) of biotech maize (white and yellow) were planted in the 10 year period 2000 to 2009. Coincidentally, the total area planted to soybeans increased from 230,000 hectares in 2008 to 270,000 hectares in 2009 and the adoption rate of herbicide tolerant soybeans increased from 80 to 85%. Consistent with global trends, the total cotton area continued to decline slightly but its biotech adoption rate increased from 92 to 98%. A new range of biotech traits for maize, soybean and cotton, as well as new biotech crops are also being field-tested.

South Africa is a typical case of science and technology preceding the evolution of policies and legislation. Scientists alerted government re the advent of a new generation of genetic biotechnologies and in 1978, established a voluntary advisory committee to guide both government and industry. This South African Genetic Experimentation committee (SAGENE) issued a booklet on biosafety in early 1990 to serve as a guideline in anticipation of the first Bt cotton trials. Government accepted this document and in combination with the Agricultural Plant Pests Act and other relevant regulations, ensured safe handling of GMOs. SAGENE was provided with a small office at the Foundation for Research Development and received statutory status in 1992. After monitoring the GMO regulatory developments in other countries, the Department of Agriculture commenced drafting the GMO Act which was approved by Parliament in 2007.

The GMO Act aims at striking a balance between minimizing potential risks while creating an enabling environment for responsible research and development, and application of GMOs. It regulates all genetic modification activities on all organisms, from registration of facilities up to trade. The secretariat is housed in the Department of Agriculture. Decision making, on behalf of the Minister of Agriculture, is vested in the GMO Executive Council that comprises one senior official from each of the six government departments and the chairperson of the National Advisory Committee of scientists (having replaced SAGENE). Sub-committees and independent reviewers are used on a case-by-case basis. The Act was amended in 2006 to improve the clarity of the text and to include certain provisions to meet requirements under the Cartagena Protocol on Biosafety. Decisions by the Executive Council are largely handled on the basis of applications for permits of which there are some 11 variations.

The GMO Act was followed by the National Biotechnology Strategy published in 2001. The foresight project in the Department of Science and Technology had identified information technology, nano- and material technologies and biotechnology as the main drivers of future economies. The strategic plan acknowledged that the country "had failed to extract value from the more recent advances in biotechnology, genetics and genomics." It identified the valuable contribution that biotechnology can make to human health, food security, and environmental sustainability. Three biotechnology regional innovation centers were established for human health, bio-processing and industrial biotech, while a fourth centre was later added for plant biotechnology. Their present activities include research on genomics, proteomics, biopharma discovery, drug delivery systems, vaccine development, liquid fermentation, bio-processing, in vitro cell cultivation, bacterial production systems, bio-control products, new Bt and other bacterial products for agriculture, and various conventional biotechnologies. The onset of the 2009/2010 cropping season has been complicated by many uncertainties, including crop credit, low commodity prices and the high cost of farming inputs. It is estimated that 2.4 million hectares of maize was planted in 2009 at a ratio of 64% white grain (a small positive shift) or 1.536 million hectares and 36% yellow grain or 0.864 million hectares. Of the total maize area, 78.3% or 1.878 million hectares was biotech, significantly up 16% from 62% or 1.617 million hectares in 2008/2009. Of the 1.878 million hectares of biotech maize 70% or 1.309 million hectares were the single Bt gene events, 14% or 270,716 hectares herbicide tolerant, and 16% or 298,160 hectares with stacked Bt and herbicide tolerant genes (Table 31). Approximately 8 million hectares (7,984,000) of biotech maize (white and yellow) have been planted in the 10 year period 2000 to 2009, producing a grain crop of over 20 million MT up to the 2009 harvest without

SOUTH AFRICA



Population: 47.7 million

GDP: US$283 billion

GDP per Capita: US$ 5,910

Agriculture as % GDP: 3.2%

Agricultural GDP: US$9.06 billion

% employed in agriculture: 8%

Arable Land (AL): 14.6 million hectares

Ratio of AL/Population*: 1.3

Major crops:

- Sugarcane
- Maize
- Wheat
- Grapes
- Potato

Commercialized Biotech Crops:

- HT/Bt/HT-Bt Cotton
- HT/Bt/HT-Bt Maize
- HT Soybean

Total area under biotech crops and (%) increase in 2009:
2.1 Million Hectares (+17)

Farm income gain from biotech, 1998-2008: US$500 million

*Ratio: % global arable land / % global population

any report of negative effects on humans, animals or the environment. The yield benefit to farmers from the Bt trait over this period amounted to US$376 million (Wynand Van der Walt, Personal Communication, 2009).

Table 31. Adoption of Biotech Crops in South Africa, 2001 to 2009 (Thousand Hectares)

Year	Total area of biotech crops (maize, soybean, cotton)	Total area of biotech maize	Total area of biotech white maize (% of total white maize area)	
2001	197	166	6	(<1%)
2002	273	236	60	(3%)
2003	404	341	144	(8%)
2004	573	410	147	(8%)
2005	610	456	281	(29%)
2006	1,412	1,232	704	(44%)
2007	1,800	1,607	1,040	(62%)
2008	1,813	1,617	891	(56%)
2009	2,116	1,878	1,212	(79%)
Total	**9,198**	**7,943**	**4,485**	

Source: Compiled by ISAAA, 2009.

The white maize sector comprises 78.9% biotech or 1.212 million hectares with the single Bt gene accounting for 983,366 hectares (81%), herbicide tolerance 117,159 hectares (10%) and Bt/herbicide tolerance stacks at 111,187 hectares (9%). This sudden reverse trend in the adoption of stacked products from the previous season's 18% was caused by a shortage of seed in 2009. If white stacked maize seed had been available, the demand would have amounted to at least 30% of the total biotech maize and it is expected that the single Bt trait will lose ground rapidly. The yellow maize planting of 864,000 hectares comprised 77.1% or 666,403 hectares of biotech, up from the 72% of the previous season. The biotech breakdown by trait for yellow maize is 49% or 325,865 hectares for the single Bt trait, 23% or 153,565 hectares for herbicide tolerance, and 28% or 186,973 hectares for the stacked Bt and herbicide tolerant product.

The official maize variety list includes 446 entries (hybrids and open-pollinated) including 93 biotech hybrids equivalent to 21% of the total list of entries.

A few isolated cases of apparent resistance of the African maize stalk borer to MON 810 Bt gene were investigated over the last two years, most but not all in high density irrigated fields. It appeared that non-compliance with mandatory refugia planting may have played a role. This situation has been monitored and studied by biotech seed companies in collaboration with senior entomologists from the Agricultural Research Council - Institute for Grain Crops and the Northwest University in Potchefstroom. The standard practice was to apply insecticide whenever escapes or tolerance were observed. Recently all stakeholders participated in a small government workshop on this issue. Key recommendations were: companies to enforce compliance with refugia, government monitoring, use of stacked Bt genes, and alternate Bt genes.

Soybean planting is estimated to have grown by 10% in 2009 to reach 270,000 hectares. The herbicide tolerance trait has worked well with adoption close to saturation. Herbicide tolerance adoption in soybean is estimated at 85% or 229,500 hectares of the total area planted. Of the 66 soybean varieties listed for 2009, 18 or 27% were biotech.

Cotton production has also been subject to higher input costs, uncertainties on credit and low seed cotton prices in local currency, the Rand having gained some 25% since January 2009 versus the US$. Irrigated cotton production faces competition from maize and vegetables, while dry-land cotton is considered risky by commercial farmers. The anticipated low hectarage planted in 2009 will exceed 8,300 hectares only if subsistence farmers get timely government financial support. The area is expected to be 98% biotech cotton made up of 75% stacked with a single Bt and herbicide tolerance, down slightly from 2008/2009, 10% Bt, 10% herbicide tolerance, and 3% herbicide tolerance with stacked double Bt genes. Conventional cotton used as refugia comprises barely 2% as most refugia are planted to RR® trait for Bt fields. The official variety list includes 9 biotech varieties equivalent to 25% of the 36 total approved varieties.

There were 229 GMO permits approved in 2008, down from 272 in 2007. Around 84% is for maize grain and seed imports and exports (LMOs in terms of the Protocol). Biotech seed imports amounted to 5,581 metric tons (MT) while 3,430 MT were exported; the balance of permits were small samples for multiplication, breeding, trials and contained use. The other 16% dealt with other crop species, as well as microbes and GM vaccines for clinical trials. For the period January to September 2009, some 267 permits were issued. Permits for maize dominated applications with 222 approvals (83%), followed by 24 permits for cotton, 15 for vaccines, 3 for soybeans, and one each for sugarcane, sorghum and table grapes. Most permits for maize involved commercial seed for planting or for research, multiplication, trials, or contained use, and none for commodity maize. There were 80 permits for imports and 121 for exports. Commercial seed consignments sales amounted to 377 MT imports and 8,586 MT exports. These statistics show a strong increase in reciprocal trade or exchange of maize seed for commercial, research or off-season production objectives. It should be noted that

GMO-LMO imports require two permits; one for import and the other for conducting trials, clinical trials or contained use. South Africa does not distinguish between confined and open field trials in permit application. It is also noteworthy that South Africa remains an active exporter of conventional (not indicated in permits) and exporter of GM cotton seed. As of September 2009, 215 MT of GM cotton seeds were exported (compared with 74 MT in 2008/2009) and only 3 MT imported.

Field trials approved for 2009/2010 include the following:

1. Maize: Drought tolerance trials to continue, stacked Bt genes, various stacked Bt – herbicide tolerance, stacked herbicide tolerance, ,
2. Cotton: BG®II x GlyTol x LLC25, Twinlink (IR-HT), LLGlytol x LL 25, Twinlink x Glytol, BG®II x LL25, GHB, RR®Flex.
3. Sorghum: African Biofortified Sorghum (in greenhouse)
4. Table grape: Fungal resistance to test gene expression (grapes do not set berries in greenhouse)
5. Sugarcane: Two types of alternative sugars
6. Cassava: Altered starch (in green house)

FARMER TESTIMONIES:

Farmer Patrick Buda and wife Sarah on their Bt white maize at Bapsfontein:

"This hectare has produced so much maize that we have sufficient food for one year and enough over to give to our neighbours. It is the first time that we have planted Bt maize. There is no stalk borer damage. The yield is so good that we will continue to plant it in future."

Andrew Kona planted trials with Bt and conventional maize at Bronkhorstspruit.

"I have been farming for 14 years. It is the first time that I planted Bt maize and I am convinced that it is the way to go for small-scale farmers. It is not vulnerable to stalk borer."

Clive Sekgobela, a smallholder farmer at Bronkhorstspruit.

"Just look at my maize. I have never seen anything like this before."

Richard Sithole, farmer from KwaZulu-Natal province, in his presentation at the FANRPAN regional stakeholders meeting held in Maputo, Mozambique, with 200 delegates in attendance.

"I have farmed 15 hectares of maize with Bt and stacked genes and plan to increase my planting next year. I am happy with my success with this technology."

In response to a question from a delegate on whether he was feeding his family with Bt maize, he replied: ***"My family, myself, my chickens and my animals all eat this maize and there has been no ill effect."*** He then added, ***" Just look at my face and see how healthy I am."***

Benefits from Biotech crops in South Africa

South Africa is estimated to have benefited US$507 million over the period 1998 to 2008 and US$119 million in 2008 alone.

URUGUAY

Uruguay increased its biotech plantings of soybean and maize to 790,000 hectares in 2009, an increase of approximately 12%, and importantly, has also lifted the moratorium for consideration of new events, in place since 2005. Seven new events have been submitted for approval in 2009.

Uruguay, which introduced biotech soybean in 2000, followed by Bt maize in 2003 increased its biotech crop area once again in 2009 to reach 790,000 hectares, up by approximately 15.3% from 2008, with the entire gain coming from biotech soybean. A significant increase was recorded in the hectarage of herbicide tolerant soybean which now occupies 100% of the national soybean hectarage of 700,000 hectares, compared with 545,000 hectares in 2008.

Bt maize which Uruguay first approved in 2003, occupied 90,000 hectares, down from 110,000 hectares in 2008, and occupied 82% of the total maize plantings of 110,000 hectares in 2009. Farmers have switched from maize to RR®soybean because it is more profitable than maize and the cost of production is also lower.

Importantly, the moratorium for consideration of new events, in place since 2005, has been lifted and a government Commission has been established to consider approval of new events. New single and stacked trait events have been submitted for approval consideration by the Commission.

Benefits from Biotech Crops in Uruguay

Uruguay is estimated to have enhanced farm income from biotech soybean and maize of US$52 million in the period 2000 to 2008 and the benefits for 2008 alone is estimated at US$8 million (Brookes and Barfoot, 2010, forthcoming).

URUGUAY

Population: 3.3 million

GDP: US$34 billion

GDP per Capita: US$ 10,220

Agriculture as % GDP: 11%

Agricultural GDP: US$1.2 billion

% employed in agriculture: 10.8%

Arable Land (AL): 1.35 million hectares

Ratio of AL/Population*: 1.8

Major crops:
- Rice
- Maize
- Soybean
- Wheat
- Barley

Commercialized Biotech Crops:
- HT Soybean
- Bt Maize

Total area under biotech crops and (%) increase in 2009:
0.8 Million Hectares (+14%)

Farm income gain from biotech, 2000 to 2008: US$52 million

*Ratio: % global arable land / % global population

BOLIVIA

In 2008, Bolivia became the tenth country to officially grow RR®soybean. In 2009, it is estimated that 750,000 hectares (~0.8) of RR®soybean was planted in Bolivia, compared with 600,000 hectares in 2008 – a significant 25% increase in area. The adoption rate for RR®soybean hectarage in Bolivia in 2009 is equivalent to 78% of the total national hectarage of 960,000 hectares, up from 63% in 2008.

Bolivia is a small country in Latin America with a population of 10.1 million and a GDP of approximately US$20 billion. Agriculture contributes approximately 14% to GDP and employs just over 39.7% of the total labor force. Agriculture in the eastern Amazon region of Bolivia benefits from rich soils and modern agriculture, which is in contrast to the traditional subsistence farming in the mountainous west of the country. There are approximately 2 million hectares of cropland,

BOLIVIA

Population: 10.1 million

GDP: US$20 billion

GDP per Capita: US$1,940

Agriculture as % GDP: 14%

Agricultural GDP: US$2.8 billion

% employed in agriculture: 39.7%

Arable Land (AL): 3 million hectares

Ratio of AL/Population*: 2.0

Major crops:
- Soybean
- Maize
- Coffee
- Cocoa
- Sugarcane
- Cotton
- Potato

Commercialized Biotech Crop: HT Soybean

Total area under biotech crops and (%) increase in 2009:
0.8 Million Hectares (+33%)

Farm income gain from biotech, 2008: US$ 52 million

*Ratio: % global arable land / % global population

and soybean is a major crop in the eastern region. In 2007, Bolivia grew approximately 1 million hectares of soybean (960,000 hectares) with an average yield of 1.97 tons per hectare to generate an annual production of 2 million tons. Bolivia is a major exporter of soybeans (approximately 5% of total exports) in the form of beans, oil, and cake.

Certified seed in Bolivia in 2009

It is not a well recognized fact that the seed industry business in Bolivia is exemplary in the organization and use of certified seeds. In 2008, the percentage of certified soybeans in Bolivia reached a high of 75% despite the fact that in Bolivia there is a tradition, which is constantly changing, for smaller farmers to save their own soybean seed. However, smaller farmers are becoming increasingly aware of the benefits associated with certified seed and are adopting it within their traditional farming systems, resulting in a high level of adoption of 75% in 2008. At the national level and at the Santa Cruz State level, Bolivia has well organized extension programs that provide technical assistance to seed producers regarding the value of high quality certified seed with a focus on the significant benefits it offers smaller low-income farmers. The presence of an effective and efficient certified seed industry in Bolivia greatly facilitates access and adoption of certified RR®soybean seed which is used not only by the larger farmers but increasingly by smaller subsistence farmers.

IFPRI reports that 97% of the soybeans are grown in Santa Cruz where most of the producers are relatively small farmers (classified as less than 50 hectares), although the majority of the production is by larger farms. RR®soybean was grown on 750,000 hectares or 78% of the estimated total hectarage of 960,000 hectares of soybean planted in Bolivia in 2009.

According to the most recent data on global hectarage of soybean (FAO, 2007), Bolivia ranks eighth in the world with 960,000 hectares, after the USA (30.5 million hectares), Brazil (20.637), Argentina (16.1), China (8.9), India (8.5), Paraguay (2.3), and Canada (1.2). Of the top eight soybean countries, five (USA, Argentina, Brazil, Paraguay and Canada) grow RR®soybean.

In 2008, Bolivia became the tenth soybean country to officially grow RR®soybean. In 2008, 600,000 hectares of RR®soybean were planted in Bolivia, equivalent to 63% of the total national hectarage of 960,000 hectares. RR®soybean has been adopted on extensive hectarages in Bolivia's two neighboring countries of Brazil (over 16 million hectares) and Paraguay (over 2 million hectares) for many years.

Benefits from RR®soybean in Bolivia

Table 32. Partial Budget for Production of RR®soybean and its Conventional Equivalent in Bolivia

Variable	Non-RR	RR
Yield (t/ha)*	1.47	1.91
Price (US$/t)*	409.32	398.59
Gross Benefit (US$/ha)*	600.26	780.83
Costs (US$/ha)		
Seed	23.46	26.78
Herbicides	41.53	32.25
Insecticides	21.34	24.12
Fungicides	37.93	37.86
Labor cost for chemical input application	4.98	5.03
Machinery	55.02	52.13
All other labor costs*	3.50	2.25
Other variable costs	161.74	146.67
Net Benefits (US$/ha)*	436.53	632.54
Difference RR – non RR (US$/ha)		196.01

Source: IPFRI Annual Report, Paz *et al*, 2009.

Paz et al. 2008 noted that Bolivia is one of the few countries in Latin America where there is a significant number of small farmers producing soybeans. In Bolivia, soybeans are important, contributing 4.6% of GDP and 10% of total exports. Paz et al. (2008) noted that despite the lack of government incentive, RR®soybeans continue to expand because cost-benefit analysis favors RR®soybean over conventional. More specifically, the partial budget analysis (Table 32) indicates that the net benefits favor RR®soybean over conventional, which is approximately US$200 (US$196) per hectare (Table 32). The principal benefits, include a 30% increase in yield, a 22% savings on herbicides and more modest savings in labor and other variable costs; in some cases cost of RR® seed was lower than conventional seed. Based on a net return of US$196 per hectare with 750,000 hectares of RR®soybeans, the 2009 benefits at the national level were of the order of approximately US$150 million, which is a significant benefit for a small poor country such as Bolivia.

PHILIPPINES

In 2009, the area planted to biotech maize in the Philippines is projected to increase to 490,000 hectares, up by 40% from the 350,000 hectares of biotech maize in 2008. Notably, the area occupied in 2009 by the stacked traits of Bt/HT maize is 338,000 hectares, compared with only 200,000 hectares in 2008, up by a substantial 69% reflecting the preference of farmers for stacked traits and the superior benefits they offer over single traits.

The adoption of biotech maize in the Philippines has increased consistently every year since it was first commercialized in 2003. The area planted to biotech maize was projected to significantly increase in the wet and dry seasons in 2009 to reach 490,000 hectares, up by 40% from the 350,000 hectares of biotech maize in 2008 (Figure 29). Notably, the area occupied by the stacked traits of Bt/HT maize has continuously increased every year reaching 338,000 hectares in 2009, compared with only 200,000 hectares in 2008, up by a substantial 69% reflecting the preference of farmers for stacked traits and the superior benefits they offer over single traits. This shift in farmers' preference from single trait maize to those with combined traits has been observed since their introduction in 2006. The total area planted to the single trait Bt maize was down by more than 32% in 2009, equivalent to 54,000 hectares compared to last year's 80,000 hectares. Herbicide tolerant (HT) maize was planted on 98,000 hectares in 2009, an increase of about 40% from 2008 and almost equivalent to the area planted in 2007. On a percentage basis, biotech yellow maize has consistently increased by about 5% of the total yellow maize hectarage every single year from the first year of commercialization in 2003, reaching the highest ever level of 38% in 2009 (up from 26.7% in 2008). Consistent with the experience of other biotech maize growing countries the year-by-year steady increase in adoption of biotech maize reflects the significant and consistent benefits generated by biotech maize to farmers in the Philippines.

PHILIPPINES

Population: 85.9 million

GDP: US$144 billion

GDP per Capita: US$1,640

Agriculture as % GDP: 14.1%

Agricultural GDP: US$20.2 billion

% employed in agriculture: 37.1%

Arable Land (AL): 5.7 million hectares

Ratio of AL/Population*: 0.4

Major crops:

• Sugarcane	• Maize	• Pineapple
• Coconut	• Banana	• Mango
• Rice	• Cassava	

Commercialized Biotech Crop: Bt/HT/Bt-HT Maize

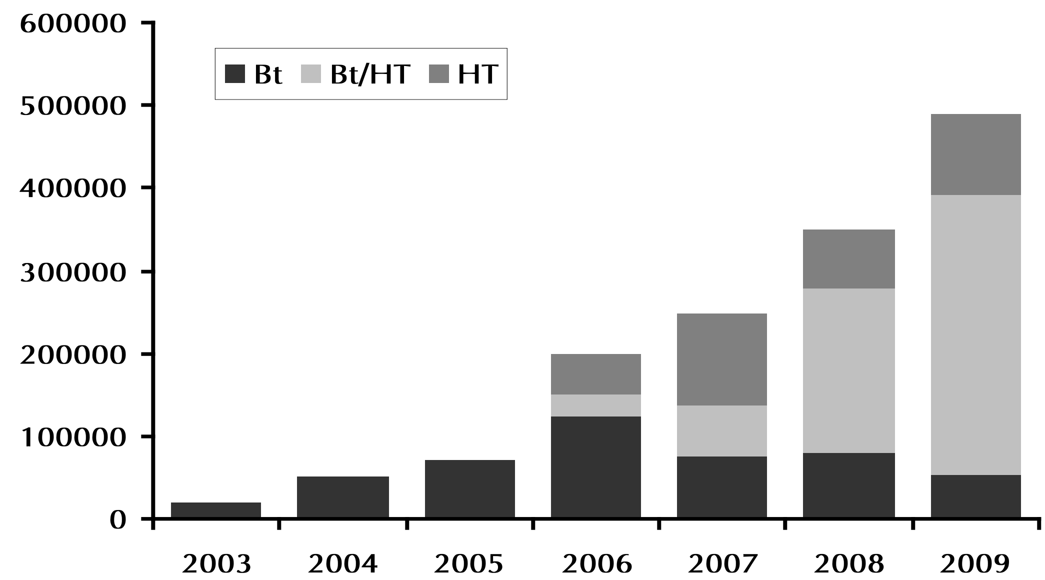
Total area under biotech crops and (%) increase in 2009:
0.5 Million Hectares (+25%)

Increased farm income for 2003-2008: US$88 million

*Ratio: % global arable land / % global population

The number of small resource-poor farmers, growing on average 2 hectares of biotech maize in the Philippines in 2009, was estimated at 250,000, up significantly by 75,000 from 175,000 in 2008. A total of five events of biotech maize are approved for commercial planting in the Philippines: MON810 for insect resistance (first approved in 2002 and the approval was renewed in 2007), NK603 for herbicide tolerance (2005), Bt11 for insect resistance (2005), the stacked gene product of MON810/NK603 (2005), and this year, the stacked trait GA21 for herbicide tolerance. In addition, a total of 19 stacked trait maize and cotton products have been approved for importation for direct use as food, feed and for processing. Among these include the triple stacked maize with MON863/MON810/NK603 approved in 2005 and maize with DAS59122/TC1507/NK603 approved in 2007. A total of 49 biotech crops and products are currently approved for direct use as food, feed and for processing. The future acceptance prospects for biotech crops in the Philippines look very promising with products also being developed by national and international institutes. These are Golden Rice, and biofortified rice that are being developed by the Philippine Rice Research Institute (PhilRice) and the International Rice Research Institute (IRRI). The Golden Rice of IRRI was tested in advanced field trials in the Philippines in 2008. It is expected that field trials of the Golden Rice being developed by PhilRice will be planted soon. In addition to the trait for pro-Vitamin A, the biotech rice of PhilRice, also dubbed as a '3-in-1' rice, incorporates resistance to tungro virus and to bacterial blight diseases (Pablico, 2008; Icamina, 2008).

Figure 29. Increase in Hectarage Traits of Biotech Maize in the Philippines and Proportion of Commercialized Traits, 2003 to 2009.



Source: Compiled by ISAAA, 2009.

The fruit and shoot borer resistant eggplant and biotech papaya with delayed ripening and PRSV resistance being developed by the Institute of Plant Breeding at the University of the Philippines Los Baños (IPB-UPLB) have already been tested in confined field trials. The multi-location field trials of the biotech eggplant are expected to commence in 2010. New initiatives in other crops include the development of a virus resistant sweet potato through collaborative activities between the Visayas State University (VSU) and IPB-UPLB and the initial efforts to generate transgenic lines of virus resistant abaca (*Musa textilis*) by the Fiber Industry Development Authority (FIDA) in collaboration with the University of the Philippines. The Philippine Department of Science and Technology and the Department of Agriculture Biotechnology Program Office have been very supportive of research and development activities on biotech crops and have been eager to support the products that will emerge from the R&D pipeline for commercialization in the near term.

It is important to note that the Philippines is the first country in the ASEAN region to implement a regulatory system for transgenic crops; the system has also served as a model for other countries in the region. The Philippine biotechnology regulatory system was formalized with the issuance of Executive Order No. 430 in 1990 establishing the National Biosafety Committee of the Philippines

(NCBP). In 2008, the country launched its national biosafety clearinghouse, BCH Pilipinas, to serve as the Philippine node of the Biosafety Clearing-House mechanism established under the Cartagena Protocol on Biosafety. Among the new government policies in 2009 is the Department of Agriculture's Administrative Order adopting the Codex guidelines on food safety assessment in situations of low level unintentional presence of recombinant DNA plant materials in food and feed. The Philippines, which grows approximately 2.6 million hectares of maize is the only country in Asia to approve and grow a major biotech feed crop; moreover, the Philippines achieved a biotech mega-country status with biotech maize in 2004, i.e. 50,000 hectares or more. Asia grows 32% of the global 158 million hectares of maize with China itself growing 29 million hectares, plus significant production in India (7.8 million hectares), Indonesia (3.6 million hectares), Philippines (2.7 million hectares), and Vietnam, Pakistan and Thailand (each with about 1 million hectares) (FAO, 2009).

Benefits from Biotech Crops in the Philippines

The benefits of biotech maize to Filipino farmers' livelihood, income, the environment and health have been well studied and documented. Farms planting Bt maize in the Northern Philippine provinces have significantly higher populations of beneficial insects such as flower bugs, beetles, and spiders than those planted with conventional hybrid maize (Javier et al. 2004).

The farm level economic benefit of planting biotech maize in the Philippines in the period 2003 to 2008 is estimated to have reached US$88 million. For 2008 alone, the net national impact of biotech maize on farm income was estimated at US$49 million (Brookes and Barfoot, 2010 forthcoming).

Other studies report that gain in profit at the farmer level was computed at 10,132 pesos (about US$180) per hectare for farmers planting Bt maize with a corresponding savings of 168 pesos (about US$3) per hectare in insecticide costs (Yorobe and Quicoy, 2006). In another socio-economic impact study (Gonzales, 2005), it was reported that the additional farm income from Bt maize was 7,482 pesos (about US$135) per hectare during the dry season and 7,080 pesos (about US$125) per hectare during the wet season of the 2003-2004 crop year. Using data from the 2004-2005 crop year, it was determined that Bt maize could provide an overall income advantage that ranged from 5 to 14% during the wet season and 20 to 48% during the dry season (Gonzales, 2007). Overall, the four studies which examined net farm income as well as other indicators, confirmed the positive impact of Bt maize on small and resource-poor farmers and maize producers generally in the Philippines.

The projected benefits from other biotech crops nearing commercialization, such as the Golden Rice could be higher than maize at US$88 million per year (Zimmermann and Qaim, 2004), while benefits from Bt eggplant are projected at almost nine million pesos (about US$200,000) (Francisco, 2007). The benefits from Golden Rice are derived from gains due to reduced mortality and reduced disability. Benefits from Bt eggplant include higher income from higher marketable yields, reduction in insecticide use by as much as 48%, and environmental benefits associated with less insecticide residue in soil and water and the protection of beneficial insects and avian species. Bt eggplant adoption could result to savings of about 2.5 million pesos (about US$44,414) in human health costs, and 6.8 million pesos (about US$120,805) in aggregated projected benefits for farm animals, beneficial insects, and avian species (Francisco et al. 2009). For the virus resistant papaya, a substantial increase in the farmer's net income is projected, with expected returns of up to 275% more than conventional papaya (Yorobe, 2006).

Other recently completed ex-ante studies in Bt cotton and abaca (*Musa textilis*) indicate significant potential social and economic benefits. These studies were conducted to assist Philippine policy makers decide whether the development and commercialization of these biotech crops in the country is a sound investment. Chupungco et al. (2008) has concluded that Bt cotton commercialization in the Philippines will improve yield by about 20% with a return on investment (ROI) of between 60-80%, compared to 7-21% when using conventional varieties. The biotech abaca resistant to abaca bunchy top virus (ABTV), abaca mosaic virus (AbaMV) and bract mosaic virus (BrMV), were estimated to be able to provide an additional increase in yield of 2.5 tons per hectare and 49.36% ROI after 10 years (Dumayas et al. 2008).

In summary, the Philippines has already gained US$88 million from biotech maize in a short span of five years, 2003 to 2008, and is advancing the adoption of the maize stacked traits, Bt/HT, faster than any other biotech maize-growing developing country. In 2009, stacked traits in maize represented almost 75% of the total biotech maize area in the Philippines. Future prospects look encouraging, with several "home grown" biotech products likely to be commercialized in the next 3 years including Bt eggplant, biotech papaya, and with a reasonable possibility that the Philippines might be the first country to commercialize Golden Rice around 2012.

Stakeholder Experiences

Emil Q. Javier, President of the National Academy of Science and Technology (NAST), former President of the University of the Philippines, and Minister of Science, says ***"Much of this was made possible through collective leadership, a strong group of scientists who believed in transgenics for modern agriculture, and government support,"*** referring to the several Philippine biotech products in the pipeline such as Bt eggplant, virus-resistant and delayed ripening papaya, Golden Rice, blight resistant rice, and virus resistant abaca (Navarro, 2009).

Fr. Emmanuel Alparce, vice rector of the Dulce Nombre de Maria Cathedral Basilica in Guam, and former executive director of the Social Action Center (SAC) of Sorsogon province in the Philippines, says ***"I was a defender of biotechnology even in many countless conferences that I would be attending. I would vocally defend on the side of morals."*** Father Noli is among the religious group of stakeholders who believes that biotechnology is a moral imperative because it addresses problems of poor farmers and it has a lot of potential in positively impacting humanity (Navarro, 2009).

Edwin Paraluman, corn farmer in South Cotabato province in the Philippines, narrated that ***"Many anti-biotech groups are neither farmers nor have direct experience in agriculture. I started planting cotton ever since I was a small boy. I have been planting corn for a long time, even before the advent of Bt corn. I know how it feels to be at the mercy of the Asian corn borer and reaping almost nothing from a corn field due to infestation. My family always got poor quality grain and small milling recovery with traditional corn due to corn borer. Even rampant spraying did not solve the problem. Yield reduction with non Bt-corn is around 70 percent. I also found health problems because of what we spray. We found it (pesticides) really hazardous. Farmer's health suffered. I tried Bt corn and my yield increased from 3.5 tons per hectare to a high of 8 tons per hectare. My life changed."*** Mr. Paraluman was among the first to inquire about the technology when it was introduced in their province. He has become a strong advocate of biotechnology in the Philippines pushing for farmers to have options in the type of crops they are planting (Panopio, 2009).

AUSTRALIA

In 2009, Australia grew approximately 230,000 hectares of biotech crops, comprising 190,000 hectares of biotech cotton, (up from 150,000 hectares in 2008), approximately 40,000 hectares of biotech canola (up four-fold from 10,000 hectares in 2008). In 2009, a remarkable 94% of all the cotton grown in Australia was biotech and 83% of it featured the stacked genes for insect resistance and herbicide tolerance. Thus, total biotech crop hectarage is approximately 43.75% more than the 160,000 hectares grown in 2008, and represents a four-fold increase over the 48,000 hectares of biotech crops in 2007 during which Australia suffered a very severe drought which continued in 2008 and to a lesser degree in 2009 when the country was still recovering from the multi-year drought which is the worse on record in Australia.

AUSTRALIA

Population: 20.6 million

GDP: US$821 billion

GDP per Capita: US$39,070

Agriculture as % GDP: 3.4%

Agricultural GDP: US$27.9 billion

% employed in agriculture: 3%

Arable Land (AL): 46.1 million hectares

Ratio of AL/Population*: 10.0

Major crops:
- Wheat
- Sugarcane
- Cotton
- Barley
- Fruits

Commercialized Biotech Crops:
- Bt/Bt-HT Cotton
- HT/F/HT-F Canola

Total area under biotech crops and (%) increase in 2009:
0.2 Million Hectares (0%)

Farm income gain from biotech, 1996-2008: US$224 million

*Ratio: % global arable land / % global population

Australia is the fifth member of the six "founder biotech crop countries", having commercialized Bt cotton in 1996, the first year of global commercialization of biotech crops. Australia was expected to plant 230,000 hectares of biotech crops in 2009, 43.75% more than 2008 and five-fold more than the 48,000 hectares in 2007. The biotech crop hectarage of 48,000 hectares in 2007 was significantly less than Australia's previous normal biotech crop plantings of over 200,000 hectares. The unusually low plantings of biotech crops in 2007 were due to the effects of the severe droughts in 2006 and 2007 which continued to have an impact in 2008 – this was the worst drought that Australia has experienced. As a result, there is continuing uncertainty amongst cotton growers regarding irrigation supplies, and dry-land growers will be completely dependent on late rains for planting. Assuming 200,000 hectares of cotton in 2009, the overall percentage adoption of biotech cotton in 2009 was expected to be 94%, similar to 2008. In 2009, 83% of all cotton in Australia featured the stacked genes for herbicide tolerance and insect resistance (RR® or RR®Flex and Bollgard®II); 3% with the Bollgard®II dual Bt genes, compared with 4% in 2008; 8% with a single gene for herbicide tolerance including RR®, RR® Flex or Liberty Link®, and the remaining 6% in conventional cotton, the same as 2008.

The Australian biotech cotton program is extremely well managed and it is to the credit of Australia that it achieved complete substitution of the single Bt gene product (Bollgard®I) with the dual Bt gene varieties (Bollgard®II) in only two years, 2002/03. This greatly accelerated and enhanced the stability of Bt resistance management, which simultaneously benefited from better and more reliable protection against the major insect pests. In 2002-2003, there was a limitation in place on the percentage of Bt cotton allowed to be planted in Australia. In 2003-2004, the single Bt gene product was restricted to 15% on any farm in Australia and the combined area of the single and dual gene Bt products was restricted to a maximum of 40%. With the introduction of the dual Bt gene product (Bollgard®II) in Australia, these deployment limitations that applied to the single gene product because of concern related to the deployment of resistance to the single Bt gene, were lifted.

In 2009, Australia, for the second time, grew herbicide tolerant RR®canola in two states, New South Wales (NSW) and Victoria. According to the Australian Oilseeds Federation, an estimated 1.249 million hectares of canola were grown in Australia in 2009 of which 459,000 hectares equivalent to 37% of the national total were grown in the two states of NSW and Victoria (Table 33). Victoria grew an estimated 219,000 hectares of canola in 2009 of which 28,840 hectares or 13% were RR®canola – this is a six-fold increase over the 4,750 hectares grown in 2008 which represented only 2%. In NSW, 240,000 hectare of canola were grown in 2009, of which 12,360 hectares were RR®canola – this is more than a doubling of the 4,750 hectares planted in 2008 which represented only 2% adoption. At the national level RR®canola adoption in Australia has increased four-fold from the 9,500 hectares in 2008 (1% adoption) to 41,200 hectares in 2009 representing a 3% adoption at the national level (Table 33) compared with 1% in 2008. Thus, there has been almost a quadrupling of percentage adoption rates (<1% to >3%) and in absolute hectarage an increase from (9,500 hectares to 41,200 hectares), in only the second year of commercialization in 2009. In November 2008, Western Australia lifted a ban on the commercial growing of biotech cotton in the Ord River Irrigation area that would be worth more than US$50 million per year (Australian Broadcasting Corporation [ABC] News, 2008). Western Australia (WA) which grows approximately half (610,000 hectares) the total hectarage of canola in Australia (1.2 million hectares), is also considering "a pathway towards commercial trials of canola". When the State ban on biotech canola in WA is lifted, this, along with hectarage in NSW and Victoria would release up to 85% of the canola hectarage in Australia to biotech herbicide tolerant canola.

Table 33. Hectares of Canola, Conventional and RR Biotech, Planted in Australia, by State, 2008 and 2009.

State	Total Canola (ha)		Biotech Canola (ha)		Biotech Canola %	
	2008	2009	2008	2009	2008	2009
NSW	220,000	240,000	4,750	12,360	2%	5%
Victoria	220,000	219,000	4,750	28,840	2%	13%
South Australia	175,000	180,000	-	-	-	-
Western Australia	620,000	610,000	-	-	-	-
Total	1,235,000	1,249,000	9,500	41,200	1%	3%

Source: Compiled by Clive James, 2009 from Industry sources

It is instructive to review the adoption of biotech crops in Australia and trace the debate prior to the introduction of biotech canola in 2008. To date, Australia, through the Office of the Gene Technology Regulator (OGTR, 2009), has approved three crops for commercial planting: cotton, carnations and canola, with only one of these crops, biotech cotton, grown widely at this time, plus an initial hectarage of biotech canola in 2008; biotech carnation occupies a very small area which is not included in the global biotech crop hectarage. Despite a success story with biotech cotton in Australia, there was a continuing vigorous debate over herbicide tolerant canola which was approved by the federal OGTR in 2003 and until 2008 was banned from cultivation by all the major canola growing states in Australia through the implementation of moratoria by state governments. These bans by the states were instituted because of perceived potential market access restrictions for exports of biotech canola from Australia. However, most farmer groups opposed the ban because they believed it disadvantaged them and that Australian canola exports would suffer with long-term negative consequences.

Detection of low levels of biotech canola in conventional crops of canola in September 2005 in Australia refueled the initial debate amongst parties. The ban on biotech canola could have had negative implications for Australia in the USA-Australian Free Trade Agreement, signed in 2004. This trade agreement opens markets for Australian exports to the USA for manufactured products and services of US$270 billion, including a modest potential for agricultural products and services. In September 2006, the Federal Government initiated a campaign to try and convince the states to reconsider their decisions on banning canola because of the risk of Australia becoming non-competitive in canola. Elsewhere in the world, canola benefited from current biotech traits and will continue to do so when new traits become available in the future. Of particular concern for Australia, as a drought prone country was the significant advantage that competitors would gain when genes or drought tolerance would become available in biotech crops around 2010 and beyond.

In Australia, where biotech cotton has been very successfully grown for more than 10 years, there was growing support from the Federal Government and farmer organizations in 2007 to lift the state-level moratoria on commercialization of biotech canola. A 2007 Australian Bureau of Agricultural and Resources Economics (ABARE) Report by Apted and Kazur (2007) on the impact of commercializing biotech canola on organic producers in Australia concluded that there would be little or no effect, whereas the organic industry continued to oppose the commercialization of biotech canola in the absence of data to support their case. Australian farm organizations, including the apex body, the National Farmers Federation, supported the abolition of the biotech canola moratoria based on the following reasoning: Canada, the major producer of biotech canola globally, has consistently increased its world exports of biotech canola and increased its yield by over 15% in the last ten years, whereas in contrast, the area and yield of conventional canola in Australia had decreased. A reality check confirmed that conventional canola was not a preferred product over biotech canola in world export markets contrary to the views of those in Australia opposed to biotech canola – furthermore, there was no price premium in the export market for conventional canola. The ability to dry sow biotech canola and apply less herbicide over-the-top conferred a significant yield advantage due to a longer growing season and improved conservation of moisture – the latter can be a critical factor in Australia which is prone to severe drought.

The former Australian Minister of Agriculture **Peter McGauran** favored the lifting of the State bans on biotech canola and stated that, ***"Research is underway into the development of GM oil seed crops that produce healthier oils with better ratios of unsaturated fats, high levels of omega-3 oils which is normally sourced from fish, and increased levels of essential amino acids and vitamins. GM oils have the potential to cut production costs, increase product value and diversify the range of goods produced by the oilseed industry. With acceptance of such GM oil seed varieties, Australia would successfully compete with GM canola and soybean varieties currently produced overseas."*** A survey commissioned by Biotechnology Australia in 2007 indicated that biotechnology was gaining public favor with support for biotech crops increasing from 46% in 2005 to 73% in 2007 (Department of Innovation, Industry, Science and Research Report, 2008).

The increasing support from different segments of the community in Australia, including the federal Government, finally led to the lifting of the ban on biotech canola in the states of New South Wales (NSW) and Victoria where a total of 9,500 hectares of herbicide tolerant canola were grown for the first time in 2008. Notably in December 2008, Western Australia approved for the first time 20 biotech canola trials for 2009, totaling an area of 1,000 hectares. Australia has an active program of R&D in crop biotechnology, some of the highlights of which are summarized below.

Drought tolerant wheat

The Victorian Department of Primary Industries has field tested biotech wheat expressing candidate genes for drought tolerance over the 2007-2009 period. The trials were planted in Northern Victoria in a drought prone area that suffered significant crop losses due to severe drought in recent years. Lines of biotech wheat were identified in the field trials that yielded over 20% more than the controls under water stress. The stated goal of this important research effort is to develop and commercialize the world's first biotech wheat within the next 5 to 10 years. Given that water constraints is by far the most important constraint globally to increased productivity, the encouraging results from this research effort is extremely important (German Spangenberg, 2009. Personal Communication).

Panama disease of bananas

The Panama disease of bananas called "verticillium wilt" caused by the fungus *Verticillium* is an extremely important disease of bananas in the South East, threatens the northern territories of Australia, and Queensland is also at risk. A team of scientists from Queensland, led by Dr. Jim Dale has developed a transgenic biotech banana which has proven resistance to the disease when challenged with severe epidemics of the disease under greenhouse conditions. The resistance is conferred by a single gene in both Cavendish and lady finger bananas and field tests were planned to study the resistance under field conditions. Coincidentally, efforts are underway to increase the nutrition of bananas as well as resistance to Panama disease which is an endemic and important disease of bananas worldwide and is particularly important in developing countries where bananas are a staple food (ABC News, 2007).

GM perennial pasture grasses, rye grass and fescues

The first field trials of biotech /GM perennial pasture grasses, rye grass and fescues, were approved by the Federal Gene Regulator in October 2008. The trials featured biotech varieties which are more nutritious, have a reduced non-digestible content, could reduce the amount of feed required and could also help farmers survive drought (The Age, 2008).

Improving crop yield

At the University of Newcastle, Australia, Yong Ling Ruan discovered that deleting a gene from tomatoes allows the plant to produce sweeter and longer-lasting leaves, which can boost crop yield and shelf life (University of Newcastle, Australia, 2009). Scientists found genes that can feed millions). It is estimated that at least five more years are required to verify the value of the technology at the field level. The research is at a preliminary stage and further work needs to be completed to explore whether the technique could be applied to important commercial food, feed and fiber crops. The research is a collaborative effort between the University of Newcastle and the Zhejiang Academy of Sciences in Hangzhou, China.

Biotech Sugarcane

In November 2009, The Bureau of Sugar Experiment Stations (BSES) announced a A$25 million partnership with DuPont to field test biotech sugarcane over the next 5 years on approximately 2 hectares of land in Queensland; preliminary approval has been granted by the Office of the Gene Regulator for these trials. The trials will feature unspecified new biotechnology applications which can contribute to increased productivity and efficiency of sugarcane production which is used for both food and biofuel. Commercial biotech sugarcane is not expected to be available until about 8 years from now, around 2017. Australia produces about 33 million tons of sugar annually of which about 85% is exported, making it the second most important crop export after wheat. In 2009, Australian farmers reaped about A$1.5 billion from sugarcane (Australian Financial Review, 2009).

Benefits from Biotech Crops in Australia

Biotech Cotton in Australia

Australia is estimated to have enhanced farm income from biotech cotton by US$224 million in the period 1996 to 2008 and the benefits for 2008 alone is estimated at US$28 million (Brookes and Barfoot 20010, forthcoming). The results of a federal study released in September 2005 by the Australian Bureau of Agricultural and Resource Economics (ABARE), Apted et al. (2005) is consistent with the views of some farmers, and estimates that a ban on biotech canola in Australia over the next 10 years could have cost Australian farmers US$3 billion.

Scientists and Farmers Support Biotech Crops in Australia

Delegates at the 2008 ABARE conference learned that the introduction of GM crops in Australia were creating both opportunities and challenges for farmers:

Australia's Chief Scientist, Dr. Jim Peacock, said biotechnology will play an important role in addressing global issues of food security. ***"We lose 12 percent of yields around the world to disease pathogens, and GM technologies offer a means to increase global food supply,"*** Dr Peacock said.

ABARE Principal **Research Economist Max Foster** said that evidence of separate markets for GM and non-GM grains is already present in world markets. ***"World trade in soybeans, corn, canola and cotton is dominated by GM varieties, but non-GM crop varieties coexist as niche markets,"*** Mr. Foster said.

Victorian canola grower Andrew Broad told the conference that biotechnology will play a significant role in the Australian grain industry remaining competitive, with declining yields and profitability from canola becoming significant issues. ***"Without biotechnology, the Australian canola industry will not remain viable,"*** Mr. Broad said.

GM canola grower Reuben Cheesman from St. Arnaud in Victoria grew 56 hectares of Roundup Ready canola last year and is increasing this to 180 hectares this year. ***"Lower herbicide costs and the ease of use of the system were true benefits. Together with higher yields, oil content and superior weed control in comparison to Clearfield® varieties, Roundup Ready has a distinct advantage over other systems,"*** he said.

Biotech Canola in Australia

A survey (Personal Communication, 2009) was commissioned by the developer of RR®canola subsequent to the harvest of the first 2008 RR®canola crop, to determine farmer perception of the new technology, and the performance of RR®canola versus comparator alternative technologies practiced by farmers.

The major findings of the survey, involving 100 farmers, were that 100% of them decided to plant RR®canola again, citing improved weed control, on average higher yields ranging from 5 to 12%, higher oil content of approximately 5%, and gross margin increases ranging on average from A$59 to A$93 per hectare (Table 34). Farmer perception of RR®canola is that it offers a simple, flexible, reliable and effective weed control system. These perceptions of farmers with RR®canola in Australia during the launch of RR®canola in 2008 are entirely consistent with farmer decisions in 2009 which elected to increase their hectarage of RR®canola four-fold from 9,500 hectares in 2008 to 41,200 hectares in 2009, with further increases expected in 2010 and beyond.

Biotech canola offers Australia the opportunity of again competing in the growing world canola markets responding to increased biofuel needs, and to expand biotech canola production in Australia. These can be attained through the establishment of employment-generating regional canola crushing plants, producing improved meal for the dairy industry (to partially substitute for imports of biotech soybean) and utilizing processed canola oil for the growing domestic biodiesel market.

Table 34. Performance of RR®canola and Farmer Comparator Technologies in Australia

Crop	RR®canola	Comparator	RR® versus Comparator
Yield (kg/ha) A*	1.27	1.21	+ 5%
Yield (kg/ha) B*	1.16	0.95	+ 12%
Oil Content % A	39.8	38.0	+ 5%
Oil Content % B	39.4	37.4	+ 5%
Gross margin A$/hectare A	343	284	+ A$59/hectare
Gross margin A$/hectare B	172	179	+ A$93/hectare

Source: Compiled by ISAAA, 2009.

In summary, biotech canola offers Australia a way to increase yield in a sustainable manner and generating higher profits for farmers and a more affordable product for consumers who are not prepared to pay a premium for conventional canola. In the past 10 years, Canada has successfully produced and marketed the equivalent of 50 years of conventional canola in Australia which has missed out on significant domestic and export opportunities with biotech canola (Australian Ministry of Agriculture, Fisheries and Forestry Press Release, 2007). The guidance for Australia, which operates the best managed biotech cotton program in the world, is to take the experience with biotech cotton, apply it to correct the mistakes of late commercialization of biotech canola and apply the learnings from both crops to prepare in advance for the successful, and timely introduction of biotech wheat, which is judged to be inevitable – wheat is Australia's most important crop and significant export.

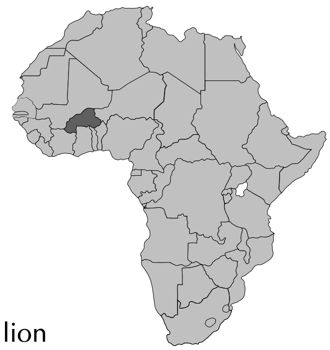
BURKINA FASO

In 2008, for the first time ever, approximately 4,500 Burkina Faso farmers successfully produced 1,600 tonnes of Bt cotton seed on a total of 6,800 farmer fields; the first 8,500 hectares of commercial Bt cotton was planted in the country in 2008. In 2009, approximately 115,000 hectares of Bt cotton were planted for commercialization in Burkina Faso. Compared with 2008, when 8,500 hectares were planted, this was an unprecedented year-to-year increase of approximately 14-fold (1,353% increase), to 115,000 hectares, the fastest increase in hectarage of any biotech crop in any country in 2009. Thus, the adoption rate in Burkina Faso has increased from 2% of 475,000 hectares in 2008 to a substantial 29% of 400,000 hectares in 2009. Enough Bt cotton seed was produced in Burkina Faso in 2009 to plant around 380,000 hectares in 2010. It is estimated that Bt cotton can generate an economic benefit of over US$100 million per year for Burkina Faso, based on yield increases of close to 30%, plus at least a 50% reduction in insecticides sprays, from a total of 8 sprays required for conventional cotton, to only 2 to 4 sprays for Bt cotton.

Located in the Sahel, Burkina Faso is rated as one of the poorest countries in the world with per capita GDP of US$522 per year. Annual average rainfall is 100 centimeters in the South to 25 centimeters in the North. The terrain is a savannah plateau at an altitude of 300 to 400 meters. Almost 30 percent of the country's GDP of US$18 billion is derived from agriculture which also provides up to 90% of national employment, making it the most important sector. The major crops are cotton planted to 600,000 to 700,000 hectares in 2006 and 2007, respectively, as a cash crop, and the food crops include sorghum, millet, rice, peanuts, shea nuts and maize. Drought, poor soil, insect pests and lack of infrastructure and financial resources pose significant challenges to socio-economic development, which revolves around agriculture.

Cotton remains Burkina Faso's principal cash crop generating over US$300 million in annual revenues. This represents over 60% of the country's export earnings (ICAC, 2006). Exports of cotton have ranged from 775,000 bales per year to 1.4 million bales. Some 2.2 million people depend directly or indirectly on cotton, often referred to locally as "white gold" (Vognan et al. 2002) "the king" (CARITAS, 2004; Elbehri and MacDonald, 2004) and "the foundation" of rural economies. Increasing productivity in cotton would therefore directly translate into a boost in GDP. Other commercial crops for exportation include fruits, vegetables, French beans and tomatoes.

BURKINA FASO



Population: 15.21 million

GDP: US$7.95 billion

GDP per Capita: US$522

Agriculture as % GDP: 34%

Agricultural GDP: US$2.7 billion

% employed in agriculture: 99.3%

Arable Land (AL): 4.8 million hectares

Ratio of AL/Population*: 1.5

Major crops:
- Cotton
- Millet
- Peanuts
- Maize
- Sorghum
- Rice
- Shea nuts

Commercialized Biotech Crops: Bt Cotton

Total area under biotech crops and (%) increase in 2009:
115,000 Million Hectares (1,353%)

Farm income gain from biotech, 2008: US$ 1 million

*Ratio: % global arable land / % global population

In 2008, Burkina Faso became the second country in Africa to adopt biotech cotton, Bollgard®II after South Africa, which adopted it in 1998/99. Approximately 8,500 hectares of Bt cotton were planted for seed production and initial commercialization.

In 2009, the second year of commercialization, the area under production rose dramatically to approximately 115,000 hectares (a 14-fold increase or 1,353 %) of Bollgard®II (Bt cotton) out of an estimated nationwide hectarage of 400,000 hectares of cotton planted equivalent to a 29% adoption rate.

The potential economic impacts of Bollgard®II introduction in Burkina Faso are expected to be significant. Even with the application of recommended insecticides, crop losses of 30% or more due to insect pests of cotton have been recorded (Goze et al. 2003; Vaissayre and Cauquil, 2000). On average, at the national level, the annual cost for insecticides for the control of cotton bollworms and related pests is US$60 million per year (Toe, 2003). However, insecticides are proving ineffective with losses due to bollworm as high as 40% even with the full treatment of insecticides (Traoré et al. 2006). Moreover, Bt cotton may prove to be the only option in areas where pest infestations are so high that growing conventional cotton with insecticides is unprofitable. Adoption of Bt cotton is thus inspired by the need to improve productivity, raise farmers' incomes and reduce pesticide use. It is expected that in 2009 alone, 650,000 tonnes will be harvested depending on climatic conditions.

Insect pests and drought are the two significant constraints to increased productivity in the country. All the cotton is produced by small resource-poor subsistence farmers, similar to the situation in countries like China and India. Yield is however low at approximately 367 kg per hectare, compared with 985 kg per hectare in the USA (Korves, 2008). Burkina Faso's cotton production in 2006/07 was 1.3 million bales but this decreased to 0.68 million bales in 2007/08. Preliminary projections by USDA has estimated production for 2008-09 at 0.95 million bales. In 2008-2009 production increased to 457,000 tonnes of cotton seed. It is expected that the production will soar to approximately 650,000 tonnes of cotton seed for the 2009-2010 season (USDA, 2009).

In an effort to address the challenge posed by insect pests, the national research institute, Institut de l'Environnement et de Recherches Agricoles (INERA), field tested Bt cotton over a four-year period (2003 to 2007) with excellent results. INERA scientists in collaboration with Monsanto incorporated the Bt gene (Bollgard®II) into selected popular cotton varieties that are well adapted to the local environment. After rigorous risk assessment and stakeholder consultations, the National Bio-Security Agency approved two varieties of Bt cotton for seed production and commercialization. The approved Bt cotton varieties have the following advantages:

- Firstly, the Bt cotton requires only 2 insecticide applications compared with 6 to 8 for conventional cotton;
- Secondly, insecticides represent 30% of the total cost of growing cotton in Burkina Faso and thus, the savings of approximately 75% in insecticides and labor, is valued at US$85 per hectare excluding the additional important and positive implications for the environment and for small producers applying insecticides by hand;
- Thirdly, the yield of Bt cotton was approximately 30% higher than conventional cotton resulting in a more competitive product for the international cotton market and higher profits for small resource-poor subsistence farmers, thus making a contribution to the alleviation of their poverty.

According to the Director of INERA Dr. Gnissa Konate, the scientific work to evaluate performance and selection of the two approved varieties was done by local scientists under authority of Burkina Faso's National Biosecurity Agency (Personal Communication, 2009). The capability of local researchers to produce Bt cotton seed locally counters the long-held perception of dependency on foreign firms for seed. The State is co-owner of the genetically modified varieties with Monsanto. The price of the seed and the distribution of value added were determined by mutual agreement. Currently, royalties have been negotiated in such a way that the technology fee accruing to Monsanto will be dependent on the farmer's income. The general formula is that the value of increased yield plus savings in insecticide sprays will be considered as gross income which will be divided into three parts. Two-thirds will remain at the farm gate, thus, most of the gain goes to the farmers with the remaining one-third to be shared between Monsanto and the seed companies that provide planting seed.

The cotton sector is well organized into village associations and cotton companies that have exclusive rights to buy seed cotton from producers and provide them with inputs, including seed. The main cotton producing regions are in the west which is covered by the Textile Fiber Company of Burkina Faso SOFITEX. The regions as indicated in the map below are: (1) N'dorola, Kenedogou, (2) Banfora, Comoe, (3) Bobo-Dioulasso, Houet, (4) Diebougou, Bougouriba, (5) Hounde, Tuy, (6) Dedougou, Mouhoun, (7) Koudougou, Boulkiemde (Figure 30).

Another company, the Cotton Society of Gourma (SOCOMA) takes care of production in six provinces in the East namely: Gnagna, Gourma, Komandjari, Kompienga, Tapoa and Koulpelogo. (SOCOMA, 2007). FASO COTON situated in central Burkina Faso is the smallest company. It covers 11 provinces grouped into 5 regions: Zorgho (Oubritenga, Kourwéogo, Ganzourgou, Kouritenga, and Namentenga), Tenkodogo (Boulgou), Manga (Zoundweogo), Pô (Nahouri) and Kombissiri (Bazega, Kadiogo et Bam).

Burkina Faso serves as an example within the Economic Community of West African States (ECOWAS) for its development capabilities in biotechnology with Bt cotton in a legal context. In 2009, the second year of commercialization, approximately 115,000 hectares of Bt cotton were planted compared with 2008 when 8,500 hectares were planted. This is an unprecedented 14-fold increase, a substantial 29% of 400,000 hectares of cotton planted in 2009. This is a significant milestone by any standard, and compares favorably with the earlier impressive Bt cotton adoption trends in China, India and South Africa. Thus, the adoption rate in Burkina Faso has increased from 2% of 475,000 hectares in 2008 to a substantial 29% of the estimated 400,000 hectares in 2009. Enough Bt cotton seed was produced in Burkina Faso in 2009 to plant 380,000 hectares, in 2010, assuming a total cotton planting of 475,000 hectares, the same as 2008, the adoption rate in 2010 could be as high as 80%.

Burkina Faso's Bt cotton program, initiated and expedited by the Government can serve as a model for many other developing countries growing cotton. It is also consistent with the recommendation of the 2008 G8 Hokkaido meeting which recommended the utilization of biotech crops acknowledging the significant and multiple benefits they offer. Burkina Faso, as the leader of the group of four cotton growing countries in West Africa (Burkina Faso, Benin, Chad and Mali) is now in a position to share its important knowledge and experience on Bt cotton with its neighboring countries, so that they, if they so wish, can expedite the commercialization of Bt cotton in their respective countries. This would ultimately expedite the commercialization process in those countries for the benefit of their cotton farmers. It is noteworthy that these countries are beginning to put regulatory mechanisms in place as a first step towards preparing themselves for the safe and responsible uptake of the technology. The National Assemblies of Mali and Togo for example, passed national biosafety laws in 2008 (James, 2008).

In an effort to generate evidence on the real and potential benefits of Bt cotton in Burkina Faso and indeed the western African region, several ex-ante socio-economic studies have been conducted. Vitale et al. (2008) estimated that Bt cotton would generate US$106 million per year for Burkina Faso based on yield increases of 20% and a decreased need for insecticides. Falck-Zepeda et al. (2008) studied potential payoffs and economic risks of adopting biotech cotton in 5 countries in West Africa namely; Benin, Burkina Faso, Mali, Senegal and Togo. The study concluded that Bt technology needs to be adopted, in order to ‘catch up' with major cotton-producing countries in the rest of the world. Under the assumptions of the model, all of the study countries would be worse off economically by not adopting Bt cotton. Referencing the cotton initiative in the WTO's Doha Round of discussions, a paper from the World Bank (WPS3197, Anderson et al. 2006) concluded that cotton-growing developing countries in Africa and elsewhere do not have to wait until the Doha Round is completed before benefiting from increased income from cotton.

Summary of Bt Cotton Seed Production in the First Season: 2008-2009

The three cotton producing companies in Burkina Faso, SOFITEX, Faso Cotton and SOCOMA, together with the INERA Cotton Program were collectively responsible for the first year of Bt cotton seed production in the country. To ensure seed multiplication of highest quality, a stringent appraisal process was followed with regard to selection of production areas and seed producers. While there was a slight delay in arrival of the seed, the results were impressive. About 4,500 farmers were involved with a total of 6,800 fields. An estimated 1,600 tons of delinted Bt cotton seeds were produced from the 8,500 hectares planted. Farmers were impressed with the efficiency of BG®II gene in controlling target pests and the reduction in use of insecticides during the growing season – a first sign of satisfaction with the technology. Farmers reported, on average, a reduction of the number of sprays from 8 to 2 - 4, plus a yield increase of 28%.

Figure 30. Map of Cotton-Growing Areas in Burkina Faso*

*Main cotton growing regions in Burkina Faso: (1) N'dorola, Kenedogou, (2) Banfora, Comoe, (3) Bobo-Dioulasso, Houet, (4) Diebougou, Bougouriba, (5) Hounde, Tuy, (6) Dedougou, Mouhoun, (7) Koudougou, Boulkiemde.

Source: Compiled by ISAAA, 2009.

Benefits from Bt cotton

Farmer surveys to assess the initial impact of Bt cotton

A survey of Bt cotton and conventional cotton farmers was conducted and the results are summarized in Table 35.

Table 35. Summary of Results of Bt Cotton and Conventional Cotton Farmers in Burkina Faso, 2008

Variable	Conventional cotton A	Bt cotton B (A/B%)
Yield (kg/ha)	1,085	1,500 +38%
Quality	Fair	Very good
Frequency of Spraying	8 times	2-4 times ->50%
*Cost of spraying	34,736 FCFA (US$78)	8,684 FCFA (US$20)

Currency US $ 1.-- = FCFA 437.0
** Data analysis incomplete*
Source: Correspondance from TANI G. François through Athanase YARA, Chef de service agroéconomie, Coordonnateur du programme coton biologique, BP:1677 Bobo Dioulasso/Burkina Faso

Farmer observations on Bt cotton

The socio-economic benefits of growing Bt cotton in Burkina Faso have succinctly been described by the growers themselves. SOFITEX, the biggest company has been monitoring individual farmers to gauge their experiences with their first Bt cotton crop. Casimir Zoungrana of the National Union of Cotton Producers of Burkina (UNPCB) for example produced on average 1,287 kgs/hectare compared to 450 kgs/hectare from conventional cotton; this is a near three-fold increase. Burkina Faso researchers also reported a substantial reduction in insecticide use in the number of sprays (from 6-8 to 4-2), cost of chemicals and savings in labor.

Farmer, Tani G. François, the first vice-chairman of the National Union of Cotton Producers (UNPCB) from Koumbia of Wally village, planted 6 hectares of Bt cotton and 22 hectares of conventional cotton. He planted the Bt cotton on 4 July 2008 and despite the late planting got an average yield of 1,600 kg per hectare. In contrast, conventional cotton, planted much earlier from June 4 to 25 2008, yielded only 900 kg/ha and required 6 insecticide treatments. He attributed the low yield from conventional cotton to poor distribution of rainfall given that the usual yield with conventional cotton is 1,600 to 1,800 kg per hectare with 7 to 8 insecticide treatments. The farmers' particular satisfaction with Bt cotton was the significant reduction in the number of insecticide sprays.

Some interesting findings have emerged on the impact of the technology on family relationships. Since most of the spraying is done by men, they reported improved relationship with their spouses who no longer resent the strong odor from pesticide. In addition, most farmers felt that Bt cotton farming is allowing them more time to attend to other duties and puts cotton growing on the same footing as maize or beans that do not require so much time. This is an important spill-over benefit that will contribute to increased production of food crops which in turn will contribute to food security (Mr. George Yaméogo, SOFITEX Development Director of the Cotton Production October 2009, Personal Communication).

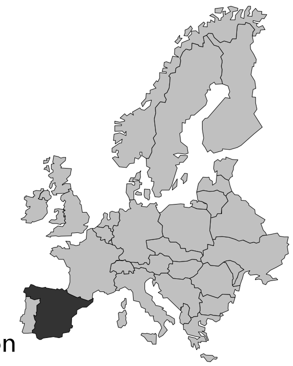
The successful production of Bt cotton in Burkina Faso has also had implications for facilitating greater interest in other biotech crops in the country. For example, the African Agricultural Technology Foundation (AATF) has established a project on Bt cowpea (which confers resistance to the cowpea pod borer, *Maruca vitrata*) for sustainable production of food, for and by resource poor farmers of Sub-Saharan Africa. The Gates Foundation also has a project on biotech cassava to meet the needs of limited resource farmers in Africa while the Africa Harvest has initiated activities for the introduction of biofortified sorghum. Thus, following its initial success with Bt cotton, Burkina Faso can explore other biotech crops to increase food supplies and incomes for farmers.

SPAIN

Spain is the lead biotech crop country in Europe, having successfully grown Bt maize for twelve years. Spain grew approximately 76,057 hectares of Bt maize in 2009, equivalent to a 22% adoption rate, when total plantings of maize were 4% less than 2008 at 349,402 hectares. This compares with 79,269 Bt maize hectares in 2008 when the adoption rate was the same as 2009 at 22% but when total plantings of maize was 4% higher than 2009. Thus, the decrease in absolute Bt maize hectares in 2009 is due to a 4% decrease in total maize plantings in 2009 with percentage adoption rate remaining the same at 22% which is the highest ever adoption rate in Spain.

Spain is the only country in the European Union to grow a substantial area of a biotech crop. Spain has grown Bt maize for twelve years since 1998 when it planted approximately 22,000 hectares out of a national maize area of 500,000 hectares. Since 1998, the area of Bt maize has grown consistently reaching a peak of over 50,000 in the last four years, qualifying Spain as one of the 15 biotech mega-countries globally growing 50,000 hectares or more of biotech crops. In 2009, the Bt maize area in Spain reached 76,057 hectares compared with 79,269 hectares in 2008, which represents a 4% decrease over 2008 and a 22% adoption of the total maize plantings of 349,042 hectares in 2009 compared with a 22% adoption rate of 358,000 hectares in 2008. Thus, the 2009 percent adoption rate of 22% is the highest on record and is the same as 2008 because there was also a 4% decrease in maize area planted in 2009 compared with 2008. The adoption rate of 22% for both 2008 and 2009 compares with 75,148 hectares of Bt maize or 21% adoption in 2007, 53,667 hectares at 15% adoption in 2006 and 53,226 hectares and a 13% adoption in 2005. Thus, the decrease of an estimated average of 4% in total maize plantings in Spain in 2008 [349,042/366,110 = 4.7% and 349,042/358,512 = 2.7 for an average of 3.7% (4%)] is the principal cause of the 4% decrease in Bt maize area in 2009. The principal areas of Bt maize in Spain in 2009 were in the provinces of Aragon (29,540 hectares) where the adoption rate for Bt maize was 45%, followed by Cataluña (28,260 hectares) with the highest adoption rate of 84%, with significantly less area of Bt maize in Extremadura (8,308 hectares), with an adoption rate of 19%, with the balance of Bt maize grown in seven other provinces in Spain in 2009 (Tables 36 and 37).

SPAIN



Population: 43.6 million

GDP: US$1,437 billion

GDP per Capita: US$32,020

Agriculture as % GDP: 3.6%

Agricultural GDP: US$51.7 billion

% employed in agriculture: 5%

Arable Land (AL): 13.6 million hectares

Ratio of AL/Population*: 1.5

Major crops:

- Grape
- Sugarbeet
- Maize
- Potato
- Wheat

Commercialized Biotech Crops: Bt maize

Total area under biotech crops and (%) increase in 2009: 76,057 Hectares (-4.2%)

Farm income gain from biotech, 1996-2008: US$78 million

*Ratio: % global arable land / % global population

Currently, varieties of nine seed companies, including event MON810 biotech maize have been approved for commercial planting. Up until 2002, only the variety COMPA CB was grown with Bt-176 for insect resistance, and this variety was grown until the 2005 season. MON810 varieties for insect resistance were approved in 2003 and now there are 46 varieties registered with MON810. In November 2004, herbicide tolerant NK603 maize was approved for import, but the approval for planting in the European Union is still pending. When approved, biotech maize varieties with NK603 are likely to be deployed throughout Spain.

Table 36. Hectares of Biotech Bt Maize in the Autonomous Communities of Spain, 1998 to 2009

Provinces	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Aragon	11,500	7,300	9,000	4,250	9,200	12,592	25,547	21,259	23,734	35,860	31,857	29,540
Cataluña	1,700	3,000	4,500	3,250	5,300	5,430	15,699	16,830	20,365	23,013	25,298	28,260
Extremadura	1,000	2,500	2,500	600	1,500	1,899	2,026	1,171	2,071	6,460	10,416	8,308
Navarra	1,760	300	220	80	500	1,387	2,446	2,604	2,821	5,327	5,150	4,397
Castilla-La Mancha	4,500	6,800	5,650	870	4,150	7,682	8,197	7,957	4,176	3,659	4,739	3,128
Andalucia	780	2,800	1,500	450	1,800	2,067	2,770	2,875	298	592	1,372	2,175
Madrid	660	1,560	1,970	1,940	780	1,034	1,385	155	80	193	381	130
Islas Baleares	2	2	26	0	30	6	29	29	0	3	3	92
Castilla Y Leon	200	360	270	0	0	74	0	12	0	13	28	19
La Rioja	25	30	30	0	0	0	35	41	122	4	11	8
Murcia	0	0	0	0	0	0	12	0	0	24	0	0
Asturias	0	0	0	0	0	0	0	0	0	0	0	0
Valencia	190	300	150	100	20	72	73	293	0	0	14	0
Total	**22,317**	**24,952**	**25,816**	**11,540**	**23,280**	**32,243**	**58,219**	**53,226**	**53,667**	**75,148**	**79,269**	**76,057**

Source: Ministry of Agriculture, Spain, 2009.

Spain is a feedstock deficit country and therefore, there is an incentive for Spanish farmers to increase productivity and be competitive, by employing innovative and cost effective technologies. The future growth of biotech maize in Spain will be dependent on the continued growth in the area planted to Bt maize, the approval of NK603, and particularly a progressive and tolerant government policy especially in relation to coexistence.

Spain is the leader in biotech crops in the EU and conducts 42% of all the biotech field trials planted in the EU. In Spain, field trials of biotech crops are very carefully controlled and must be reviewed and recommended for approval by the National Biosafety Committee and are then subject to final approval by the Federal Government.

Table 37. Hectares of Maize in Spain by Province, 2009

Province	Hectares
Castilla Y León	109,640
Aragon	65,106
Extremadura	43,700
Castilla-Mancha Cataluna	33,479
Cataluña Castilla-Mancha	31,922
Andalucía	24,786
Galicia	17,600
Navarra	12,971
Madrid	5,450
La Rioja Canarias	1,000
C. Valenciana	905
La Rioja	800
Baleares	470
Pais Vasco	453
Pais DeAsturias	400
R. De Murcia	250
Cantabria	110
Spain Total	**349,042**

Source: Ministry of Environment Rural Development and Fisheries, Spain, 2009. Avances Suopefices y Producciones Agricolas, July 2009.

Benefits from Biotech Crops in Spain

Spain is estimated to have enhanced farm income from biotech Bt maize by US$78 million in the period 1998 to 2008 and the benefits for 2008 alone is estimated at US$18 million (Brookes and Barfoot, 2010, forthcoming).

The benefits to Spanish farmers from Bt maize has been reported by PG Economics and indicates that the average increase in yield was 6%, and the net impact on gross margin is US$112 per hectare. Data from the Institute of Agro-Food Research and Technology (IRTA, 2008), a public research institute in Spain indicates that for an area where the corn borer is prevalent, Bt-varieties have a yield advantage of 7.5% with an 83% reduction in levels of fumonisins. There is potential for increasing Bt maize hectarage in Spain, up to one-third of the total maize area, and the national gain is estimated at US$13 to US$18 million per year. The grain harvested from Bt maize in Spain is sold through the normal channels as animal feed or fed to animals on the farm.

MEXICO

The most significant development in Mexico in 2009 was the planting of the first biotech maize trials in the country. After an 11 year moratorium, the Mexican government approved 21 experimental field trials of GM maize; Mexico grows approximately 7.4 million hectares of maize annually. In 2009, Mexico planted 56,000 hectares of biotech cotton, equivalent to 80% of the 80,000 hectares of the national cotton hectarage and 17,000 hectares of biotech RR®soybean for a country total of 73,000 hectares of biotech crops, compared with 95,000 hectares in 2008.

The most significant biotech crop development for Mexico in 2009 was the ending of an 11 year moratorium on field trials of biotech maize. In 2009, 21 experimental, open field trials of biotech maize were approved (Table 38) and planted in the northern region of Mexico. Twelve of the 21 trials were planted in October and November 2009 in the northern states of Sonora and Sinaloa and the balance of 9 trials will be planted between February and April 2010, in the states of Tamaulipas and Chihuahua. The trials were approved following the passage of the GMO Biosafety Law (2005), its By Laws (2008) and the Mexican regulatory framework for GM maize was concluded in March 2009. This was accompanied with the enactment of the Special Protection Regime for Maize, which provides for the protection of the Mexican maize landraces – Mexico is the center of origin and diversity for maize. The biosafety requirements demand that the seed and all other harvestable products from these trials not be commercialized.

Mexico is the last of the six "founder biotech crop countries" having grown biotech Bt cotton in 1996, the first year of the global commercialization of biotech crops. In 2009, the total cotton plantings in Mexico were approximately 80,000 hectares. Approximately 80% or 56,000 hectares were biotech products, compared with 70% or 85,000 hectares in 2008. In addition to biotech cotton, 17,000 hectares of RR®soybean were planted in 2009 compared with only 10,000 hectares in 2008. Thus, the total hectarage of biotech crops in Mexico in 2009 was 73,000 hectares compared with 95,000 hectares in 2008.

In 2009, the following was the hectarage of biotech cotton traits: of a total of 52,000 hectares of biotech cotton, 40,000 hectares, or 78% was the stacked trait product for insect resistance and herbicide tolerance, compared with 6,000 hectares for Bt and 6,000 hectares for herbicide tolerance.

MEXICO

Population: 109.6 million

GDP: US$1,023 billion

GDP per Capita: US$ 9,720

Agriculture as % GDP: 3.7%

Agricultural GDP: US$37.9 billion

% employed in agriculture: 14%

Arable Land (AL): 25.6 million hectares

Ratio of AL/Population*: 1.0

Major crops:

- Maize
- Soybeans
- Cotton
- Wheat
- Rice
- Coffee

Commercialized Biotech Crops:

- Bt Cotton
- HT Soybean

Total area under biotech crops and (%) increase in 2009:
73,000 Hectares (-30%)

Farm income gain from biotech, 1996-2008: US$91 million

*Ratio: % global arable land / % global population

Mexico has no trade constraints related to biotech crops and is a major importer of food, feed and fiber from the USA. In 2005, Mexico imported US$9.9 billion worth of agricultural products from the USA. These included 5.7 million tons of maize, 3.7 million tons of soybeans and 387,000 tons of cotton. While Mexico has no trade constraints related to biotech crops generally, it is the center of diversity for maize and the conservation of biodiversity in Mexican landraces has fuelled a long standing debate vis-à-vis the potential for gene flow from biotech maize imported from the USA. The content and detail of the debate is beyond the scope of this Brief and interested readers are directed to the voluminous literature on this subject, with the latest study contradicting earlier findings, by reporting no trace of Bt genes in Mexican maize.

Table 38. Field Trials of Biotech Maize Approved for Planting in Mexico in 2009

Company	Event	Number of Field trials	Trait
Dow AgroSciences – Pioneer Hi-Bred	DAS-01507-1	4	Glufosinate tolerance Lepidoptera resistance
	MON-00603-6	4	Glyphosate tolerance
	DAS-01507-1 x MON-00603-6	4	Glufosinate tolerance Glyphosate tolerance Lepidoptera resistance
Monsanto	MON-00603-6	3	Tolerance to the herbicide glyphosate
	MON 89034-3 x MON 88017-3	3	Glyphosate tolerance Coleoptera resistance European corn borer resistance Corn root borer resistance (*Diabrotica virgifera*) Mediterranean corn borer resistance (*Sesamia nonagroides*)

Source: Government of Mexico

Following years of debate, the Mexican Congress and Senate approved a Biosafety Law on 15 February 2005 that facilitated the introduction of biotech crops despite the fear of some regarding gene flow in maize. Under the new law, authorization for the sale, planting and utilization of biotech crops and products is on a case-by-case basis, under the control of Comision Intersecretarial de Bioseguridad y Organismos Geneticamento Modificados (CIBIOGEM), an inter-ministerial body. Increasing trade in biotech crops made the new law necessary, and Mexican policy makers believe it is a major step forward in dealing with an issue that required urgent attention.

The conduct of field trials with biotech maize in Mexico, which is a special case because Mexico is the center of origin for maize, has been stalled for the last three years because of legal indecision leading to long delays in the approval process for field trials. Given that Mexico is the center of origin of maize, the Mexican Biosafety Law for GMOs, which was passed in March 2005, requires a special regime to protect maize in its center of origin. The necessary By-Laws for the Law, which should have been published within 6 months of its passage in 2005, were delayed for 3 years and only approved and published on March 18, 2008.

In summary, legal delays precluded the conduct of the essential biotech maize experiments that are a prerequisite for generating the scientific data that is needed for defining the biosafety parameters for field trials and the growing of commercial biotech maize in Northern Mexico, where the precursor of maize, Teosinte, is not found.

Benefits from Biotech Crops in Mexico

Mexico is estimated to have enhanced farm income from biotech cotton and soybean by US$91 million in the period 1996 to 2008 and the benefits for 2008 alone is estimated at US$11 million (Brookes and Barfoot, 2010, forthcoming).

CHILE

> **Chile grew a total of 32,200 hectares of biotech maize, soybean and canola, for seed exports in 2009, approximately the same as the 36,000 hectares in 2008.**

In 2009-10, Chile was projected to plant over 28,000 hectares of biotech maize, 3,000 hectares biotech soybean and 1,200 hectares of biotech canola for a total of 32,200 hectares for seed export; this is approximately the same as the 36,000 hectares planted in 2008-09. There is legislation in Parliament to allow consumption of domestically grown biotech crops in Chile.

Chile has a population of approximately 16.6 million and a GDP of US$242.4 billion, 5% of which is generated from agriculture, and forestry is a strong sector in the country. Fruits are major exports worth US$2 billion per year and it has a thriving global export market in wines. A significant 14% of the population is involved in agriculture and the export market requires that the products are of top quality to compete in the global market.

From a biotech crop standpoint it is important to recognize that Chile is the seventh largest producer of export seed in the world (Table 1 in Appendix 3). The latest data from Chile indicate that the export market for all seed, conventional and biotech in 2007/08 was valued at US$240 million, of which approximately US$190 million was biotech seed alone. Chile has been producing biotech seed for export since commercialization began in 1996 and this activity is fully covered by the current law. Chile has clearly demonstrated over the last fourteen years that like the other 24 countries that commercialize biotech crops, it has all the necessary management and skills to responsibly handle all the aspects related to the growing of biotech crops. The only difference between Chile and the other countries planting biotech crops is that the current law only allows commercialization of biotech crops for export. However, there is a new law in passage in the Chilean Parliament that would also allow commercialization and consumption of biotech crops produced in Chile. This is a logical development given that Chile already imports significant quantities of biotech crops, such as biotech maize, for consumption from its neighboring country, Argentina, which is the third largest producer of biotech crops in the world. Chile has 120,000 hectares of maize which could benefit significantly from biotechnology and substitute for some of the imports of biotech maize from Argentina. The most recent REDBIO regional meeting on biotechnology recognized this opportunity for Chile to grow biotech maize for domestic consumption.

The area of biotech crops grown for seed export in Chile has shown a strong growth trend over the last six years, tripling from 10,725 hectares in 2002/03 to 32,200 hectares in 2009/10 (Table 39). Multiplication of biotech seed for export is now a significant business activity worth approximately US$500 million in 2008, of which the value of biotech seed alone is at least US$200 million. Maize has always been the most important biotech seed crop grown in Chile at 28,000 hectares in 2009/10 followed by soybean and canola. The total biotech crop area for export seed production in Chile in 2009/10 was over 30,000 hectares, for the second time. The number of biotech seed crops multiplied in Chile is now approximately 10 crop/trait combinations. The country has broad and diversified experience in successfully managing all aspects related to the growing of biotech crops for over 10 years.

Table 39. Hectares of Major Biotech Seed Crops Grown for Export in Chile, 2002/03 to 2009/10

Crop	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09*	2009/10	Total
Maize	10,400	8,450	7,614	12,120	17,981	25,000	30,000	28,000	111,565
Canola	110	140	746	628	444	2,500	4,200	1,200	8,768
Soybean	215	128	273	166	250	500	1,800	3, 000	3,332
Total	**10,725**	**8,718**	**8,633**	**12,914**	**18,675**	**28,000**	**36,000**	**32,200**	**123,665**

Source: Government of Chile statistics, SAG, 2009. *industry estimates

Several organizations in Chile have been pursuing the development of biotech crop products for several years, including the following: The Catholic University of Santiago is developing citrus species that are resistant to drought and tolerant to nitrogen deficiency, virus resistant potatoes, and *Pinus radiata* species that are resistant to shoot moth and also tolerant to glyphosate. The National Institute for Agricultural Research (INIA) is developing grapes that are resistant to *Botrytis*, and in a joint program with the University of Santo Tomas they are developing stone fruits (nectarines and peaches) with improved quality and shelf life. Fundacion Chile provides technical and financial support for some of these projects.

Biotech activities in Chile are not restricted to crops but also include forestry products. Recently some Chilean Research Institutes have joined forces to develop drought-tolerant *Eucalyptus*. Chile's Institute for Agricultural Research (INIA) and Chile's Forest Research Institute (INFOR) have announced a joint program to develop varieties of eucalypts, *Eucalyptus globulus*, with increased tolerance to drought. The project aims to provide farmers and forestry industry with plants and trees better adapted to the conditions of the arid interior regions of Chile. It is estimated that currently 1.8 million hectares of land are not realizing their production potential due to the low availability of water. More information can be obtained from INIA Chile (2007).

COLOMBIA

Colombia grew 24,000 hectares of biotech cotton in 2009, of which about 85% was the stacked product Bt/HT.

In 2009, Colombia grew approximately 24,000 hectares of biotech cotton, compared with 28,000 hectares in 2008. Of the 24,000 hectares, notably 85% equivalent to about 20,000 hectares were the stacked traits Bt and herbicide tolerance, about 4,000 hectares were Bt and less than 1,000 hectares were herbicide tolerant. The cotton is planted in two seasons, 4,000 hectares in the first season and the balance of about 20,000 hectares in the second season. Colombia first introduced Bt cotton in 2002 on approximately 2,000 hectares and in the interim, this has increased to over 20,000 hectares.

Biotech maize is not approved for commercialization in Colombia. However in 2009, Colombia, for the third year, planted biotech maize in two seasons in a "controlled planting program" in two regions, one on the Coast and Llanos region and the other in the interior of the country. Bt maize MON810, TC5107 and Bt 11 were planted in 2009 on a total of 35,000 hectares, up from 15,000 hectares in 2008. Approximately, 5,000 hectares were planted in the first season and the balance of 30,000 hectares in the second season. The biotech maize hectarage grown in Colombia is not included in the global biotech data for 2009 because it has not been approved for commercialization, and is only grown in a "controlled planting program."

Colombia has approximately 600,000 hectares of maize which could be an important new potential application for biotech maize. Colombia has been growing blue biotech carnation for export only since 2002, and in 2009 planted 4 hectares in greenhouses near Bogota which, although commercial are not included in the global biotech hectarage.

Benefits from Biotech Crops in Colombia

Colombia is estimated to have enhanced farm income from biotech cotton by US$14 million in the period 2002 to 2008 and the benefits for 2008 alone is estimated at US$1 million (Brookes and Barfoot, 2010, forthcoming).

HONDURAS

> **Honduras grew 15,000 hectares of biotech maize in 2009, this compares with 9,000 hectares in 2008 – an increase of two-thirds or 67% on a modest area of maize.**

Honduras is a poor country in Central America with a GDP per capita of US$1,190 – one of the poorest in the region. Both large and small farmers cultivate maize which is the major staple in the country. The average yield is 1.6 tons per hectare which is one of the lowest in the region; this low yield is due to several factors, including lepidopteran pests which can cause significant losses, particularly on smallholdings.

Honduras was the first country to adopt biotech maize in Central America and introduced herbicide tolerant maize in 2002 with a pre-commercial introductory area of approximately 500 hectares. In the interim, the biotech maize area has increased to 15,000 hectares in 2009, up approximately 67% from 9,000 hectares in 2008. In 2009, the 15,000 hectares comprised 12,000 hectares of the stacked Bt/HT maize and 3,000 hectares of herbicide tolerant maize. The national maize crop of Honduras is approximately 362,000 hectares.

Benefits from Biotech Maize in Honduras

Assuming a modest gain of US$75 per hectare from stacked biotech maize the national benefit from 15,000 hectares would be about US$1 million per year. Preliminary results from IFPRI studies, suggest that, not surprisingly, the larger farmers (over 2 hectares) have been the initial beneficiaries of biotech maize in Honduras and studies are underway to assess the impact of biotech maize in the country. The experience of Honduras, as a small county with very limited resources, in implementing a successful biosafety program can serve as a useful model and learning experience for other small countries particularly those in the Central American region. Zamorano University in Honduras has activities in biotech crops, including a knowledge sharing initiative which should contribute to a better understanding of biotech crops and facilitate more informed decisions about biotech crops, their attributes and potential benefits.

CZECH REPUBLIC (CZECHIA)

In 2009, the Czech Republic grew 6,480 hectares of biotech maize, compared with 8,380 hectares in 2008; the decrease was associated with various factors including the recession, unusually low maize prices compared with mid-2008 and the onerous disincentive for farmers who were required to report intended biotech plantings to government authorities as early as January 2009.

The Czech Republic, more familiarly known as Czechia, approved the commercial production of a biotech crop for the first time in 2005 and grew 150 hectares of Bt maize. In 2006, Czechia grew 1,290 hectares of Bt maize, which increased to 5,000 hectares in 2007. In 2008, Czechia increased its Bt maize area for the third consecutive year by more than 68% to 8,380 hectares and this decreased to 6,480 hectares grown by about 125 farmers in 2009. The decrease in Bt maize plantings was associated with many factors, including the economic uncertainties associated with the recession, unusually low prices compared with mid-2008, and the onerous disincentive for farmers who had to report intended biotech plantings as early as January 2009.

Czechia grew up to 400,000 hectares of maize in 2009 of which the majority was for silage. It was estimated that up to 30,000 to 50,000 hectares of maize were affected by the corn borer to a degree that would warrant the deployment of Bt maize planting, thus the potential for biotech maize expansion is significant. Coexistence rules apply with 70 meters between Bt maize and conventional maize (or alternatively 1 row of buffer replaces 2 meters of isolation) and 200 meters between Bt maize and organic maize (or alternatively 100 meters of isolation and 50 buffer rows).

Benefits from Biotech Crops in Czechia

The Phytosanitary Service of the Government estimated that up to 90,000 hectares were infested with European corn borer (ECB), and that up to 30,000 hectares were being sprayed with insecticide to control ECB. In trials with Bt maize, yield increases of 5 to 20% were being realized, which is equivalent to an increase of about US$100 per hectare. Based on 30,000 hectares of Bt deployed, the income gain at the national level could be of the order of US$3 million per year.

PORTUGAL

In 2009, Portugal planted 5,094 hectares of Bt maize, a 5% increase over the 4,851 planted in 2008. At the national level in 2009, a total of 5,094 hectares of Bt maize, out of a total of 135,000 hectares were grown in 5 regions by 234 farmers with an average Bt maize area per farm of 22 hectares. The 3.8% adoption rate for Bt maize in Portugal (5,094 hectares) on a total maize hectarage of 135,000 hectares was slightly higher than 2008 when the adoption rate was 3.2%; 4,851 hectares were planted from a total of 154,000 hectares of maize.

Portugal resumed the planting of Bt maize in 2005 after a five-year gap having planted an introductory area of approximately 1,000 hectares in 1999 for one year. In 2009, Portugal planted 5,094 hectares of Bt maize, a 5% increase over 2008 when 4,851 hectares were planted. The 5% increase in 2009 followed a 14% increase in 2008, and a two and a half-fold increase to 4,263 hectares in 2007 from the 1,250 hectares planted in 2006. The major regions for planting Bt maize in Portugal are listed in Table 40 in descending order of hectarage and percent contribution to the total national hectarage of 5,094 hectares in 2009, as well as the number of notifications by farmers intending to plant Bt maize, and the average hectarage of 22 hectares Bt maize per farm in each region. The region of Alentejo has the largest hectarage of Bt maize at 2,246 hectares or 44% of the national hectarage with 62 farmers submitting notifications of their intent to plant Bt maize. Alentejo was followed by the Lisbon and Tejo Valley regions with 1,524 hectares of Bt maize or 30% of the national hectarage with 36 farmers submitting notifications. The central region was the third region with 979 hectares of Bt maize or 19% of the national hectarage with 66 farmers submitting notifications. The Northern region was the fourth region with 303 hectares of Bt maize or 6% of the national hectarage with 69 farmers submitting notifications. Finally, the Algarve region was the fifth and final region with 42 hectares of Bt maize or <1% of the national hectarage with 1 farmer submitting a notification. At the national level in Portugal in 2009, a total of 5,094 hectares of Bt maize were grown in 5 regions by 234 farmers with an average Bt maize area per farm of 22 hectares. Thus, the percentage adoption of Bt maize in Portugal in 2009 was slightly higher at 3.8%, compared with 2008 at 3.2% when 4,851 hectares were planted from a total of 154,000 hectares. All the Bt maize in Portugal is MON 810, resistant to European corn borer. As a member country of the EU, Portugal's continued cultivation of Bt maize is an important development, acknowledging that the national maize area is modest at 135,000 hectares (Ministry of Agriculture, 2009).

Table 40. Cultivation of Bt Maize in Portugal in 2009

Region	Hectares (has.)	Percentage National has.	Average has./ maize/farm	Number of Farmers (Notifications)
Alentejo	2,246	44	36	62
Lisbon/de Tejo	1,524	30	42	36
Central	979	19	15	66
North	303	6	4	69
Algarve	42	<1	42	1
NATIONAL	**9,198**	**7,943**	**4,485**	**234**

Source: Ministry of Agriculture, Rural Development, and Fisheries, Lisbon, Portugal, www.dgadr.pt, 12 October, 2009.

The Government of Portugal passed a Decree, which requires a minimum distance of 200 meters between biotech and conventional maize and 300 meters between biotech maize and organic maize; buffer zones can substitute for these distances. Implementation of coexistence laws results in biotech maize being grown in the central and southern regions of Portugal where the farms are bigger, and where coexistence distances can be accommodated and also where producers are more responsive to the introduction of new and more cost effective technologies. The Ministry of Agriculture also passed legislation to establish biotech free areas where all the farmers in one town, or 3,000 hectare area, can elect not to grow biotech varieties. All biotech varieties approved in the EC catalogue can be grown in Portugal.

Benefits from Biotech Crop in Portugal

The area infested by the European corn borer (ECB) in Portugal are in the Alentejo and Ribatejo regions and the estimated infested area that would benefit significantly from Bt maize is estimated at approximately 15,000 hectares, which is equivalent to approximately 10% of the total maize area. The yield increase from Bt maize is of the order of 8 to 17% with an average of 12% equivalent to an increase of 1.2 MT per hectare. Assuming an average increase of US$150 per hectare the gain at the national level for Portugal for Bt maize would be in the order of increase of US$2.25 million per year.

Farmer Experience

Jose Maria Telles Rasquilla is a Portuguese farmer who has planted Bt maize since 1999. He says that, ***"Growing biotech maize offers environmental advantages and economic benefits such as better yields and less spraying, which means reduced costs, larger margins per hectare and good quality products. Developing new technologies and agricultural products can help the environment and have a positive impact on rural development."***

ROMANIA

Up until 2006, Romania successfully grew over 100,000 hectares of RR®soybean, but on entry to the EU in January 2007, was forced to discontinue the use of an extremely cost-effective technology because RR®soybean is not approved for commercialized planting in the EU. This has been a great loss to both producers and consumers alike. It is noteworthy that because conventional soybeans yield substantially less than RR®soybean, the hectarage of soybeans has dropped precipitously in Romania from 177,000 hectares in 2006 to 46,000 hectares in 2008. Despite the need for Romania to discontinue the cultivation of RR®soybean, it has been able to take advantage of the fact that Bt maize is registered for commercialized planting in the EU. Romania grew its first 350 hectares of Bt maize in 2007 which increased to 7,146 hectares in 2008. Following the severe economic recession in 2009, (particularly restricted access to credit), onerous reporting requirements for farmers regarding intended planting details, and decreased total plantings of hybrid maize, (estimated at close to 20%), the biotech maize area in 2009 receded to 3,243 hectares.

Up until 2006, Romania successfully grew over 100,000 hectares of RR®soybean, but on entry to the EU in January 2007 had to discontinue the use of an extremely cost-effective technology because RR®soybean is not approved for commercialized planting in the EU. This has been a great loss to both producers and consumers alike. It is noteworthy that because conventional soybeans yield substantially less than RR®soybean, the hectarage of soybeans has dropped precipitously in Romania from 177,000 hectares in 2006 to only 46,000 hectares in 2008. As a result of cessation of cultivation of RR®soybean and the commensurate decrease in soybean production, Romania has to import soybean, it is almost certain to be RR®soybean, the very same product which the Government has banned from domestic production – an example of a negative impact from a flawed logic arising from a bureaucratic requirement. However, despite the need for Romania to discontinue the cultivation of RR®soybean, it has been able to take advantage of the fact that Bt maize is registered for commercialized planting in the EU. Romania grew its first 350 hectares of Bt maize in 2007, and this increased more than 20-fold in 2008, to 7,146 hectares; this was the highest percent increase for any country in 2008, acknowledging that the base hectarage of 350 hectares in 2007 was very low. Following the severe economic recession in 2009, (particularly restricted access to credit), and decreased planting of hybrid maize, the biotech maize area in 2009 receded to 3,243 hectares. It is noteworthy that there are 4.5 million small farms in Romania, which remarkably represent almost a third of all farms in the EU (The Economist, 2007).

Even though Romania has ceased to grow RR®soybean, it is anticipated that Romania will resume growing RR®soybean if and when it is eventually approved for planting in the EU, thus it is appropriate to discuss the history of Romania and RR®soybean. Romania ranked equally with France as the third largest producers of soybean in Europe, after Italy and Serbia Montenegro, with approximately 150,000 hectares of soybean planted in 2007. Romania first grew herbicide tolerant soybean in 2001 when it planted 14,250 hectares of RR®soybean of its national soybean hectarage of approximately 100,000 hectares – a 15% adoption rate. In 2006, of its national soybean hectarage of 145,000 hectares, 115,000 hectares were planted with RR®soybean, equivalent to a 79% adoption rate. The very high adoption rate of 79% reflects the confidence of farmers in RR®soybean, which has delivered unprecedented benefits compared with RR®soybean in other countries, particularly in terms of yield gains. A study by PG Economics in 2003 estimated that the average yield gain was over 31%, equivalent to an increase in gross margins, ranging from 127 to 185%, or an average gain of US$239 per hectare that translates to an annual economic gain at the national level of between US$10 and US$20 million. Given that RR®soybean technology is usually yield-neutral in other countries such as the USA and Argentina which have embraced the technology at high adoption rates, the yield increases in Romania are quite unprecedented. The high yield increases that ranged from 15 to 50% with an average of 31% reflect past low usage of herbicides and ineffective weed management, particularly of Johnson grass, which is very difficult to control.

Despite the above significant and unique advantages, a decision was taken by the Romanian Government, required by the European Union, to discontinue cultivation of biotech soybean as of January 2007 to qualify for membership in the EU, where RR®soybean has not been approved for planting. Many independent observers support the very strong views of Romanian farmers who are very much opposed to the decision to discontinue RR®soybean cultivation and believe that there were several compelling reasons for Romania to continue to grow RR®soybean after joining the EU, through a derogation. First, if farmers are denied the right to plant RR®soybean they will not be able to achieve as cost-effective a weed-control program, even with more expensive alternates, resulting in significant financial losses for farmers growing conventional soybeans, and less affordable soybeans for consumers. Second, given that use of RR®soybean also results in better weed control in the crops following it in the rotation, elimination of RR®soybean leads to higher cost of weed control and more use of herbicides for all other crops following it in the rotation. This will result in negative implications for the environment because of more applications of alternative herbicides, which will also erode profitability. Thirdly, preclusion of RR®soybean legal plantings in Romania has reduced national production of soybean by up to one third which illogically can only be compensated with imports of exactly the same product – RR®soybean that has been banned, which will have to be purchased with scarce foreign exchange. Experience in other countries indicates that denying the legal use of RR®soybean to Romanian farmers will lead to illegal plantings of a significant magnitude with all its negative implications for all parties concerned.

As a 2007 accession country to the EU, Romania's positive experience over the last eight years with biotech soybeans has important policy implications vis-à-vis cultivation of biotech crops in all other EU accession countries like Bulgaria, and other neighboring countries in the Black Sea region. Romania's role model as a successful grower of biotech crops in Eastern Europe is clearly important, particularly since it was a 2007 accession country to the EU. Furthermore, Romania's success with biotech crops started with RR®soybean in 2001, followed by Bt maize in 2007, 2008 and 2009. Romania was the largest grower of maize in Europe – 2.5 million hectares in 2008, compared with 1.6 million hectares in France, 1.2 million hectares in Hungary, 1 million hectares in Italy and 0.4 million hectares in Germany. In this context, it is noteworthy that in 2007, in addition to Romania, seven other EU countries, Spain, France, Czech Republic, Slovakia, Portugal, Germany, and Poland successfully grew an increasing hectarage of Bt maize on approximately 110,000 hectares. Contrary to the findings of the European Food Safety organization EFSA which declared that the event MON810 in Bt maize was safe to cultivate in Europe, France decided to discontinue Bt maize in 2008 and Germany in 2009. In both cases the evidence submitted by the two countries to support their rejection was not considered valid by EFSA – thus the decisions by both France and Germany to discontinue cultivation of Bt maize are in the view of EFSA, as an EU independent scientific organization, cannot be supported by scientific evidence.

Benefits from Biotech Crop in Romania

There has been active debate on the use of biotech crops in Romania. The Romanian Minister of Agriculture strongly supports the resumption of growing biotech soybean, stating that the Ministry of Agriculture will support biotech soybean in the EU. The Romanian Senate has also supported biotech crops with an almost unanimous vote on an Emergency Ordinance to embrace biotech products as food, whereas the Ministry of the Environment has been ambivalent on the subject.

For RR®soybean, cultivated since 2001 and occupying 145,000 hectares in 2006, the yield benefits of 30% was unique – in all other countries RR®soybean is a yield neutral technology. The high yield increases in Romania of 15 to 50% with an average of 31% reflect past low usage of herbicides and ineffective of weed management, particularly of Johnson grass, which is very difficult to control. A 2003 study by PG Economics estimated an average yield gain of 31% or more, equivalent to gross margin gains of 127 to 185% or an average gain of US$239 per hectare – equivalent to a national economic gain of US$10 and US$20 million, respectively.

Romania is estimated to have enhanced farm income from RR®soybean of US$45 million in the period 2001 to 2008. (Brookes and Barfoot, 2010, forthcoming). Romania had to stop growing RR®soybean when it became an EU member country in January 2007, and since then, the hectarage of soybean in Romania has plummeted from 177,000 hectares in 2006 to only 46,000 hectares in 2008.

Farmer Experience

The experience of farmers, who are the practitioners of biotech crops are important because they are masters of risk aversion and have no compunction in rejecting any technology that does not deliver benefits. Romanian farmers embraced biotech soybean and, Romanian soybean farmer ***Lucian Buzdugan*** predicted the fate of Romanian farmers – on entry to the EU, Romanian farmers would have to pay the high price of banning the technology.

"I can tell you that soybean farmers in Romania are very interested in biotech seeds. If one day our government says no more GMOs (genetically modified organisms), it's a disaster. Before, yields were just 1,300 to 1,500 pounds per acre with conventional soybeans and are now averaging 2,500 to 3,000 pounds per acre with biotech varieties."

POLAND

The hectarage planted to Bt maize in Poland in 2009 was the same as in 2008, and estimated at 3,000 hectares.

Poland has a population of approximately 38.12 million and a GDP (nominal) of US$526.97 billion, 4% of which is generated from agriculture equivalent to US$21.1 billion per year. Agricultural products and food stuffs represent about 8% of total exports which is US$6 billion per year. Agriculture provides employment for 16.1% of the population, the highest percentage in the EU of which Poland is a member.

There was an estimated total of 670,000 hectares of maize grown in Poland in 2009, 260,000 hectares, or 39%, was used for grain, and 61% or 410,000 hectares, used for silage. A few years ago European corn borer (ECB) used to be limited to only a few regions in the South and South East but it is now endemic in all regions of Poland and causes significant damage. Economic thresholds which merit the use of Bt maize as a control measure are at a 15% level of infestation for grain crops and 30% to 40% infestation for silage crops. Insecticide application to control ECB is infrequent due to lack of tradition, equipment, awareness of the significant damage the pest is causing and the small size of holdings and fields. *Trichogramma* is sometimes used as a biological control agent at a cost of US$90 to US$105 per hectare. Insecticide control, which is rarely used, cost about US$35 per hectare.

Some pre-commercial Bt maize was planted in Poland in 2006 on approximately 100 hectares. In 2007, Poland commercialized Bt maize for the first time when 327 hectares were planted. Based on the positive experience of farmers who planted the 327 hectares of Bt maize in 2007, the hectarage planted to Bt maize in 2008 increased more than 8-fold to 3,000 hectares and the hectarage remained the same in 2009 despite the negative effects of the recession which affected all sectors, including the agricultural sector. In 2007, Poland had the distinction of becoming the eighth EU country to plant Bt maize, which meant that over one quarter of the 27 EU countries were commercially planting biotech maize. Bt yellow maize is being used in Poland for animal feed and/or for ethanol production.

Benefits from Bt Maize in Poland

In 2007, a report entitled "The benefits of adopting genetically modified maize in the European Union; first results from 1998 to 2006 plantings," Graham Brookes (Personal Communication, 2008) reported that gross margins from Bt maize, over conventional, based on trials conducted in 2006 were on average approximately 25%, higher and associated with an increase of 2.15 tons/ha. A significant advantage of Bt maize not captured in the benefits associated with yield increase is the substantial decrease in mycotoxin level with multi-fold decreases in the levels of all the various toxins. For example, Fumonisin B1 decreased from a range of 121 to 409 ppm in conventional maize to 0 to 25 ppm in Bt maize. Similarly, Fumonisin B2 decreased from a range of 44 to 103 ppm in conventional maize to a range of 0 to 8 ppm in Bt maize.

COSTA RICA

Costa Rica is included for the first time in 2009. Like Chile, it plants commercial biotech crops exclusively for the seed export trade. In 2009, it planted approximately 1,500 hectares of biotech cotton as well as about 100 hectares of biotech soybean.

Costa Rica, is a Spanish speaking country with a population of approximately 4.5 million situated in Central America. Costa Rica is bounded by Nicaragua to the north, Panama to the east and south, the Pacific Ocean to the south and east, and the Caribbean to the East. The major cash crops for domestic consumption and exports are coffee, bananas and pineapples. About a quarter of Costa Rica is designated as national parks and the country was one of the first in the world to develop ecotourism. Whereas Costa Rica has only about 0.1% of the world's landmass, it contains 5% of the world's biodiversity. Expressed as a percentage of its land area, Costa Rica has the largest area of land devoted to national parks and protected areas than any other country in the world.

Costa Rica is included for the first time in 2009 in the global list of countries officially planting biotech crops, because like Chile, it plants commercial biotech crops exclusively for the export seed trade. The only difference between Chile and Costa Rica, and the other twenty three countries planting biotech crops in 2009, is that the current laws in Costa Rica and Chile allow only commercialization of biotech crops designated for seed export. The biosafety law was promulgated in Costa Rica in 1998 (www.cr.biosafetyclearinghouse.net). The volume of biotech seed production in Costa Rica is smaller than Chile but has potential for growth. In 2009, approximately 1,500 hectares of biotech cotton (all three types of biotech cotton – Bt, herbicide tolerant, and the stacked gene product for Bt/herbicide tolerance) were planted commercially as well as about 100 hectares of biotech soybean.

Quite apart from the commercial production of biotech crops for seed export, Costa Rica is field testing biotech pineapples featuring a nutritional quality trait and disease resistant banana. These field tests are approved under the biosafety regulations of Costa Rica which conform to international standards.

EGYPT

In 2009, Egypt continued to plant approximately 1,000 hectares of Bt maize, a modest increase of approximately 15% over 2008, when approximately 700 hectares were planted. In 2008, Egypt was the first country in the Arab world to commercialize biotech crops, by planting a hybrid Bt yellow maize, Ajeeb YG. The planned increase

in hectarage of Bt maize to over 5,000 hectares in 2009 was not realized, because import licenses for 150 tons of Ajeeb YG, sufficient for planting 5,200 hectares, were not issued. Thus, the developers of Ajeeb YG had to rely on approximately 28 tons of locally produced seed to plant 1,000 hectares in 2009.

Egypt with a population of 80 million lies in the northeastern corner of Africa with a total land area of approximately 100 million hectares. It is bounded by the Mediterranean sea to the North and the Red Sea to the East and Sudan to the South. The topography of Egypt is dominated by the river Nile, the longest river in the world, which provides the critical water supply to this arid country. Only 3% of the land, equivalent to approximately 2.5 million hectares is devoted to agriculture, making it one of the world's lowest proportion of cultivable land per capita. However, agriculture is considered the principal sector in the economy contributing about 20% to GDP and providing close to 50% of employment. About 90% of the agricultural land is in the Nile Delta and the balance within a narrow strip along the Nile between Aswan and Cairo. The rich cultivated land, irrigated by the Nile, is very fertile and allows double cropping. Nevertheless, the meager area of cultivable land as well as problems related to salinity and limited water results in Egypt being dependent on imports for about half of its food supply. The principal crops are rice, wheat, sugarcane and maize. Government policy is to enhance agriculture as a major contributor to the national economy, by promoting privatization and decreasing government controls and subsidies. The major challenges for agricultural development in Egypt are the limited arable land base, erosion of land resources, loss of soil fertility and salinity and the high population growth rate of 1.9%.

Egypt has a well established biotechnology institute, the Agricultural Genetic Engineering Research Institute (AGERI), which is the lead crop biotech institute in the Arab world. AGERI is a centre of excellence in biotechnology, molecular biology, and genetic engineering research focusing on product development. AGERI is within the Agricultural Research Centre (ARC) of the Egyptian Ministry of Agriculture and Land Reclamation. AGERI is dedicated to the production of biotech crops and biotechnology-based products. AGERI's objective is to maximize production efficiencies with scarce water resources and arable land, reduce environmental degradation and minimize production risks for farmers. AGERI has a broad range of biotech crop activities, including the development of resistance to biotic stresses caused by viruses, insect, fungal pests and nematodes, and tolerance to abiotic stresses such as drought and salinity. Some basic research is also conducted on genome mapping, and protein and bio-molecular engineering. AGERI has several collaborative research programs with universities and international institutions. Several biotech crops are under development including wheat, barley and cotton tolerant to drought and salinity. There is a suite of projects incorporating resistance to various viruses in potato, squash and melons (zucchini yellow mosaic), tomato (tomato yellow leaf curl), and banana (bunchy top and cucumber mosaic). Similarly, there is a suite of projects incorporating resistance to insect pests, mainly featuring Bt genes, including projects on the *Gossypium barbadense* species of cotton (bollworm and other lepidopteran pests), potato (tuber moth), and maize (*Sesamia* stem borer).

It is notable that in 2008, Egypt became the first country in the Arab world to commercialize biotech crops, by planting 700 hectares of a Bt yellow maize hybrid. Egypt grows approximately 728,000 hectares of maize producing about 6.1 million tons, and imports annually 4.5 million tons of yellow maize valued at US$1.3 billion. Of the 728,000 hectares of maize in Egypt, approximately 75,000 hectares are yellow maize and the balance is white maize. On March 24, 2008, the Minister of Agriculture approved decisions made by the National Biosafety Committee and the Seed Registration Committee to commercialize the first Bt maize in the Arab world. Accordingly, in 2008, Egypt planted for the first time, a biotech maize hybrid which was developed by crossing Bt maize (MON 810) with the maize variety Ajeeb to produce the new biotech Bt yellow maize hybrid Ajeeb-YG, which was planted on 700 hectares. The biotech maize hybrid is resistant to three maize insect pest borers (Massoud, 2005). Field trials were conducted in Egypt from 2002 to 2007 after which, a dossier was submitted for commercializing Ajeeb-YG maize in Egypt. Increased productivity of Bt biotech maize can contribute to import substitution of the 4.5 million tons imported annually. Field experiments of Bt maize have indicated that the yield of Bt yellow maize can be increased by up to a significant 30% over conventional yellow hybrid maize.

In 2009, Egypt continued to plant approximately 1,000 hectares of Bt maize, a modest increase of approximately 15% over 2008, when approximately 700 hectares were planted. In 2008, Egypt was the first country in the Arab world to commercialize biotech crops, by planting a hybrid Bt yellow maize, Ajeeb YG. The planned increase in hectarage of Bt maize to over 5,000 hectares in 2009 was not realized, because import licenses for 150 tons of Ajeeb YG, sufficient for planting 5,200 hectares, was not issued. Thus, the developers of Ajeeb YG had to rely on approximately 28 tons of locally produced seed to plant 1,000 hectares in 2009.

Benefits from Bt Maize in Egypt

Developers of Ajeeb YG have reported the following economic benefits. Increase in yield per hectare resulted in a gain of US$267, plus an insecticide savings equivalent to US$89 per hectare for a total gain of US$356 per hectare, minus the additional cost of seed per hectare at US$75 for a net benefit per hectare of US$281. Thus, the benefits from planting 1,000 hectares in 2009 is approximately US$280,000 in 2009, whereas the benefits from 5,200 hectares from imported seed for 2009 would have been approximately US$1.4 million. On a national basis the estimated annual opportunity cost to Egypt of not deploying Bt maize, based on a 33% and 66% adoption on the 75,000 hectares of yellow maize, would be US$7 million and US$14 million annually, respectively. Additionally, the use of Bt maize in Egypt would have resulted in lower mycotoxin levels plus an import substitution value resulting from increased self-sufficiency of maize plus savings of foreign exchange.

SLOVAKIA

In 2009, the area of Bt maize in Slovakia was 875 hectares compared with 1,931 hectares in 2008. The decrease was a result of several factors associated with the economic recession including decreased plantings of hybrid maize.

Slovakia grew its first commercial biotech crop, Bt maize in 2006 when 30 hectares of Bt maize were grown for commercial production by several farmers. In 2007, the area increased 30-fold to 900 hectares and in 2008 it again increased by over 111% to 1,931 hectares. As a result of several factors associated with the economic recession and decreased plantings of hybrid maize, the Bt maize hectarage in 2009 decreased to 875 hectares. As an EU member state, Slovakia can grow maize with the MON810 event which has been approved by the EU for all of its 27 member countries. Slovakia is estimated to have grown 236,000 hectares of maize in 2008 comprising 157,000 for grain and 79,000 for silage.

Benefits from Biotech Crops in Slovakia

It is estimated that from a third to a half of the 240,000 hectares of maize in Slovakia is infested with European corn borer with the most severe infestations in the south of the country where most of the maize is grown. Yield gains conferred by Bt maize have been measured at 10 to 15%. The average gain per hectare from Bt maize is estimated at US$45 to US$100 per hectare. Thus, at the national level, the income gain for farmers, assuming 100,000 hectares of Bt maize, would be in the range of US$4.5 million to US$10 million annually in Slovakia.

THE EUROPEAN UNION (EU 27)

Six EU countries planted Bt maize in 2009, with Germany having discontinued planting at the end of 2008. Spain was by far the largest EU grower with 80% of the total Bt maize area in the EU with a record adoption rate of 22%. The 2009 hectarage in the six EU countries was 94,750 hectares compared with a 2008 total of 107,719 hectares, including Germany's 2008 hectarage of 3,173 hectares, or a 2008 total of 104,456 hectares excluding Germany's hectarage. Thus, the decrease from 2008 to 2009 was 12,969 hectares (including Germany's 2008 hectarage) equivalent to a 12% decrease, or 9,796 hectares (excluding Germany's 2008 hectarage) equivalent to a 9% decrease). The decrease was associated with several factors, including the economic recession, decreased total plantings of hybrid maize, and disincentives for some farmers due to onerous reporting of intended plantings of Bt maize.

The European Union comprises 27 states, a population of almost 500 million (7% of global) with a GDP in 2008 of US$18.39 trillion, equivalent to over 22% of global GDP. Less than 6% of the EU's workforce is employed in agriculture and the principal major crops occupy just over 90 million hectares (versus 1.5 billion hectares globally) of which maize is 13 million hectares, about 10% of global hectarage. There are approximately 15 million farms in the EU; Romania has the largest number of farms (almost a third of the EU total, followed by Poland, Italy and Spain).

Table 41 summarizes the planting of Bt maize in the countries of the European Union from 2006 to 2009. In 2009, of the 27 countries in the European Union, six officially planted Bt maize on a commercial basis. Listed in decreasing order of hectarage they are Spain, Czech Republic, Portugal, Romania, Poland and Slovakia. Spain was by far the largest EU grower with 80% of the total Bt maize area in the EU with a record adoption rate of 22%. The 2009 hectarage in the six EU countries was 94,750 hectares compared with a 2008 total of 107,719 hectares, including Germany's 2008 hectarage of 3,173 hectares, or a 2008 total of 104,456 hectares, excluding Germany's hectarage. Thus, the decrease from 2008 to 2009 was 12,969 hectares, (including Germany's 2008 hectarage) equivalent to a 12% decrease, or 9,796 hectares (excluding Germany's 2008 hectarages), equivalent to a 9% decrease. Whereas all seven EU countries growing Bt maize in 2008 reported increases in Bt maize hectares over 2007, year-to-year hectare changes between 2008 and 2009 varied. Of the six EU countries growing Bt maize in 2009, Portugal had a higher hectarage than 2008, Poland had the same hectarage, and Spain had 4% less Bt maize hectarage but total plantings of maize were also down in 2008 by a similar margin and hence adoption rate of 22% was the same in 2008 and 2009. The three other remaining EU countries: Czech Republic, Romania and Slovakia reported lower Bt maize hectarages in 2009, albeit based on low absolute hectarages per country of 1,000 to 7,000 hectares. The decrease in 2009 was associated with several factors, including the economic recession, decreased total plantings of hybrid maize and disincentives for some farmers due to onerous reporting of intended plantings of Bt maize. All six EU countries which grew Bt maize commercially in 2009 provided benefits to farmers, to the environment and a more affordable feed source for animals, which in turn benefited consumers who eat meat.

Table 41. Hectares of Bt Maize Planted in 2006 to 2009 in the EU Countries* which Grew Bt Maize in 2009

	Country	2006	2007	2008	2009	Change 2007/08	Change 2008/09	% 2009 08/09
1	Spain	53,667	75,148	79,269	76,057	+4,121	-3,212	-4%
2	Czechia	1,290	5,000	8,380	6,480	+3,380	-1,990	-23%
3	Portugal	1,250	4,263	4,851	5,094	+588	+243	+5%
4	Romania*	- -	350	7,146	3,244	+6,796	-3,902	55%
5	Germany	950	2,685	3,173	- -	+488	- -	- -
6	Poland	100	327	3,000	3,000	+2,673	- -	0%
7	Slovakia	30	900	1,900	875	+1,000	-1025	-54%
	Total	**57,287**	**88,673**	**107,719**	**94,750**	**+19,046**	**-12,969**	**-9 to12%**

*Germany, which grew 3,173 hectares in 2008 discontinued planting at the end of 2008. France, which grew 22,135 hectares in 2007, suspended Bt maize in 2008, after growing it from 1998 to 2000 and from 2005 to 2007. Romania grew 145,000 hectares of RR® soybean in 2006 but had to cease growing it after becoming an EU member in January 2007.

Source: Clive James, 2009.

Despite the severe economic recession in 2009, the suspensions in France and Germany and Romania precluded from growing about 150,000 hectares of RR®soybean, the hectarage of biotech crops in the EU remains at about 100,000 hectares. This reflects the trust of Bt maize farmers in the EU in biotech crops, despite onerous disincentives related to significant bureaucratic and economic constraints.

Contrary to the findings of France and Germany, EFSA has clearly stated, that ***"No specific scientific evidence, in terms of risk to human and animal health and the environment, was provided that would justify the invocation of a safeguard clause"*** (EFSA, 2008). A report in September 2008 by the EU's Joint Research Council (EU-JRC, 2008) concluded that, ***"No demonstration of any health effects of GM food products submitted to the regulatory process that has been reported so far."*** This finding of the JRC endorsing the safety of biotech crops is consistent with many independent studies conducted over the last several years including the Nuffield Bioethics Council, the Royal Society and the EU's EFSA. The latest report (EU-JRC, 2008) suggested that, ***"Europe must 'move forward' and clear biotech crops amid increasing food prices."***

The events approved in the EU for imports (not planting) in 2004 to 2009 are summarized in Table 42.

Table 42. GMO Crop Approvals for Import by the European Union, 2004-2009

Crop	Trait	Event	Company	Approval for	Date Approved
Maize	IR	Bt 11	Monsanto	Food and Feed	May 19, 2004
Maize	HT	NK603	Monsanto	Food and Feed	October 26, 2004
Rapeseed	HT	GT 73	Monsanto	Import and Processing	August 31, 2005
Maize	IR	MON863	Monsanto	Food and Feed	January 13, 2006
Maize	IR/HT	DAS1507	Pioneer/ Dow Agro Science	Food and Feed	March 3, 2006
Rapeseed	Male Ster/ HT	MS8 x RF3	Bayer Crop Science	Import and Processing	March 26, 2007
Carnation Moonlite	Mod Flower Color	FLO-40644-4	Florigene Ltd	Import and Processing	May 30, 2007
Maize	IR/HT	DAS 59122-7	Dow AgroSciences/ Pioneer Hi-bred	Food/Feed Import and Processing	October 24, 2007
Maize	IR/HT	DAS1507 x NK603	Pioneer Hi-bred/ Mycogen Seeds	Food/ Feed Import and Processing	October 24, 2007
Maize	IR/HT	MON603 x MON810	Monsanto Co.	Food/ Feed	October 24, 2007
Sugarbeet	HT	H7-1	KWS SAAT AG/ Monsanto	Food/ Feed	October 24, 2007
Maize	HT	GA 21	Syngenta	Food/ Feed Import and Processing	March 28, 2008
Soybean	HT	A2704-12	Bayer Crop Science	Food/Feed Import and Processing	September. 8, 2008
Cotton	HT	LL Cotton 25	Bayer Company	Food/ Feed Import and Processing	September. 29, 2008
Soybean	HT	Mon 89788-1	Monsanto	Food/Feed Import and Processing	December 4, 2008
Rapeseed	HT	T45	Bayer Crop Science	Food/ Feed Import and Processing	March 10, 2009
Maize	IR/HT	DAS 59122 x NK603	Pioneer Hi-Bred	Food/Feed Import and Processing	October 30, 2009
Maize	IR/HT	MON88017	Monsanto	Food/Feed Import and Processing	October 30, 2009
Maize	IR	MON89034	Monsanto	Food/Feed Import and Processing	October 30, 2009
Maize	IR	MIR604	Syngenta Seeds	Food/Feed Import and Processing	November 30, 2009

Source: GMO Compass Database, 2009.

Political Support to Biotech Crops in the EU.

Whereas there is a great deal of ideological and political opposition to biotech crops in the EU, there is also some more progressive thinking.

In a very substantive report, published in October 2009, entitled "***Reaping the Benefits – Science and the sustainable intensification of agriculture",*** **The Royal Society**, the UK's most prestigious scientific academy, has recommended publicly funded research of GM crop technologies. The report concludes that the application of both conventional and biotech applications would allow northern Europe to become one of the '***major bread baskets of the world'***. The UK Government's Chief Scientist, **Dr. John Beddington** has endorsed biotech crops for the UK. In addition, the **Food Standards Agency (FSA)** is due to initiate a dialogue to explore the GM crops with consumers.

In August 2009, **Environment Secretary Hilary Benn** of the UK introduced the notion that GM crops could offer a solution to climate change and population growth. He said, "***We saw last year when the oil price went up and there was a drought in Australia, which had an impact on the price of bread here in the UK, just how interdependent all these things are… We have to feed another two and a half to three billion mouths over the next 40 to 50 years, so I want British agriculture to produce as much food as possible."*** Mr. Benn told Radio 4 Today Program that farmers would decide what to grow "***But it was important to investigate new techniques to discover the "facts" about them. If GM can make a contribution then we have a choice as a society and as a world about whether to make use of that technology, and an increasing number of countries are growing GM products… Because one thing is certain – with a growing population, the world is going to need a lot of farmers and a lot of agricultural production in the years ahead. Some GM crops could be more drought-resistant and used with pesticides to combat the expected rise in insects associated with rising temperatures"*** (Waugh, 2009). The UK Government's Food 2030 study, published in early January 2010, concluded that Britain must embrace GM crops or face serious food shortages in the future. The Report has had unusually strong support from Government, ministers, leading scientists and is consistent with the recommendations of the recent substantive report from the UK's prestigious Royal Society, referenced in the following paragraph. Speaking at the Oxford Farming Conference, after the publication of the Food 2030 Report, Professor John Beddington, the UK's Chief Scientist said, ***"GM and nanotechnology should be part of modern agriculture. We need a greener revolution, improving production and efficiency through the food chain within environmental and other constraints. Techniques and technologies from many disciplines ranging from biotechnology and engineering to newer fields such as nanotechnology will be needed"*** (Gray, 2009).

Sir David King, the UK Government's former Chief Scientific Adviser, strongly advocated the UK government and Ministers to strongly support adoption of biotech crops which he believes are critical for the UK. Sir David King cautioned that, ***"The world would need all the food it could get to feed over 9 billion people by 2050. We will only do this with the assistance of a third green revolution and GM technologies will be crucial in delivery of this."*** In 2008, Sir David King again advocated biotech crops as a technology that can contribute to more affordable food. He said, ***"GM is the only technology available to solve the world food price crisis"*** (Cookson, 2008).

A study by a group from the University of Leuven, Belgium (Demont et al. 2007) has documented the potential benefits to Europe from biotech crops. They concluded that the potential annual value of biotech crops for an EU country can be up to US$60 million per year and that biotech sugarbeet alone could generate annual gains in the order of US$1 billion per year for the EU.

Grave risks to the EU posed by zero tolerance of unauthorized biotech crop events in imported feed

In August 2009, the concession that EU animal-feed groups (represented by FEFAC – the European Compound Feed Manufacturers' Federation) were seeking in the EU for some tolerance to GM/biotech in the feeds, was sidelined by the EU commission, thus increasing the probability of steep increases in feed prices. This has negative consequences for both the feed industry and consumers in the EU as a result of increased risk of significantly higher meat prices (Clark, 2009). This negative outcome bitterly disappointed FEFAC, which had sensibly opined that some tolerance of GM/biotech crops was the best option for avoiding the risk of a "total loss" of US soybean imports to Europe, subsequent to Germany and Spain reporting traces (dust in a foreign material) of unapproved GM maize in shipments of soybean. The FEFAC understandably claim that GM crops are now so widespread globally that traces are inevitable, irrespective of the measure taken to prevent trace amounts. FEFAC was seeking a sensible concession similar to that granted to banned veterinary antibiotics, which are now allowed in the EU at trace levels. FEFAC was seeking this concession to overcome an urgent need because legislation would take at least two years, which was impractical given the urgent need to secure feed supplies before animals were taken in for the 2009 winter in the EU. The sidelining by the EU of the proposal is judged to be very serious by FFEAC given that soybean meal is the "lifeline" of Europe's livestock industry, and without it there would be "no" compound feed.

Farm animals in the 27 countries of the EU consume an estimated 470 million tonnes of feed a year, of which 150 million tonnes are produced by the compound feed manufacturers FFEAC (FEFAC, 2009). Turnover of the European compound feed industry is estimated at US$63 billion for 2008 (at exchange rate of US$1.4 = 1 Euro). FEFAC are concerned that feed prices may increase significantly at very short notice due to the EU zero-tolerance policy for the presence of trace levels of not yet EU approved GM crop products in imported feeds. Of particular concern is the potential total loss of important soybean imports from the US following positive testing for not yet EU approved GM maize in US soybeans and soybean meal. The EU livestock industry is concerned because it needs to source soybeans and soybean meal from the US at least until the next South American harvest in spring 2010. It is estimated that soya prices could rise by at least US$28/t due to additional "risk premiums" for US origin and even significantly higher if the EU could no longer import from the US, due to the lack of alternative supplies from South America.

The impractical zero tolerance policy has high risks because the EU is dependent for more than 80% on imports of vegetable proteins for which there are no substitution possibilities in the short term. Ironically, EU imports of meat are all produced from animals, which may legally be fed with not yet EU authorized GM plants. In a FEFAC communication to the President of the EU Farm Council, it was stated that "at a time when most EU livestock producers were facing economic hardship, the EU opposition to provide a practical threshold for trace levels of not yet EU authorized GM plants in imported feed may drive EU livestock farmers and feed operators out of business." FEFAC called on EU Farm Ministers "to agree on urgent measures at the EU Farm Council meeting on 13 July 2009 to prevent the export of the EU livestock industry." It was stressed that "it is the EU's foremost responsibility to ensure vital protein feed imports for livestock farmers and thus food security for EU citizens while maintaining an economically viable and sustainable livestock sector."

Past experience indicates that an EU zero tolerance policy for not yet EU approved GM events will lead to further significant feed price rises, which can be devastating. FEFAC noted that "the previous loss of US produced maize-gluten-feed and Distillers Dried Grains & Solubles in 2007 due to the presence of not yet approved GM events, cost EU livestock producers more than US$3.5 billion." The potential loss of 4 million tonnes of US soybeans and approximately 0.5 million tonnes of US soybean meal could result in an initial cost (for the total EU soya value chain) of approximately US$3.2 billion. This cost could significantly increase given the lack of sufficient alternative supplies from South America which may lead to further significant price rises during the winter season until the spring crop 2010. This is why the FEFAC called on EU Farm Ministers to take up their responsibility by agreeing on urgent measures for the setting of a practical low-level presence threshold for not yet EU approved GM events to prevent the export of the EU livestock industry while ensuring feed and food security for EU farmers and consumers.

Many EU observers were of the opinion that the EU could have faced a catastrophic problem with biotech feed, had RR2Yield™ soybean not been approved for import to the EU on 4 December 2008. On 20 November, 2008, Ministers had failed to approve or reject the approval with the necessary qualified voting majority (Smith, 2008). The 13 countries in favor of the approval were: Belgium, Bulgaria, Denmark, Estonia, Finland, Portugal, Romania, Slovakia, Spain, Sweden, the Czech Republic, Netherlands and the United Kingdom. The eight countries that voted against were: Austria, Cyprus, Greece, Hungary, Lithuania, Luxembourg, Malta and Poland. The balance of 6 EU countries abstained. Some observers estimated that in a worst case scenario with animal feed, the EU could have experienced an import feed deficit of 32 million tons, which could have been only offset to a maximum of 20% through substituted production in the EU. Given the importance of soybean as feed for pigs and poultry production of these meats, it was estimated that meat production could have fallen by up to 35% and 44%, respectively, and the price of non-biotech soybean could have escalated in the market place.

The **Danish Minister of Agriculture, Eva Kjer Hansen** published a welcome report in 2009 entitled "***Lets get rid of the myths of GMOs***" (Ministry of Agriculture and Fisheries, Denmark 2009). She calls for an evidence-based open-debate on genetically modified organisms and argues that there is nothing new in modifying plant genetic material. She points out that recombinant insulin is accepted and used daily around the world and that there are biotech crops such as blight-resistant potatoes that offer Denmark significant advantages, including substantial reduction in pesticides with positive implications for the environment (potatoes are sprayed up to 7 times a season for late-blight in Denmark) and biodiversity. She also cites benefits related to reductions in greenhouse gases. Denmark's forward-looking policy on biotech crops has anticipated that the country will plant biotech crops that offer Danish farmers advantages and that these could become available soon. Around 250 Danish farmers have already undertaken training in the practical implementation of coexistence practices so that they are prepared for planting the first commercial biotech crops determined to be safe and beneficial to Denmark.

An EU supported study conducted by the EU SIGMA research group in Girona, Spain has reported that rouge biotech maize surviving as volunteer plants contribute less than the 0.9% threshold for adventitious presence and thus do not contravene EU regulations governing the presence of biotech seed in conventional maize seed (Fundacion Antama, 2009).

An international group of scientists including some from the Scottish Crop Research Institute (2009) have sequenced the potato genome. This is an important achievement, given that potato is the fourth most important food crop in the world, and will allow the development of biotech potatoes to be expedited in "speeding the breeding" initiatives. Bt biotech potato was one of the first commercialized in the USA and Canada in the 1990s. Two biotech potatoes are at an advanced stage of field testing in the EU, and Russia is also involved in the development of Bt potatoes resistant to the devastating Colorado beetle pest.

Other Countries that are at an Advanced Stage with Commercializing Biotech Crops

Pakistan

Pakistan, with a population of 166 million (sixth most populous country in the world) is the fourth major cotton producer in the world (3 million hectares) after China, India and the United States. Pakistan lies in Southern Asia, bordering the Arabian Sea between India on the east, Iran and Afghanistan on the west, and China in the North. The country has a total land area of 79.6 million hectares, and 22 million hectares is cultivated. The soils are predominantly calcareous and 21% is affected with surface salinity. Pakistan is an impoverished country with an estimated GDP of US$168.3 billion, 20.4% of which is from agriculture which provides work for 43% of the labor force. Around 60% of the global cotton harvest and more than 70% of the world's cotton growers are in China, India and Pakistan. It is a crop of the poor in Asia, providing the main source of income to millions of low-income, small scale farmers. Cotton production supports the textiles and apparel industry which accounts for nearly 40% of employment in Pakistan and two thirds of the country's total exports. Cotton processing provides jobs for millions of factory workers, many of them women.

In Pakistan, cotton is grown on about 3 million hectares and planted by 928,800 farmers with an average cotton holding of 3.23 hectares. The government has recognized the importance of Bt cotton and has taken several steps to facilitate the commercial use of genetically modified cotton. It recommended that GM cotton lines must be adapted to the prevailing climatic conditions with plans to incorporate resistance to the important pests and diseases common to the region, particularly cotton leaf curl virus (CLCV). In a defining step in 2009, two varieties of Bt cotton were approved for commercialization during the seventh meeting of the National Biosafety Committee, Pakistan Environment Protection Agency, and the Ministry of Environment. The two varieties CEMB-01 (with a single Bt gene) and CEMB-02 (with double Bt genes) were developed by the Centre of Excellence in Molecular Biology (CEMB) and will be available in Kharif 2010 pending approval by the Punjab Seed Council in February 2010. (Note Kharif are monsoon crops planted from end of May onwards whereas Rabi crops are winter crops harvested in the spring).

The approval of these two Bt cotton varieties and the planned approval of other Bt cotton varieties, reflects a progressive strategy by government to increase national cotton production from this year's 13 million bales to 25 million bales over the next five years. The increase of cotton exports from 7,931 metric tons last year to 25,728 metric tons this year (a 224% increase) requires a continuous increased supply of raw cotton material which cannot be supplied by existing conventional varieties but where Bt cotton varieties can make a significant contribution, as they have already done in other countries including neighboring India (Bt cotton hybrids), and China (Bt cotton varieties), the largest producer of cotton in the world.

Cuba

Cuba imports around 60% of its food and feed, including large tonnages of maize, soy and wheat. The President of Cuba, Raul Castro has called for increased agricultural output to contribute to "national security" following the unprecedented high food prices in 2008. Food and feed imports was expected to require up to US$2 billion of foreign exchange in Cuba in 2009. Furthermore, Cuba's harvests were battered in 2008 by three hurricanes that the government estimated caused nearly US$10 billion in damages and destroyed 30% of the country's crops, resulting in brief food shortages.

In a determined and carefully planned research effort to significantly increase productivity of maize, Cuba, a country of 11 million people, is developing biotech maize to control losses from the insect pest fall armyworm (*Spodoptera frugiperda*). Armyworm is the most serious threat to maize production in Cuba and some other tropical countries, where it causes significant yield losses. The Bt maize is being developed and field-tested in a rigorously designed biosafety program, which meets the demanding standards of international protocols, by the country's internationally recognized Institute for Genetic Engineering and Biotechnology (CIGB).

To - date, field tests in Cuba have indicated that the significant and multiple benefits associated with Bt maize are similar to those reported by other countries which have already commercialized Bt maize. These benefits include, reduction in insecticides for the control of fall armyworm, less exposure of farmers and the environment to pesticides, protection of the enhanced diversity of more prevalent beneficial insects, and sustainable increases in productivity of up to 30%, or more, depending on the severity of the armyworm infestation, which varies significantly with climatic and ecological conditions. The multiple location field trials are at an advanced phase, and are estimated to have occupied up to 1,000 hectares in 2009 in 7 provinces. The rigorously executed program of regulated field trials is designed to address the issues of producers, consumers and society by comprehensively evaluating all aspects of the technology, prior to submission of an extensive dossier to the regulatory authorities in Cuba, for commercial approval consideration in the near term.

The Bt maize being developed by Cuba is similar to that grown on over 40 million hectares in over 17 countries in 2009 alone. Thus, Cuba has the advantage of benefiting from the extensive commercial experience of a large number of countries in all continents of the world, including six EU countries which have been successfully growing and benefiting from Bt maize for more than a decade. The potential benefits of commercializing Bt maize in Cuba are significant. The latest published import information is for 2006 which indicates that Cuba imported approximately 600,000 tonnes of maize valued at approximately US$86 million (FAO Stats, 2006). Some of these imports could be substituted by domestic production if the yield losses due to armyworm, which are up to 30%, are controlled, thus making the country substantially more self-sufficient in maize production. This is a very important benefit to Cuba because the alternative is to keep relying on imports, which are likely to become more expensive when prices of staples trend upwards in the future. Work is also underway in Cuba to develop biotech soybean, potatoes and tomato, but unlike Bt maize, these are pipeline technologies in development.

Distribution of Biotech Crops, by Crop

The distribution of the global biotech crop area for the four major crops is illustrated in Figure 31 and Table 43 for the period 1996 to 2009. It clearly shows the continuing dominance of biotech soybean occupying 52% of the global area of biotech crops in 2009; the entire biotech soybean hectarage is herbicide tolerant RR®soybean. Biotech soybean retained its position in 2009 as the biotech crop occupying the largest area globally, occupying 69.2 million hectares in 2009, 5% higher than 2008 and biotech maize had the second highest area at 41.7 million hectares and also had the second highest year-to-year growth rate for any biotech crop at 12%. Biotech cotton reached 16.1 million hectares in 2009 and grew at the lowest of all biotech crops at a rate of only 4% between 2008 and 2009. Canola reached 6.4 million hectares in 2009 with an 8% global growth rate and planted in Australia for the first time in 2009. Sugarbeet is an important relatively new biotech crop first commercialized in the USA and Canada in 2007, and an increased adoption rate of 59% in 2008, and 95% in 2009 when hectarage reached 0.5 million hectares – this makes it the fastest adopted biotech crop since the genesis of commercialization in 1996. RR®alfalfa, first grown in 2006, occupied 102,000 hectares equivalent to approximately 5% of the 1.3 million hectare seeded in the USA in 2009, with no further planting taking place in 2009 until the restraining order on planting is rescinded in the USA. Small hectarages of biotech virus-resistant squash and papaya continue to be grown in the USA and China also grows about 4,500 hectares of PRSV resistant papaya and 447 hectares of Bt poplar.

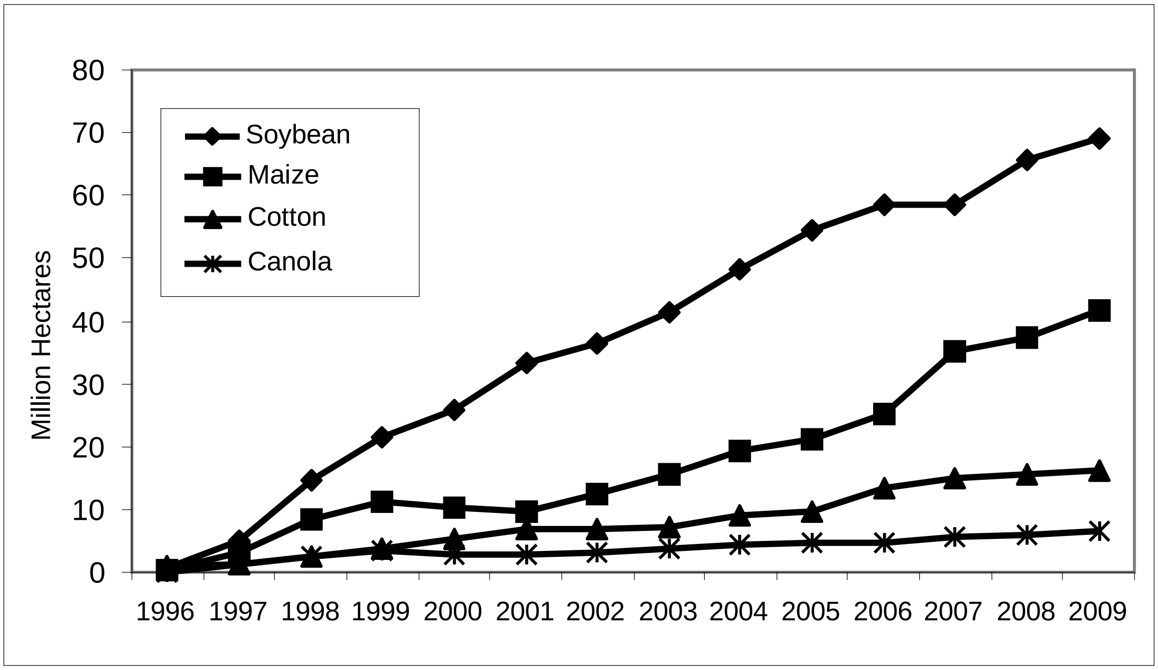
Distribution of economic benefits for the four major biotech crops for the first 13 years of commercialization 1996 to 2008 were as follows: herbicide tolerant soybean US$23.3 billion, Bt cotton US$15.6 billion, Bt maize US$8.3 billion, herbicide tolerant maize US$1.9 billion, herbicide tolerant canola US$1.8 billion, herbicide tolerant cotton US$0.8 billion, and the balance in virus resistant squash US$107 million and papaya US$53 million for a total of approximately US$51.9 billion (Brookes and Barfoot, 2010, forthcoming).

Distribution of economic benefits for the major biotech crops for 2008 only were as follows: herbicide tolerant soybean US$2.9 billion, Bt cotton US$2.9 billion, Bt maize US$2.6 billion, herbicide tolerant maize US$0.4 billion, herbicide tolerant canola US$0.4 billion, herbicide tolerant cotton US$55 million, with the balance in virus resistant squash (US$26 million) and papaya (US$4 million), for a total of US$9.2 billion (Brookes and Barfoot, 2010, forthcoming).

Biotech soybean

In 2009, the global hectarage of herbicide tolerant soybean was 69.2 million hectares, up by 3.4 million hectares from 2008 at 65.8 million hectares. The increase resulted from the following significant changes at the country level. The largest increase by far, equivalent to 22% of the global biotech crop hectarage increase of 9 million hectares in 2009, was in Brazil at 16.2 million hectares; more

Figure 31. Global Area of Biotech Crops, 1996 to 2009: by Crop (Million Hectares)



Source: Clive James, 2009.

Table 43. Global Area of Biotech Crops, 2008 and 2009: by Crop (Million Hectares)

Crop	2008	%	2009	%	+/-	%
Soybean	65.8	53	69.2	52	3.4	+5
Maize	37.3	30	41.7	31	4.4	+12
Cotton	15.5	12	16.1	12	0.6	+4
Canola	5.9	5	6.4	5	0.5	+8
Sugarbeet	0.3	<1	0.5	<1	0.2	+66
Alfalfa	0.1	<1	0.1	<1	- -	- -
Papaya	<0.1	<1	<0.1	<1	--	- -
Others	<0.1	<1	<0.1	<1	-	- -
Total	**125**	**100**	**134**	**100**	**+9.0**	**+7**

Source: Clive James, 2009.

modest increases were recorded in Canada, South Africa, Bolivia and Uruguay, offset by a decrease in Paraguay, which was principally due to a decrease of 300,000 hectares in total soybean plantings in the country in 2009. The 69.2 million hectares of biotech soybean worldwide is equivalent to a record 73% of the global 95 million hectares of soybean. In Brazil, 71% of the 22.9 million hectare soybean crop was estimated to be RR®soybean in 2009, up from 65% in 2008. In the USA, herbicide tolerant soybean hectarage in 2009 occupied 29.2 million hectares of the 31.4 million hectare crop. In Argentina, continued growth is projected to result in 18.8 million hectares in 2009, up from 18.1 million hectares in 2008; virtually all the Argentinean national soybean hectarage is planted with herbicide tolerant soybean. Paraguay reported 2.2 million hectares of herbicide tolerant soybean in 2009 down from the 2.6 million hectares in 2008 but with a high adoption rate of 90%. Canada planted about 71% of its national soybean hectarage of 1.4 million hectares with herbicide tolerant soybean in 2009. Uruguay's herbicide tolerant soybean continued to occupy 100% of the national soybean hectarage of 700,000 hectares in 2009 up from 575,000 hectares in 2008. South Africa biotech soybean hectarage increased to approximately 223,000 hectares up from 184,000 hectares in 2008, and 145,000 hectares in 2007. Bolivia increased its hectarage of RR®soybean from 600,000 hectares in 2008 to 750,000 (~0.8) hectares in 2009. Of the global hectarage of 95 million hectares grown in 2008, an impressive 73% or 69.2 million hectares were RR®soybean. Biotech soybean is grown in 11 of the 25 biotech crop countries worldwide.

The increase in income benefits for farmers growing biotech soybean during the thirteen year period 1996 to 2008 was US$23.3 billion and for 2008 alone, US$2.9 billion (Brookes and Barfoot, 2010, forthcoming).

Biotech maize

In 2009, biotech maize increased by 12% or 4.4 million hectares to 41.7 from 37.3 million hectares in 2008. It is noteworthy that 16 countries grew biotech maize in 2009. The largest increase in any country in 2009 was in Brazil, which was expected to plant 5 million hectares of Bt maize in the two seasons of summer and winter (safrinha). Approximately 50% of the 5 million hectares is planted in the summer season (2.4 million hectares), and the other 50% in the safrinha season (2.6 million hectares) with planting starting in about the last few week of December 2009 and continuing through to January and February of 2010; note that in this Brief, the second season safra crop is classified as a 2009 crop given that earliest planting begins at the end of December. Total plantings of maize in the USA in 2009, were 1% higher and the increased adoption rate resulted in an increase of almost 1 million hectares of biotech maize. An important feature of biotech maize in the USA in 2009 continued to be stacking, which will be discussed in the section on traits. Modest increases were reported by several countries and small decreases in others particularly in the EU where with the exception of Spain, Bt maize hectares in all countries is under 10,000 hectares.

Of the global hectarage of 158 million hectares of maize grown in 16 countries in 2009 for the first time, over a quarter, 27%, or 41.7 million hectares, were biotech maize; this compares with 24% or 37.3 million hectares grown in 16 out of 25 biotech crop countries worldwide in 2008.

Preliminary projections of yield gains from drought tolerant maize in the USA, expected to be available about 2012, or earlier, are 8 to 10% in the non-irrigated areas from North Dakota to Texas. By 2015, current yields of 5.5 metric tons in the dry regions of the USA may increase to 7.5 metric tons per hectare.

As the economies of the more advanced developing countries in Asia and Latin America improve, this will significantly increase demand for feed maize to meet higher meat consumption in diets as people become more prosperous. Coincidentally, maize continued to be used for ethanol production, particularly in the USA.

The increase in income benefits for farmers growing biotech maize during the 13 years (1996 to 2008) was US$10.2 billion and US$3.0 billion for 2008 alone (Brookes and Barfoot, 2010, forthcoming).

Biotech cotton

The area planted to biotech cotton globally in 2009 was up by 0.6 million hectares, equivalent to a 4% growth over 2008, reaching 16.1 million hectares globally and equivalent to 47% of the global cotton area of 34 million hectares in 2009. Thus, although total plantings of cotton decreased globally in 2009 the hectares of biotech cotton increased globally from 15.5 million hectares to 16.1 million hectares and the corresponding adoption rate increased from 46% to 47% globally. Virtually all of the growth was in India (0.8 million hectares), followed by an increase of approximately 106,500 hectares in Burkina Faso, with small decreases in all other biotech cotton growing countries. These decreases in biotech cotton are consistent with reports that world cotton hectarage decreased by 2% in 2009 as a result of lower prices relative to other major crops, including soybean and maize, and increased cost of inputs particularly fertilizer and pesticides.

RR®Flex cotton was introduced in the USA and Australia for the first time in 2006 by Monsanto and continues to enjoy strong growth in 2009. It is marketed as a single gene and also as a stacked product with insect resistance in Bollgard®II. The simultaneous marketing of biotech cotton from the public and private sectors is unique to China and India at this time but is likely to also become more prevalent as biotech crops are developed by government supported public sector institutions in developing countries. It is notable that in 2009, the biotech cotton area in India again exceeded the Bt cotton in China. In 2009, biotech hybrid cotton in India, the largest cotton growing country in the world, occupied 8.4 million hectares of approved Bt cotton increasing by an impressive 11% gain between 2008 and 2009, despite almost optimal levels of adoption which reached 80% in 2008. The advantages of Bt cotton hybrid in India are significant and the substantial increase in

2009 was due to the significant gains in production, economic, environmental, health and social benefits, which has revolutionized cotton production in India. Finally it is notable that, Burkina Faso which grew 8,500 hectares of Bt cotton (Bollgard®II) for the first time in 2008 increased this area to 115,000 hectares in 2009. This represents a 1,353 percent increase over 2008 making it the highest year-to-year increase for any country in the world in 2009.

Of the global hectarage of 33 million hectares of cotton grown in 2009, almost one half, 49% or 16.1 million hectares, were biotech cotton and grown in 11 of the 25 biotech crop countries worldwide.

The increase in income benefits for farmers growing biotech cotton during the thirteen year period 1996 to 2008 was US$16.4 billion and US$2.9 billion for 2008 alone (Brookes and Barfoot, 2010, forthcoming).

Biotech canola

The global area of biotech canola in 2009 is estimated to have increased by a modest 0.5 million hectares, from 5.9 million hectares in 2008 to an estimated 6.4 million hectares in 2009. There was a significant increase of 500,000 hectares in Canada. Notably, Australia grew more than 40,000 hectares herbicide tolerant biotech canola for the second time after a protracted debate at the national level (Table 33). In Canada, by far the largest grower of canola globally, the adoption of herbicide tolerant canola has consistently increased reaching a record 93% in 2008 compared with 86% in 2008, with only 1% of the crop now conventional, compared with 2% in 2007; the balance of 6% is made up of a product developed through mutagenesis rather than biotechnology. Only four countries currently grow biotech canola: Canada, the USA, Australia and Chile but the global acreage and prevalence could increase significantly in the near term in response to the likely increased use of canola for vegetable oil and biodiesel. Less than 1% of the canola crop in Canada was used for biodiesel in 2008 and this is expected to remain low at around 2% in 2012 when new biodiesel plants come on stream.

Of the global hectarage of 30 million hectares of canola grown in 2009, 21%, or 6.4 million hectares (up from 21% and 5.9 million hectares in 2008) were biotech canola grown in Canada, the USA and Australia.

The increase in income benefits for farmers growing biotech canola during the thirteen year period 1996 to 2008 was US$1.8 billion and US$0.4 billion for 2008 alone (Brookes and Barfoot, 2010, forthcoming).

Biotech alfalfa

Herbicide tolerant RR®alfalfa was approved for commercialization in the USA in 2005. The first pre-commercial plantings (20,000 hectares) were sown in the fall of 2005, followed by larger commercial plantings of 60,000 in 2006. The 60,000 hectares of RR®alfalfa represent approximately 5% of the 1.3 million hectares alfalfa seeded in 2006. Herbicide tolerance is expected to be the first of several traits to be incorporated into this important forage crop. A court injunction in 2007 suspended further plantings of RR®alfalfa until a new dossier of information is submitted to the regulators for consideration. Before the injunction came into force, another 22,000 hectares were planted bringing the total of RR®alfalfa in the USA in 2007 to 102,000 hectares. There are approximately 9 million hectares of alfalfa grown for dry hay in the USA annually worth US$7 billion. Unlike the large biotech row crops of soybean and maize, biotech alfalfa is likely to be more of a niche market. As of November 2009, resumption of RR®alfalfa plantings was pending subject to a decision by the regulatory authorities in the USA. The original injunction was upheld in a later hearing in 2009 and as ISAAA Brief 41 went to press, Monsanto announced that it had filed a petition requesting the U.S. Supreme Court to review a federal appeals court's decision to block the cultivation of the company's RR®alfalfa until the USDA completes its environmental assessment (Tomich, 2009). Immediately before this Brief went to press, USDA published its environment impact assessment of RR®alfalfa for public comments; USDA recommends deregulation of the product (*Feedstuffs*, 2009).

Other biotech crops

Small areas of biotech virus resistant squash (2,000 hectares) and PRSV resistant papaya in Hawaii (2,000 hectares with a 60% adoption) continued to be grown in the USA in 2007. In China, in 2009 there were approximately 4,500 hectares of PRSV resistant papaya (90% adoption rate) and 447 hectares of Bt poplars.

Distribution of Biotech Crops, by Trait

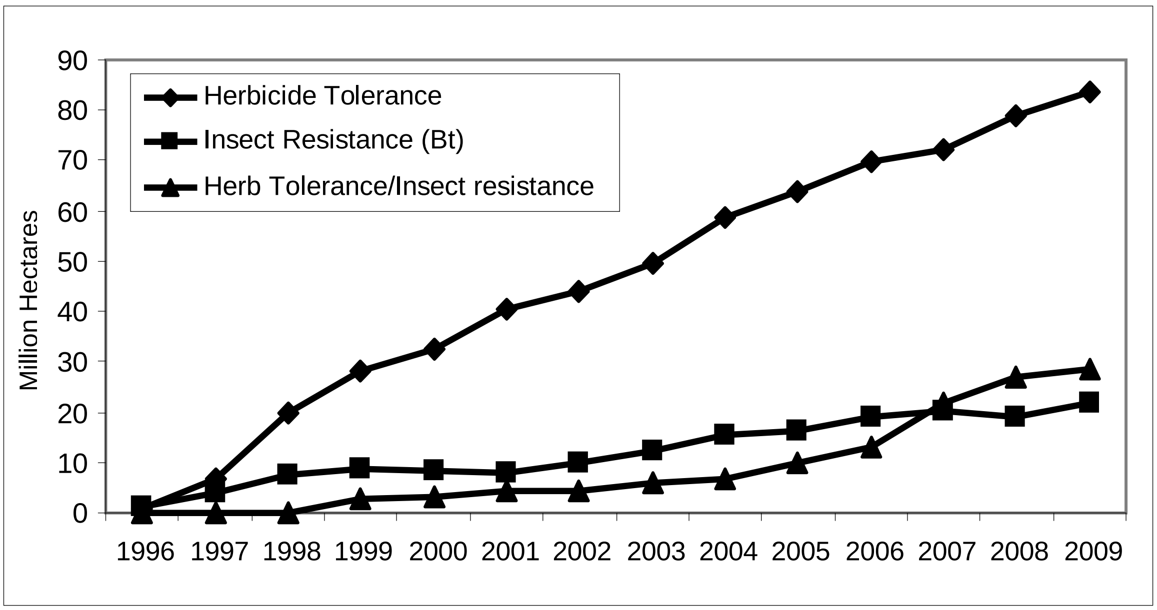
During the fourteen year period 1996 to 2009, herbicide tolerance has consistently been the dominant trait (Figure 32). In 2009, herbicide tolerance, deployed in soybean, maize, canola, cotton, sugarbeet and alfalfa occupied 83.6 million hectares or 62% of the 134 million hectares of biotech crops planted globally (Table 44); this compares with 79.02 million hectares equivalent to 63% in 2008. RR®Flex cotton, introduced in a significant launch in the USA and Australia for the first time in 2006, continued to grow in 2009. It is noteworthy that an entirely new herbicide tolerant crop, RR®sugarbeet was grown for the first time in the USA in 2007; in 2008 it increased to 59% adoption with a further increase to a remarkable 95% in 2009. In contrast to the 83.6 million hectares of herbicide tolerant crops, there was much less Bt cotton and Bt maize, at 12.4 million hectares and 9.2 million hectares, respectively. In 2009, the stacked traits reached 28.7 million hectares, up from 26.9 million hectares in 2008. Biotech crops with Bt genes alone occupied 16% of the global biotech area in 2009, compared with 21% of stacked traits for herbicide tolerance and insect resistance deployed in both cotton (Bt/HT) and maize (Bt/Bt, Bt/HT, and Bt/Bt/HT) (Table 44); this reflects the significant increase in Bt maize in Brazil and to a lesser extent the increase in Bt cotton in India. The stacked traits in maize and cotton increased by 6% between 2008 and 2009 approximately the same as herbicide tolerance (6%) with insect resistance increasing at 14% (Table 44). The increase of stacked traits in maize and cotton between 2008 and 2009 was 1.8 million hectares. For the longer term, stacked traits in both maize and cotton are expected to continue to increase and reflect the needs of farmers who have to simultaneously address the multiple yield constraints associated with both biotic and abiotic stresses. This stacking trend will continue and intensify as more traits become available to farmers and is a very important feature of the technology, and Smartstax™ will be launched in 2010.

The deployment of stacked traits of Bt and herbicide tolerance is becoming increasingly important and is most prevalent in the USA with approximately 108 million "trait hectares" in 2009, compared with only 102.6 million hectares planted in 2008. Globally, the USA has by far the largest area of stacked traits at 25.9 million hectares, equivalent to 90% of global, with the other eleven countries collectively planting approximately 2.8 million hectares of stacked traits and reporting the following hectarages: Argentina (1.1 million hectares), Canada (0.6 million hectares), South Africa (0.3 million hectares), Philippines (0.3 million hectares), South Africa (0.3 million hectares), Australia (0.2 million hectares), with Mexico, Honduras, Chile, Colombia, and Argentina each with less than 0.1 million hectares. The stacked trait in maize, approved in the Philippines in 2005 and first deployed in 2006, was planted on 25,000 hectares in the first year of adoption in 2006, more than doubled to over 60,000 hectares in 2007 and grew rapidly to 200,000 hectares in 2008 and over 300,000 hectares in 2009. These countries will derive significant benefits from deploying stacked products because productivity constraints at the farmer level are related to multiple biotic stresses, and not to a single biotic stress. On a global basis, the 143.7 million "trait hectares" planted in 2007 increased by 15% to 166 million hectares in 2008 with a modest growth of 8% in 2009.

Biotech maize in the USA is the best example of the dynamics of the very rapid adoption of stacked traits. The triple gene products in biotech maize, featuring two Bt genes, (one to control the European corn borer complex and the other to control rootworm) and one herbicide trait, first commercialized in the USA in 2005, continued to grow in adoption in 2009. The European corn borer and the corn rootworm can both be major economic pests that cost US farmers up to US$1 billion dollars each, per year, in losses and insecticide control costs.

The data in Table 45 illustrate that in the USA in 2007, only 37% of biotech maize had single traits (both HT and Bt) compared with 35% for double traits, and 28% with triple traits; thus approximately two thirds, 63%, of all biotech maize in the USA in 2007 was already planted with maize with stacked traits. In 2008, the single trait market share of biotech maize dropped by 15%, to only 22%, and even the double traits lost 5% of market share, but triple traits gained 20% to occupy almost half, 48%, of all biotech maize in the USA. In 2009, the single trait share stabilized at 23%, the share for the double trait decreased by 8% allowing the triple stack to gain 8% in share and reach over 50% of all biotech maize in the USA for the first time. In the USA in 2009, 70% of biotech cotton

Figure 32. Global Area of Biotech Crops, 1996 to 2009: by Trait (Million Hectares)



Source: Clive James, 2009.

Table 44. Global Area of Biotech Crops, 2008 and 2009: by Trait (Million Hectares)

Trait	2008	%	2009	%	+/-	%
Herbicide tolerance	79.0	63	83.6	62	+4.6	+6
Stacked traits	26.9	22	28.7	21	+1.8	+6
Insect resistance (Bt)	19.1	15	21.7	16	+2.6	+14
Virus resistance/Other	<0.1	<1	<0.1	<1	<0.1	<1
Total	**125.0**	**100**	**134.0**	**100**	**+9.0**	**+7**

Source: Clive James, 2009.

featured the stacked traits for insect resistance and herbicide tolerance. Similarly in Australia in 2009, 88% of the biotech cotton had stacked traits for insect resistance and herbicide tolerance.

Table 45. Adoption of Single, Double and Triple Stacked Traits in Biotech Maize in the USA in 2007 and 2009

Trait	2007	2008	2009	Change in 2009 +/-
Single	37%	22%	23%	+ 1%
Double	35%	30%	22%	- 8%
Triple	28%	48%	55%	+ 7%

Source: Compiled by Clive James, 2009.

Distribution of economic benefits at the farm level by trait, for the first thirteen years of commercialization of biotech crops 1996 to 2008 was as follows: all herbicide tolerant crops at US$27.8 billion and all insect resistant crops at US$23.9 billion. For 2008 alone, the benefits were: all herbicide tolerant crops US$3.7 billion, and all insect resistant crops US$5.5 billion for a total of approximately US$9.2 billion (Brookes and Barfoot, 2010, forthcoming).

Dominant Biotech Crops in 2008

Herbicide tolerant soybean continued to be the dominant biotech crop grown commercially in 11 countries in 2009; listed in order of hectarage, the 11 countries were: USA, Argentina, Brazil, Paraguay, Canada, Bolivia, Uruguay, South Africa, Mexico, Chile and Costa Rica. Globally, herbicide tolerant soybean occupied 69.2 million hectares, representing 52% of the global biotech crop area of 134 million hectares for all crops (Table 46). The second most dominant biotech crop was maize with stacked traits, which occupied 26.1 million hectares, and equivalent to 19% of the global biotech area and planted in seven countries, the USA, Canada, South Africa, the Philippines, Honduras, Argentina and Chile. The stacked maize category includes three combinations of traits: a double stack with insect resistance (Bt) and herbicide tolerance (HT), Bt/HT; a double stack with two traits for insect resistance, Bt/Bt; and a triple stack with two types of insect resistance, plus herbicide tolerance, Bt/Bt/HT. Maize with stacked traits occupied a total of 26.1 million hectares compared with 24.5 million hectares in 2008 a 7% year-to-year increase over 2008. The third most dominant crop was Bt cotton, which occupied 12.4 million hectares, equivalent to 9% of the global biotech area and planted in ten countries, listed in order of hectarage: India, China, Brazil, Argentina, USA, Colombia, Mexico, Australia, Burkina Faso and South Africa. The fourth most dominant crop was Bt maize which occupied 9.2 million hectares, equivalent to 7% of global biotech area and was planted in 15 countries in descending order of hectarage – Brazil, USA, South Africa, Argentina, Canada, Uruguay, Spain, the Philippines, Czech Republic, Portugal, Romania, Poland, Chile, Egypt and Slovakia. The fifth most dominant crop was herbicide tolerant maize occupying 6.4 million hectares, equivalent to 5% of global biotech crop area and planted in seven countries – the USA, Canada, South Africa, Argentina, the Philippines, Honduras and Chile. The sixth most dominant crop was herbicide tolerant canola, occupying 6.4 million hectares, 12.3% more area in 2009 than 2008 and planted in Canada, the USA, Australia and Chile. The seventh most dominant crop was stacked cotton, occupying 2.6 million hectares, equivalent to 2% of global biotech area and planted in the USA, Australia, Colombia and Mexico. The eighth most dominant trait was herbicide tolerant cotton occupying 1.1 million hectares or 1% of all biotech crops globally. The balance of other crops listed in Table 46 occupied less than 1% of global biotech crop area and include, in descending order of area: herbicide tolerant sugarbeet grown on 0.5 million hectares in the USA and Canada in 2009 and herbicide tolerant alfalfa grown on 0.1 million hectares in the USA in 2009. The "Others" category, with a total of less than 1,000 hectares, includes virus resistant papaya and squash in the USA, Bt poplars and biotech papaya, sweet pepper and tomato in China.

Table 46. Dominant Biotech Crops in 2009 (Million Hectares)

Crop	2008	2009	% Biotech in 2009
Herbicide tolerant Soybean	65.8	69.2	52
Stacked traits Maize	24.5	26.1	19
Bt Cotton	11.9	12.4	9
Bt Maize	7.1	9.2	7
Herbicide tolerant Maize	5.9	6.4	5
Herbicide tolerant Canola	5.7	6.4	5
Stacked traits Cotton	2.6	2.6	2
Herbicide tolerant Cotton	1.0	1.1	1
Herbicide tolerant Sugarbeet	0.3	0.5	<1
Herbicide tolerant Alfalfa	0.1	0.1	<1
Others	<0.1	<0.1	<1
Total	**125.0**	**134.0**	**100%**

Source: Clive James, 2009.

Global Adoption of Biotech Soybean, Maize, Cotton and Canola

Another way to provide a global perspective of the status of biotech crops is to characterize the global adoption rates as a percentage of the respective global areas of the four principal crops –

soybean, cotton, maize and canola – in which biotechnology is utilized (Table 47 and Figure 33). The data indicate that in 2009, and for the first time, more than three-quarters (77%) of the 90 million hectares of soybean planted globally were biotech – an increase over 2008 when 70% of 95 million hectares of soybean were biotech. Of the 33 million hectares of global cotton, almost one-half (49%) or 16.1 million hectares were biotech in 2009 compared with 46% or 15.5 million hectares planted to biotech cotton in 2008. Of the 158 million hectares of global maize planted in 2009, for the first time more than one-quarter (26%) or 41.7 million were biotech maize. Finally, of the 31 million hectares of canola grown globally in 2009, for the first time more than one-fifth (21%) were herbicide tolerant biotech canola, equivalent to 6.4 million hectares, compared with 5.9 million hectares or 20% in 2008. If the global areas (conventional plus biotech) of these four crops are aggregated, the total area is 312 million hectares, of which 43%, equivalent to 134 million hectares, were biotech in 2009 – up from 40% in 2008.

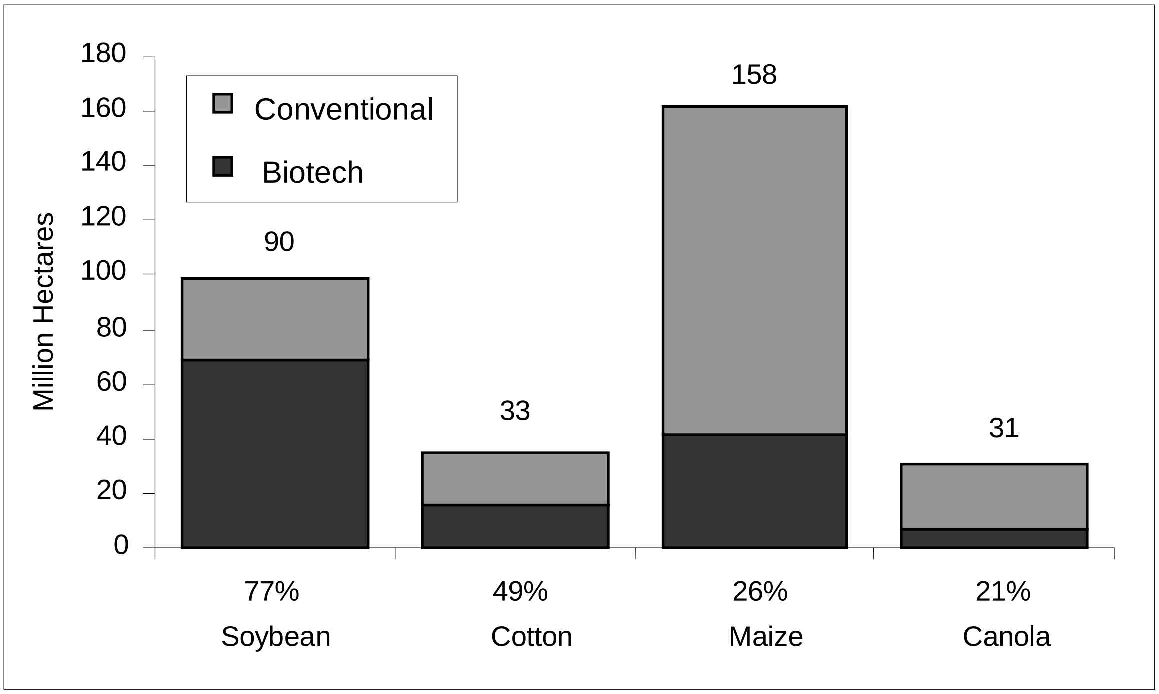
Whereas critics of biotech crops often contend that the current focus on biotech soybean, maize, cotton and canola reflects only the needs of large commercial farmers in the richer industrial countries, it is important to note that two-thirds of these 312 million hectares are in the developing countries, farmed mainly by millions of small, resource-poor farmers, where yields are lower, constraints are greater, and where the need for improved production of food, feed, and fiber crops is the greatest.

Table 47. Biotech Crop Area as Percent of Global Area of Principal Crops, 2009 (Million Hectares)

Crop	Global Area*	Biotech Crop Area	Biotech Area as % of Global Area
Soybean	90	69.2	77
Cotton	33	16.1	49
Maize	158	41.7	26
Canola	31	6.4	21
Others	- -	0.6	- -
Total	**312**	**134.0**	**43**

Source: Clive James, 2009. *Latest FAO 2007 hectarage

Figure 33. Global Adoption Rates (%) for Principal Biotech Crops, 2009 (Million Hectares)



Source: Bioch hectares compiled by Clive James, 2009. *Latest FAO Global hectarages for 2007.

The Global Value of the Biotech Crop Market

It is noteworthy that this year, Cropnosis has extensively updated their seed price assumptions in their model to more accurately take into account the rising cost of GM seeds, especially for maize and soybeans. In 2009, the global market value of biotech crops, estimated by Cropnosis was US$10.5 billion, (up from US$9.0 billion in 2008) representing 20% of the US$52.2 billion global crop protection market in 2009, and 30% of the approximately US$34 billion of 2008 (Table 48). The US$10.5 billion biotech crop market comprised of US$5.2 billion for biotech maize (equivalent to 50% of global biotech crop market, from 48% in 2008), US$3.9 billion for biotech soybean (37.2%, same as 2008), US$1.1 billion for biotech cotton (10.5%), and US$0.3 billion for biotech canola (3%). Of the US$10.5 billion biotech crop market, US$8.2 billion (78%) was in the industrial countries and US$2.3 billion (22%) was in the developing countries. The market value of the global biotech crop market is based on the sale price of biotech seed plus any technology fees that apply. The accumulated global value for the twelve year period, since biotech crops were first commercialized in 1996, is estimated at US$62.3 billion. The global value of the biotech crop market is projected at over US$11 billion for 2010.

Table 48. The Global Value of the Biotech Crop Market, 1996 to 2009

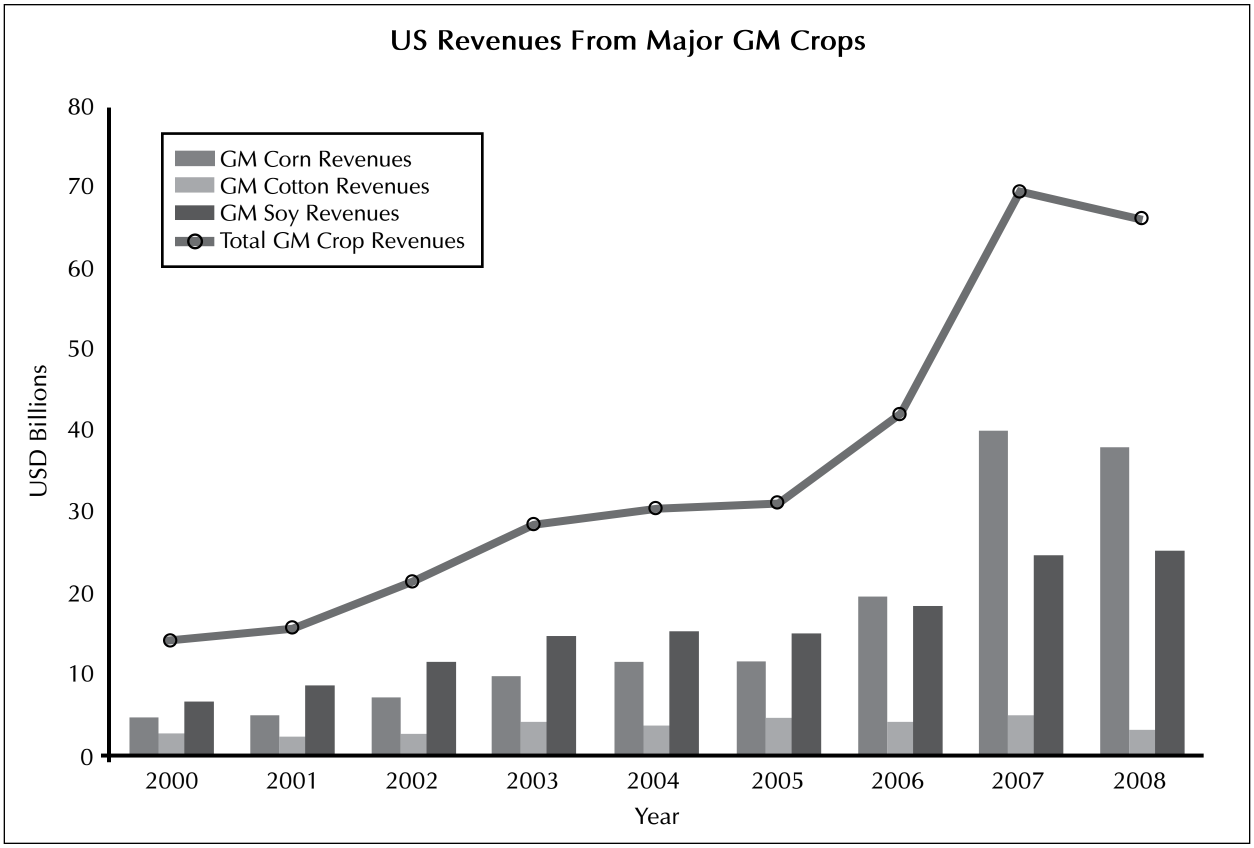
Year	Value (Millions of US$)
1996	93
1997	591
1998	1,560
1999	2,354
2000	2,429
2001	2,928
2002	3,470
2003	4,046
2004	5,090
2005	5,714
2006	6,670
2007	7,773
2008	9,045
2009	10,485
Total	**62,248**

Source: Cropnosis, 2009 (Personal Communication).

A more holistic estimate of the value of biotech crops globally and in the USA was recently documented by Carlson (2009) who noted that the annual ISAAA estimates (James, 2008) detailed above, are only "for seeds and licensing revenues rather than from 'crops', which have much greater market value." He also indicated that "Worldwide farm-scale revenues from GM crops are difficult to assess directly, but that good data are available for the United States." The USDA Economic Research Service reports that 80-90% of all corn, soy, and cotton grown in the United States is biotech transgenic (Figure 34).

Published reports by Carlson (2009) enabled him to estimate revenues from the major GM crops at about US$65 billion in 2008 in the USA alone. Given that the USA has approximately 50% of global biotech crop plantings, Carlson estimated that "global farm-scale revenues from GM corn, soy and cotton in 2008 were about double the US gains of US$65 billion, equivalent to US$130

Figure 34. US Revenues from Major GM crops.



Source: Carlson, 2009

billion." For the US alone, taking into account the biotech crop revenue figure of US$65 billion plus contributions from GM drugs ('biologics') and GM industrial products (fuels, materials, enzymes), which Carlson had previously estimated (Carlson, 2007) – he estimated that US revenues alone in 2007 from all GM products (biotech crops, biologics and industrial products) was approximately US$240 billion and growing at 15-20% annually. Given the US GDP, of about US$14.3 trillion in 2008, Carlson estimated that revenues from all GM products in the USA could amount to the equivalent of about 2% of US GDP in 2009.

Global Status of Regulatory Approvals

This section provides the latest information on the status of all biotech crop products that have received regulatory approvals worldwide. The data in Appendix 1 draws on a large number of sources including government regulatory bodies, publicly available dossiers, and public and private databases available on the internet. This global overview serves to provide an up-to-date summary of all events that have received regulatory approval for import for food and feed use and for release into the environment in a convenient format that allows the reader to quickly analyze the data on a per country basis. Information compiled here describes which crops, events, and traits have been approved in specific countries, who developed them and which year they were approved. The data presented in Appendix 1 is as comprehensive as documented in currently available databases from various countries.

A regulatory approval refers to a product that has been approved for import for food and feed use and for release into the environment. However, a regulatory approval for environmental release in a country must not be interpreted as an indication that the product is being planted commercially in that country. There are many examples of products that were granted regulatory approval but were never commercialized, or if they were, have been subsequently discontinued[1]. Furthermore, in some of the countries listed where environmental, food, and feed safety approvals have been granted, further approvals are necessary to allow commercial planting.

Note that official regulatory documents refer to canola as either Argentine canola (*Brassica napus*) or Polish canola (*Brassica rapa*). The former is the more common canola which is grown commercially in 53 countries. Canola is used in this Brief to refer to Argentine canola.

While 25 countries planted commercialized biotech crops in 2009, an additional 32 countries, totaling 57 have granted regulatory approvals for biotech crops for import for food and feed use and for release into the environment since 1996. A total of 762 approvals have been granted for 155 events[2] for 24 crops. Thus, biotech crops are accepted for import for food and feed use and for release into the environment in 57 countries, including major food importing countries like Japan, which do not plant biotech crops. Of the 57 countries that have granted approvals for biotech crops, Japan tops the list followed by USA, Canada, South Korea, Mexico, Australia, the Philippines, the European Union, New Zealand and China. Maize has the most events approved (49) followed by cotton (29), canola (15), potato (10) and soybean (9). The event that has received regulatory approval in most countries is herbicide tolerant soybean event GTS-40-3-2 with 23 approvals (EU=27 counted as 1 approval only), followed by herbicide tolerant maize (NK603) and insect resistant maize (MON810) with 21 approvals each, and insect resistant cotton (MON531/757/1076) with 16 approvals worldwide.

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1 http://www.agbio.com

2 An event refers to a unique DNA recombination event that took place in one plant cell, which was then used to generate entire transgenic plants. Every cell that successfully incorporates the gene of interest represents a unique "event". Every plant line derived from a transgenic event is considered a biotech crop. The Event Names correspond to the identifiers commonly used by regulatory authorities and international organizations, such as the Organization for Economic Cooperation and Development (OECD).

Concluding Comments

The Grand Challenge

In a provocative article entitled ***"If words were food nobody would be hungry"*** (The Economist, 2009b), the case is made that the international donor and development communities are now reversing a 30 year decline of funding and support to agriculture, following the food price crisis of 2008. It quotes Bill Gates' reassuring statement to agriculturists at the October 2009 World Food Prize that, ***"the world's attention is back on your cause,"*** which he is generously supporting. During the same address, Gates endorsed the use of biotech crops in conjunction with conventional technology in the fight against hunger and in our quest for food sufficiency and food security. There was a similar call for utilizing both conventional and crop biotechnology at the November 2009 Food Summit in Rome, the first since 2002, seven years ago. The high commodity prices of 2008, which sparked riots in over thirty countries and the overthrow of two governments in Haiti and Madagascar, galvanized the world's attention and focused on the simple truth that daily bread at affordable prices is an essential need for every man, woman and child, irrespective of creed, color and race – survival is, by far, our most important instinct. As always it is the poor that get hurt, and the year 2008 was no exception, it was the poor, not the rich, who went hungry because when food prices doubled, the poor could only afford half the food they ate before the crisis. Moreover, unlike the rich who spend up to 20% of their income on food, the poor spend 70 to 80% of their hard earned income on food. It is of great concern that many observers believe that another similar food price crisis to 2008 is in the offing in the near term if remedial actions are not taken by both development donors and governments of food insecure developing countries. In 1974 at the first Food Summit in Rome, Henry Kissinger declared that in 10 years, not a single child would go to bed hungry – 35 years later at the 2009 Food Summit in Rome, and despite MDG promises to cut hunger in half by 2015 it was declared that for the first time ever more than 1 billion people (1.02 billion) would go to bed hungry (World Food Program, UN, 2009). The World Bank estimates that the number of people living on less than US$1.25 per day will increase by 89 million between 2008 and 2010 and for those on US$2.00 a day by 120 million.

Whereas the pledge of US$20 billion from the G8 for agriculture in July 2009 is significant, and the new emphasis on self-sufficiency, in addition to food security, is welcome, it is important to ensure that this US$20 billion is new and not recycled contributions, and to recognize that it will only fund an estimated three years (at US$7 billion per year) of the activities that will be required for protecting agriculture from climate change. Nevertheless, credit should be given to several key organizations for substantially increasing their contribution to agriculture: the World bank increased its contribution by 50% to US$6 billion in 2009, the US Congress is being requested by the President Obama administration to double its budget for agriculture in USAID to US$1 billion in 2010; institutionally a new "High Level Task Force" on agriculture has been working with the UN Secretary General's Office and renowned Economist Jeffrey Sachs is advocating a global mega fund in support of agriculture, similar to the Mega Fund for HIV/AIDS. However, it is policy and technology initiatives at the national program level in developing countries, not in the donor community, that is more important and encouraging. African nations are starting to deliver on the 2003 promises of spending 10% of budgets on agriculture. Many countries are subsidizing inputs of seeds and fertilizers with Malawi used as an example where an investment of 4.2% of GDP resulted in a trebling of maize yield in four years, transforming the country from a significant importer (40% of its needs) of food in 2005 to a significant exporter (50% of its production) in 2009. Malawi is one of the lead countries in Africa committed to enhancing maize yields further, as already successfully done in South Africa, through adopting biotech crops such as Bt maize now effectively deployed in 15 countries around the world – white maize is the staple food for 300 million people in Sub-Saharan Africa.

When several major food producing countries blocked food exports during the 2008 food price crisis some rich food deficit countries assigned high priority to acquisition of arable land in foreign countries. In the last few years, several countries which anticipate food shortages in their own countries in the future, have been acquiring arable land in other countries in order to have access to an additional secure and independent supply of food. For example, the six member states of the Gulf Cooperation Council, which collectively import food valued at US$10 billon annually, are pursuing a strategy to create a new "bread basket in Africa". The African countries involved include Mozambique, Senegal, Sudan, Tanzania and Ethiopia. The Ethiopian Central Statistics Agency reports that 13.3 million small Ethiopian farmers are developing up to 1 million hectares of new land for foreign investors (The Economist, 2009a). Critics view this acquisition as "land grabbing" attempts in countries which are themselves food insecure and poverty stricken, and where there are also concerns about environmental degradation of marginal land brought into production.

The 2008 World Bank Development Report emphasized that, ***"Agriculture is a vital development tool for achieving the Millennium Development Goals that calls for halving by 2015 the share of people suffering from extreme poverty and hunger"*** (World Bank, 2008). The Report noted that three out of every four people in developing countries live in rural areas and most of them depend directly or indirectly on agriculture for their livelihoods. **It recognizes that overcoming abject poverty cannot be achieved in Sub-Saharan Africa without a revolution in agricultural productivity for the millions of suffering subsistence farmers in Africa, most of them women.** However, it also draws attention to the fact that Asia's fast growing economies, where most of the wealth of the developing world is being created, are also home to 600 million rural people (compared with the 800 million total population of Sub-Saharan Africa) living in extreme poverty, and that rural poverty in Asia will remain life-threatening for millions of rural poor for decades to come. It is a stark fact of life that poverty today is a rural phenomenon where 70%, of the world's poorest people are small and resource-poor farmers and the rural landless labor that live and toil on the land. The Grand Challenge is "to transform a problem into an opportunity" by transforming the concentration of poverty in agriculture into an opportunity for alleviating poverty by sharing with resource-poor farmers the knowledge and experience of those from industrial and developing countries which have successfully employed biotech crops to increase crop productivity, and in turn, income. The World Bank Report recognizes that the revolution in biotechnology and information offer unique opportunities to use agriculture to promote development, but cautions that there is a risk that fast-moving crop biotechnology can easily be missed by developing countries if the political will and international assistance support is not forthcoming, particularly for the more controversial application of biotech/GM crops which is the focus of this ISAAA Brief. The **Grand Challenge** is to optimize the use of crop biotechnology in conjunction with conventional technology, to double food production, with less resources, in a sustainable manner by 2015.

The Epilogue and Norman Borlaug's legacy

Two events stand out in 2009 – first the passing of a personal and noble friend, Nobel Peace Laureate Norman Borlaug on 12 September 2009 – second the approval by the Government of China, on 27 November 2009, of biotech rice and biotech maize. Rice is the most important food crop in the world and provides food for 3 billion people or almost half of humanity; importantly it is also the most important food crop of the poor of the world. Maize is the most important feed crop in the world that provides feed for China's 500 million swine herd (equivalent to 50% of the global swine herd) and its 13 billion chickens, ducks and other poultry. China's exertion of leadership in approving the first major biotech food crop, rice, and its determination to elect to use technology, both conventional and biotech crops, to achieve food self–sufficiency, is a momentous development and deserves to be emulated by other developing countries in Asia, Africa and Latin America – the potential implications in terms of a world that is more secure, prosperous, just and peaceful is enormous.

Norman Borlaug's success with the wheat green revolution hinged on his ability, tenacity and single-minded focus on one issue – **increasing the productivity of wheat per hectare** – by intent, he also assumed full responsibility for gauging his success or failure by measuring productivity at the farm level (not at the experimental field station level), and production at the national level, and most importantly, evaluating its contribution to peace and humanity. He titled his acceptance speech for the Nobel Peace Prize on 11 December 1970, 40 years ago – **The Green Revolution, Peace and Humanity.** Remarkably, what Borlaug crusaded for 40 years ago – **increasing crop productivity is identical to our goal of today** except that the challenge has become even greater because **we also need to <u>double productivity sustainably, using less resources</u>, particularly water, fossil fuel and nitrogen,** in the face of **new climate change challenges.** The most appropriate and noble way to honor Norman Borlaug's rich and unique legacy is for the global community involved with biotech crops to come together in a "**Grand Challenge**". North, south, east and west, involving both public and private sectors should engage collectively in a supreme and noble effort to optimize the contribution of biotech crops to productivity using less resources. **Importantly, the principal goal**

should be to contribute to the alleviation of poverty, hunger and malnutrition, as we have pledged in the Millennium Development Goals of 2015, which coincidentally marks the end of the second decade of the commercialization of biotech crops, 2006 to 2015.

The closing words in this Epilogue in the form of a verse is dedicated to Norman Borlaug, a personal friend for thirty years, ISAAA's first Founding Patron, who having saved one billion from hunger, was the world's most ardent and credible advocate of biotech crops because of their capacity to increase crop productivity, alleviate poverty, hunger and malnutrition and contribute to peace and humanity. Borlaug opined that "***Over the past decade, we have been witnessing the success of plant biotechnology. This technology is helping farmers throughout the world produce higher yield, while reducing pesticide use and soil erosion. The benefits and safety of biotechnology has been proven over the past decade in countries with more than half of the world's population. What we need is courage by the leaders of those countries where farmers still have no choice but to use older and less effective methods. The Green Revolution and now plant biotechnology are helping meet the growing demand for food production, while preserving our environment for future generations***"

He cared, more than others thought wise
He dreamed, more than others thought real
He risked, more than others thought safe
And he expected, and normally achieved
What others thought impossible

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References

ABC News. 2008. WA lifts ban on GM cotton crops. Australian Broadcasting Corporation, November 14, 2008. http://www.abc.net.au/news/stories/2008/11/14/2420142.htm?section=justin

ABC News. 2007. GM bananas could solve Panama plight. December 20, 2007. http://www.abc.net.au/news/stories/2007/12/20/2124584.htm?section=justin

ABSP II. 2007. Fruit and Shoot Borer Resistant Eggplant- Fact Sheet, Cornell University, Newsletter, Agricultural Biotechnology Support Project II, South Asia, July 2007.

Adam D. 2008. GM will not solve current food crisis says industry. Guardian, June 27, 2008, United Kingdom. http://www.guardian.co.uk/environment/2008/jun/27/gmcrops.food

Adams J and J Wilsdon. 2009. Research and Collaboration in the New Geography of Science. Global Research Report, China. Thomson-Reuters, 2009.

All India Coordinated Vegetable Improvement Project (AICVIP). 2007. Performance of Multilocation Research Trials of Bt Brinjal Hybrids, Indian Institute of Vegetable Research, Indian Council of Agricultural Research.

Anderson K, E Valenzuela and LA Jackson. 2006. Recent and prospective adoption of genetically modified cotton: A Global CGE Analysis of Economic Impacts. World Bank Policy Research Working Paper. 3917 pp. 1-27.

Apted S and M Kazur. 2007. Potential impacts from the introduction of GM canola on organic farming in Australia. ABARE Research Report 07.11. Published May 2007. http://www.abareconomics.com/publications_html/crops/crops_07/organic_farm.pdf

Apted S, D McDonald and H Rodgers. 2005. Transgenic Crops: Welfare Implications for Australia. Australia Bureau of Agriculture and Research Economics (ABARE).

Aragao FJL and JC Faria. 2009. First transgenic geminivirus-resistant plant in the field. Nature Biotechnology. 27 (12):1086-1088.

Avellaneda J. 2006. Voices of Plant Biotechnology. Council for Biotechnology Information http://whybiotech.com/html/pdf/Voices.pdf.

Australian Financial Review. 2009. www.afr.com. 13 Nov 2009

Australian Minister for Agriculture, Fisheries, and Forestry Press Release. 2007. Australia: Oils ain't oils – the benefits of GM oilseed crops. Press release. August 24, 2007. http://www.gmofoodforthought.com/2007/08/gm_crops_australian_brs_report_on_the_benefits_of_gm_oilseed_crops.html

Bangladesh Agricultural Research Institute (BARI). 1995. Annual Research Report 1993-94. Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh.

Barry G. 2009. Experiences from the Golden Rice Network, Fourth Asian Conference on Biotechnology and Development, February 12-13, 2009, Kathmandu, Nepal

Bayer CropScience. 2009. Bayer CropScience expands Global R&D activities in seeds and traits by setting up new research focus area in cereals. Bayer Crop Science July 21, 2009. http://www.press.bayercropscience.com/bcsweb/cropprotection.nsf/id/EN_20090721?open&l=EN&ccm=500020

Bearden R. 2006. Voices of Plant Biotechnology. Council for Biotechnology Information http://whybiotech.com/html/pdf/Voices.pdf.

Biospectrum-ABLE Survey. 2008. Growth Slows (Vol.-I), Biospectrum Magazine, Bangalore, India. June 2009. http://biospectrumindia.ciol.com/content/CoverStory/10906091.asp

Borlaug N. 2009. Researcher behind Green Revolution. http://agnews.tamu.edu/showstory.php?id=1054

Brazilian Agriculture Ministry. (Menisterio de Agricultura, Pecuaria e Abastecimento)

Brazilian Central Bank. 2009. http://www.bcb.gov.br/?english

Brazilian External Trade Secretariat (SECEX), 2007. http://www.datamark.com.br/administrator/secex/pesquisa/pesquisapais.asp?BTN=1

Brookes G and P Barfoot. 2009. GM Crops: Global Socio-economic and Environmental Impacts 1996-2007. P.G. Economics Ltd, Dorchester, UK. http://croplife.intraspin.com/Biotech/gm-crops-global-socio-economic-and-environmental-impacts-1996-2007/

Buzdugan L. 2006. The experience of farmer Lucina Buzdungan with RR Soybean in Romania. Council for Biotechnology Information. http://whybiotech.com/html/pdf/Voices.pdf

Carlson R. 2007. Laying the Foundation for a Bio-economy. Syst. Synth. Biol. 1, 109-117 (2007). http://www.springerlink.com/content/n211746672413507/fulltext.pdf

Carlson R. 2009. The Market Value of GM Products. Nature Biotechnology 27, 984 (2009) http://www.nature.com/nbt/journal/v27/n11/pdf/nbt1109-984a.pdf and http://www.agbioworld.org/newsletter_wm/index.php?caseid=archive&newsid=2926.

CARITAS. 2004. Unfair Trade and Cotton: Global Challenges, Local Challenges,

Carniero P. 2009. Environmental Benefits Associated with Round Ready Soybean. Celeres. http://www.celeres.com.br/estudos/SumarioExecutivoBeneficioAmbiental_SojaRR_Port_090202.pdf

Celeres. 2009. http://www.celeres.com.br/

Central Insecticides Board and Registration Committee (CIBRC), 2008. Ministry of Agriculture, Government of India. http://cibrc.nic.in/

Chavan P. 2009. Bt brinjal: A Pioneering Push. In. BiotechNews of the Department of Biotechnology, December Issue 2009

Chemical Industry. 2007. Cotton Market Comparison from 1996 to 2006. Mumbai. India

Chinese Academy of Agricultural Sciences. (CAAS). 2008. Big Funding For GM Research. March 26, 2008. RSC. Advancing the Chemical Sciences. http://www.rsc.org/chemistryworld/News/2008/March/26030801.asp

Chile's Forest Research Institute (INFOR). http://www.infor.cl/

Chile's Institute for Agricultural Research (INIA). http://www.inia.cl/link.cgi/URI/969

China Daily. 2009. GM Rice may join the Menu. 25 August 2009. http://www.china.org.cn/business/2009-08/25/content_18394775.htm

China Daily. 2005. Biotech prepares for rapid expansion. Sept. 15, 2005. http://www.edu.cn/20050915/3151906.shtml.

Choudhary B and K Gaur. 2009. The Development and Regulation of Bt Brinjal in India (Eggplant/Aubergine). ISAAA Brief No.38. ISAAA: Ithaca, NY. http://www.isaaa.org/Resources/publications/briefs/38/download/isaaa-brief-38-2009.pdf

Choudhary B and K Gaur. 2008. Trust in the Seed, ISAAA publication, ISAAA: New Delhi, India. http://www.isaaa.org/resources/publications/downloads/ISAAA-Trust%20in%20the%20Seed.pdf

Clark E. 2009. EU's ban on soy imports hurts both US and Europe. November/December 2009. http://www.feedmanagement-digital.com/feedmanagement/20091112?pg=13#pg13

Crop Biotech Update. 2009. GM Rice in China gets biosafety certificate. 4 December 2009. http://www.isaaa.org/kc/cropbiotechupdate/online/default.asp?Date=12/4/2009#5114

Chupungco AR, AC Rola and DD Elazegui (eds.) 2008. Consequences of Bt Cotton Technology Importation in the Philippines. ISPPS-CPAF-UPLB, UPLB-FI, College, Laguna; DA Biotechnology Program, Quezon City; and PhilRice, Munoz, Nueva Ecija.

Companhia Nacional de Abastecimento (CONAB), Menisterio de Agricultura, Pecuaria e Abastecimento. http://www.conab.gov.br/conabweb/

Commisão Tèchnica Nacional de Biossegurança (CTNBIO). 2009. Menisterio de Ciencia e Tecnologia. http://www.ctnbio.gov.br/index.php/content/view/12492.html

Cotton Advisory Board (CAB). 2009. Minutes of the second meeting of the Cotton Advisory Board for the cotton season 2009-10, Office of the Textile Commissioner, Ministry of Textile, Government of India, 29 August 2009. http://www.txcindia.com/html/CAB_tables_for_website[1]%2001092009.pdf

Cookson C. 2008. Time to sow? GM food could curb cost of staples. Financial Times. 10 July 2008.
http://www.truthabouttrade.org/content/view/12053/54/
http://www.ft.com/cms/s/0/f8b45556-4e97-11dd-ba7c-000077b07658.html?nclick_check=1

Cotton Advisory Board (CAB), 2008. Minutes of the meeting for the cotton year 2007-08 and cotton projection for 2008-09, Office of the Textile Commissioner, Ministry of Textile, Government of India.
http://www.txcindia.com/html/production,%20yield%202007089%20cabmeeting%2020102008.pdf

Cotton Corporation of India. 2009. National Cotton Scenario, Ministry of Textile. http://www.cotcorp.gov.in/national_cotton.asp

Costa Rica Biosafety Clearing House. www.cr.biosafetyclearing house.net.

de Carbonnel E. 2009. Catastrophic Fall in 2009 Global Food Production. Global Research: Centre for Research on Globalization. 10 February 2009. http://www.globalresearch.ca/index.php?context=va&aid=12252

Delaney S. 2009. Vatican, food experts say biotechnology will improve African farming Catholic News Service. September 29, 2009. http://www.catholicnews.com/data/stories/cns/0904317.htm

Demont M, K Dillens, E. Mathijs and E Tollens. 2007. GM crops in Europe: How much value and for whom? EuroChoices. 6(3): 46-53. http://www.agr.kuleuven.ac.be/aee/clo/euwab.htm

Department of Biotechnology (DBT). 2009. News update, Department of Biotechnology, Ministry of Science and Technology. Government of India. http://dbtindia.nic.in/

Department of Primary Industries. 2009. Victoria forms alliance with Dow AgroSciences for crop innovation, May 22, 2009 http://www.health.gov.au/internet/ogtr/publishing.nsf/Content/dir092-3/$FILE/dir092techsum.pdf

Department of Innovation, Industry, Science and Research Report 2008. Evaluation of the national biotechnology strategy and biotechnology Australia, Final Report. 17 January 2008. http://www.biotechnology.gov.au/assets/documents/bainternet/NBSBA%20Evaluation_17-01-0820080612160741.pdf

Diouf J. 2009. Agriculture to 2050 – the challenges ahead: Diouf opens High-Level Forum on food's future. October 12, 2009. http://www.fao.org/news/story/en/item/36193/icode/

Dumayas EE, AC Rola and DD Elazegui (eds). 2008. Returns to Research and Development Investments for Genetically Modified (GM) Abaca. ISPPS-CPAf-UPLB, UPLB-FI, College, Laguna; DA Biotechnology Program, Quezon City; and PhilRice, Munoz, Nueva Ecija.

Economic Survey, 2009. For July 2009. http://ibef.org/economy/economicsurvey2009.aspx

Elbehri A and S MacDonald. 2004. 'Estimating the impact of transgenic Bt cotton on West and Central Africa: a general equilibrium approach', World Development, 32 (12): 2049-2064.

European Food Safety Authority. 2008. Request from the European Commission related to the safeguard clause invoked by France on maize MON810 according to Article 23 of Directive 2001/18/EC and the emergency measure according to Article 34 of Regulation(EC) No 1829/2003 - Scientific opinion of the Panel on Genetically Modified Organisms. October 29, 2008. http://www.efsa.europa.eu/EFSA/efsa_locale-1178620753812_1211902156394.htm

EU-Joint Research Council Report. 2008. Scientific and technical contribution to the development of an overall health strategy in the area of GMOs. September 2008. http://ec.europa.eu/dgs/jrc/downloads/jrc_20080910_gmo_study_en.pdf

Falck-Zepeda J, D Horna and M Smale. 2008. Betting on cotton: Potential payoffs and economic risks of adopting transgenic cotton in West Africa. http://www.aaae-africa.org/afjare/docs/AfJAREFalck-ZepedaFINAL.pdf

Feedstuffs, March 6, 2006 and Sept. 29, 2008 as cited in Feedstuffs, June 29, 2009. Court Upholds Biotech Alfalfa Injunction. NewsWatch. http://fdsmagissues.feedstuffs.com/fds/PastIssues/FDS8126/fds02_8126.pdf

Feedstuffs, January 18, 2009. http://www.feedstuffs.com Jacqui Fatka. 19 January 2009. US greenlight for GM alfalfa. http://sl.farmonline.com.au

FEFAC. 2009. EU feed prices may rise due toEU zero-tolerance on not yet authorised GM plants fears FEFAC president Pedro Correa de Barros. 8 July 2009 http://www.fefac.org/file.pdf?FileID=21141.

Food and Agriculture Statistics, 2007. http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor

Fox J. 2009. What Happened to GM Wheat. Nature Biotechnology 27, 974 – 976. http://www.nature.com/nbt/ and http://www.agbioworld.org/newsletter_wm/index.php?caseid=archive&newsid=2926

References

Francisco S. 2007. Ex-ante economic impact assessment of Bt eggplant crop production in the Philippines. Philippine Journal of Crop Science. 32(2): 3-14.

Francisco S. 2009. Cost and Benefits of Bt Eggplant with Resistance to Fruit and Shoot Borer in the Philippines. In. GW Norton and DM Hautea (eds). 2009. Projected Impacts of Agricultural Biotechnologies for Fruits and Vegetables in the Philippines and Indonesia. International Service for the Acquisition of Agri-biotech Applications (ISAAA) and SEAMEO Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), Los Banos, Laguna. Pp35-54.

Frisvold GB, JM Reeves and R Tronstad. 2006. Bt cotton adoption in the United States and China: International trade and welfare effects. AgBioForum, 9(2): 69-78.

Fundacion Antama. 2009. Premier estudio cientifico sobre coexistencia en condiciones reales. 8 October, 2009. http://fundacion-antama.org/primer-estudio-cientifico-sobre-coexistencia-en-condiciones-reales/

G8 2009. "L'Aquila" Joint Statement on Global Food Security L'Aquila Food Security Initiative (AFSI). July 10, 2009. http://www.g8italia2009.it/static/G8_Allegato/LAquila_Joint_Statement_on_Global_Food_Security%5B1%5D,0.pdf

G8 Leaders Statement on Global Food Security. July 2008 Annual Meeting in Hokkaido http://www.g8summit.go.jp/eng/doc/doc080709_04_en.html

Gates W. 2009. Bill Gates Calls for United Action to Support World's Poorest Farmers: Bill & Melinda Gates Foundation announces $120 million in new agriculture grants. 14 October 2009http://www.gatesfoundation.org/press-releases/Pages/bill-gates-calls-for-united-support-poorest-farmers-091014.aspx

Golden Rice Website. http//www.goldenrice.org/

Gonzales LA. 2005. Harnessing the Benefits of Biotechnology: The Case of Bt Corn in the Philippines. SIKAP/STRIVE Foundation, Los Baños, Laguna, Philippines.

Gonzales LA. 2007. Four Seasons of Post-Commercialization: Monitoring and Evaluating the Socio-Economic Impact of Bt Corn in the Philippines. SIKAP/STRIVE Foundation, Los Baños, Laguna, Philippines.

Gray L. 2010. Chief scientist says GM and nanotechnology should be part of modern agriculture. http://www.telegraph.co.uk/earth/earthnews/6943231/Chief-scientist-says-GM-and-nanotechnology-should-be-part-of-modern-agriculture.html

Genetic Engineering Approval Committee (GEAC). 2009. Expert Committee (EC-II) Report on Bt Brinjal Event EE-1 Developed by M/s Maharashtra Hybrid Seeds Company Ltd. (Mahyco), Mumbai, University of Agricultural Sciences (UAS), Dharwad and Tamil Nadu Agricultural University (TNAU), Coimbatore submitted to Genetic Engineering Approval Committee (GEAC), Ministry of Environment and Forests (MOEF), Government of India, New Delhi, October 8, 2009.
http://moef.nic.in/downloads/public-information/Report%20on%20Bt%20brinjal.pdf

Goze E, S Nibouche and J Deguine. 2003. 'Spatial and probability distribution of Helicoverpa armigera (Lepidoptera: Noctuidae) in cotton: systematic sampling, exact confidence intervals and sequential test', Environmental Entomology, 32 (5): 203–1210.

Government of Chile Statistics, Servicio Agricola y Ganador (SAG) 2009. http://www.sag.gob.cl/

Hills S. 2009. FBD: Consumers want more GM food info from supermarkets (UK) Food Biz Daily .Com. London 26 Nov 2009. http://foodbizdaily.com/articles/94619-consumers-want-more-gm-food-info-from-supermarkets-uk.aspx

Huang J, R Hu, R Scott and C Pray. 2005. Insect-Resistant GM Rice in Farmers' Fields: Assessing Productivity and Health Effects in China. Science: 308:5722 (688-690). http://dx.doi.org/10.1126/science.1108972

Icamina PM 2008. 3-in-1 rice helps prevent Vitamin A deficiency. The Manila Times. November 3, 2008 issue.

IIMA, 2007. Emerging Markets for GM Foods: An Indian Perspective on Consumer Understanding and Willingness to Pay. An e-copy of the report is available at: http://www.iimahd.ernet.in/publications/data/2007-06-08Deodhar.pdf

IMRB, 2009. Socio-economic benefits and product satisfaction of BG and BG-II in india, SAMIKSHA-09, IMRB International, Mumbai, Feb 2009.

Indian GMO Research Information System (IGMORIS), 2009. Department of Biotechnology (DBT), Government of India. http://www.igmoris.nic.in/

Indian Institute of Vegetable Research (IIVR), 2009. Two year performance report of Bt brinjal hybrids containing cry1Ac gene in Large Scale Trials during 2007-08 and 2008-09 conducted by the Indian Institute of Vegetable Research, Varanasi, India, April 2009.

Indicus Analytics, 2007. Socio-economic appraisal of Bt cotton cultivation in India. Indicus Analytics Study.

Institute of Agro-Food Research and Technology (IRTA). 2008.

Institute of Agricultural Research (INIA). 2007.

Instituto Nacional de Tecnologia Agropecuaria, INTA. 2009 http://www.inta.gov.ar/bariloche/

International Cotton Advisory Committee, (ICAC) 2009 THE ICAC RECORDER. Biotech Cotton and the Technology Fee - Argentina, Australia, Brazil, Burkina Faso, Colombia, India and South Africa. Volume XXVII, No. 1, March 2009

International Cotton Advisory Committee. 2008. COTTON: WORLD STATISTICS,Washington, D.C.publications@icac.org Internet: http://www.icac.org/

International Food Policy Research Institute, http://www.ifpri.org/

International Food Policy Institute (IFPRI), 2008. Bt cotton and farmer Suicides in India, IFPRI Discussion Paper 00808. Reviewing the Evidence, by Guillaume P Gruere, Purvi Mehta-Bhatt and Debdatta Sengupta, October 2008. An e-copy of the report is available at: http://www.ifpri.org/publication/bt-cotton-and-farmer-suicides-india

International Sugar Statistics. 2009. http://www.illovosugar.com/World_of_sugar/Sugar_Statistics/International.aspx

ISAAA. 2009. ISAAA Celebrates the Life of its Founding Patron, Nobel Peace Laureate Dr. Norman E. Borlaug (1914-2009), ISAAA Brochure available at: http://www.isaaa.org/kc/cropbiotechupdate/tribute/borlaug/ISAAA-Tribute.pdf

References

James C. 2008. Global Status of Commercialized Biotech/GM Crops: 2008. ISAAA Brief No. 39. ISAAA: Ithaca, NY.

James C. 2007. Global Status of Commercialized Biotech/GM Crops: 2007. ISAAA Brief No. 37. ISAAA: Ithaca, NY.

James C. 2006. Global Status of Commercialized Biotech/GM Crops: 2006. ISAAA Brief No. 35. ISAAA: Ithaca, NY.

James C. 2005. Global Status of Commercialized Biotech/GM Crops: 2006. ISAAA Brief No. 34. ISAAA: Ithaca, NY.

James C. 2004. Global Status of Commercialized Biotech/GM Crops: 2004 ISAAA Brief No. 32. ISAAA: Ithaca, NY.

James C. 2003. Global Status of Commercialized Biotech/GM Crops: 2003. ISAAA Brief No. 30. ISAAA: Ithaca, NY.

James C. 2002. Global Review of Commercialized Transgenic Crops: 2001 Feature Bt cotton. ISAAA Brief No. 29. ISAAA: Ithaca, NY.

James C. 2001. Global Review of Commercialized Transgenic Crops: 2001. ISAAA Brief No. 24. ISAAA: Ithaca, NY.

James C. 2000. Global Review of Commercialized Transgenic Crops: 2000. ISAAA Brief No. 21. ISAAA: Ithaca, NY.

James C. 1999. Global Review of Commercialized Transgenic Crops: 1999. ISAAA Brief No. 17. ISAAA: Ithaca, NY.

James C. 1998. Global Review of Commercialized Transgenic Crops: 1998. ISAAA Brief No. 8. ISAAA: Ithaca, NY.

James C. 1997. Global Review of Commercialized Transgenic Crops: 1997. ISAAA Brief No. 5. ISAAA: Ithaca, NY.

James C and AF Krattiger. 1996. Global Review of the Field Testing and Commercialization of Transgenic Plants 1986 to 2005. The First Decade of Crop Biotechnology, 1986 to 1995. ISAAA Brief No. 1. ISAAA: Ithaca, NY.

Javier PA, MV Agsaoay and JL dela Cruz. 2004. Influence of YieldGard on the effectiveness of Trichogramma evanescens (Hymenoptera:Trichogrammatidae), an egg parasitoid of Asian corn borer, Ostrinia furnacalis (Guenee). Project Terminal Report. National Crop Protection Center, University of the Philippines Los Baños. 40 pp.

Karembu M, F Nguthi and H Ismail. 2009. Biotech Crops in Africa: The Final Frontier, ISAAA AfriCenter, Nairobi, Kenya, 2009.

Korves R. 2008. Burkina Faso plants Bt cotton. Truth about Trade and Technology, 22 August 200, India.

Kranthi KR. 2009. Personal Communication, Central Institute of Cotton Research (CICR), Nagpur, India, 30 July 2009.

Krishna VV and Qaim M. 2007a. Potential Socio-Economic Impacts of Bt Eggplant in India, Chapter 5, the Economic and Environmental Benefits and Costs of Transgenic Crops: Ex-Ante Assessment, Tamil Nadu Agricultural University (TNAU), Coimbatore, Tamil Nadu.

Krishna VV and Qaim M. 2007b. Estimating the Adoption of Bt Eggplant in India: Who Benefits from Public-Private Partnership, Food Policy, pp. 523-543.

Krishna, VV and Qaim, M. 2008. Potential Impacts of Bt Eggplant on Economic Surplus and Farmers' Health in India, Agricultural Economics, pp 167-180.

Lin G. 2009. Agriculture fastest-growing research in China. 12 November 2009 http://www.scidev.net/en/news/agriculture-fastest-growing-research-in-china.html

Mahyco 2006. Studies on Bt Brinjal, Presentation to GEAC, Maharashtra Hybrid Seeds Company Ltd, Mumbai.

Massoud MA. 2005. The influence of encoding BT corn hybrids (MON 810 event) on the infestation of the corn borers in Egypt. The 3rd International Conference of Plant Protection Research Institute, 26-29 November, 2005, 83 (2): 469-496.

McWilliams J. 2008. China import approval bolters New Monsanto soybean seed. St. Louis Post – Dispatch, USA. Retrieved 8 September, 2008. http://www.soyatech.com/news_story.php?id=10146

Ministry of Agriculture. 2007. Cotton Statistics at a Glance. 2007. Directorate of Cotton Development, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India.

Ministry of Agriculture and Fisheries, Denmark. 2009. Denmark: GMO crops can help climate and environment, according to a new report from the Danish Food Ministry. Sept. 18, 2009. http://bites.ksu.edu/news/135342/09/09/18/denmark-gmo-crops-can-help-climate-and-environment-according-new-report-danish-

Ministry of Agriculture, Rural Development, and Fisheries, Lisbon, Portugal. 2009. dgadr@dgadr.pt, 12 October, 2009

Ministry of Environment Rural Development and Fisheries, Spain, 2009. Avances Suopefices y Producciones Agricolas, July 2009.

Ministry of Environment and Forest. 2009. Press Statement by Mr. Jairam Ramesh, Minister of State for Environment and Forest (MOEF), Government of India dated 15th Oct 2009 available at: http://moef.nic.in/downloads/public-information/Press_Bt%20Brinjal.pdf

Ministry of Finance, India. 2009. The Economic Survey, 2008-09. http://indiabudget.nic.in/es2008-09/esmain.htm

Ministry of Finance, India. 2008. The Economic Survey, 2007-08.

Monsanto. 2009a. Company Invests in Developing New Technologies for Wheat With Acquisition of WestBred Business. July 14, 2009. http://monsanto.mediaroom.com/index.php?s=43&item=727

Monsanto. 2009b. Monsanto's Beachell-Borlaug International Scholars Programhttp://www.monsanto.com/responsibility/sustainable-ag/produce_more/beachell_borlaug/program.asp

Monsanto. 2008. News Release.Monsanto Company to Invest in Technologies for Sugarcane with Acquisition of CanaVialis and Alllyx. November 3, 2008.http://monsanto.mediaroom.com/index.php?s=43&item=656

Natesh S and MK Bhan. 2009. Biotechnology sector in India: strengths, limitations, remedies and outlook, Current Science, Vol. 97, No. 2, PP. 157-169, 25 July 2009. http://www.ias.ac.in/currsci/jul252009/157.pdf

National Agency of Petroleum, Natural Gas and Biofuels. 2009. http://www.anp.gov.br/

National Association of Wheat Growers, 75% of wheat growers approve biotech petition. Washington, DC, Feb, 26, 2009. http://www.wheatworld.org/wp-content/uploads/biotech-petition-press-release-20090226.pdf

Navarro M. 2009. Walking tall in the biotech debate: an interview with edwin paraluman. In. Mariechel J. Navarro (ed) Brief 40. Communicating Crop Biotechnology: Stories from Stakeholders. International Service for the Acquisition of Agribiotechnology Applications (ISAAA). Los Baños, Laguna. Pp. 12-14.

Navarro M. 2009. Trail blazing biotech in the philippines: an interview with academician Emil Q. Javier. In. Mariechel J. Navarro (ed) Brief 40. Communicating Crop Biotechnology: Stories from Stakeholders. International Service for the Acquisition of Agribiotechnology Applications (ISAAA). Los Baños, Laguna. Pp. 81-83.

National Sample Survey, Organization's Situation Assessment Survey of Farmers (NSS, 59th Round), India, 2003. http://www.mospi.gov.in/sarvekshana_publication_main.htm

Office of the Gene Technology Regulator (OGTR). 2009. http://www.health.gov.au/internet/ogtr/publishing.nsf/Content/dir092-3/$FILE/dir092techsum.pdf and http://www.ogtr.gov.au/

O'Brien D and M Woolverton. 2009. Corn Supply Propects for U.S. Ethanol Production. October 26, 2009. http://www.agmanager.info/energy/CornSupplyPropects_US-EthanolProduction_10-26-09.pdf

Oikeh SO. 2009. Water Efficient Maize for Africa. AATF/WEMA (Kenya). Paper presented at the 3rd African Grain Summit. Tanzania 4-6 November 2009.

PR Newswire. 2009. SmartStax corn receives japanese import approval. Monsanto, Dow AgroSciences note key import approval represents a significant step toward 2010 launch. July 31, 2009. http://news.prnewswire.com/DisplayReleaseContent.aspx?ACCT=104&STORY=/www/story/07-31-2009/0005069653&EDATE

Pablico SM. 2008. PhilRice Develops 3-in-1 Rice. The Philippine STAR. August 31, 2008 issue.

Paine JA, CA Shipton, S Chaggar, RM Howells, MJ Kennedy, G Vernon, SY Wright, E Hinchliffe, JL Adams, AL Silverstone and R Drake. 2005. Improving the nutritional value of Golden Rice through increased pro-vitamin A content. Nature Biotechnology. 23: 482-487.

Panopio J. 2009. The morality of genetic engineering: an interview with Fr. Emmanuel Alparce. In. Mariechel J. Navarro (ed) Brief 40. Communicating Crop Biotechnology: Stories from Stakeholders. International Service for the Acquisition of Agribiotechnology Applications (ISAAA). Los Baños, Laguna. Pp. 134-136.

Paz R, W Fernandez, O Zambrano and J Falck Zepeda. 2007. Socio-Economic considerations of genetically-modified soybean Adoptio: The Case of Bolivia. http://www.cbd.int/doc/external/mop-04/ifpri-cs-bolivia-en.pdf

People's Daily Online. 2009. From self-sufficiency to grain contribution, China's agriculture passes 60 memorable years, 26 August, 2009. http://english.people.com.cn/90001/90776/90882/6739421.html

Poerter S. 2009. GM Sugarbeet hit by California Court Ruling. Northern Colorado Business Report. Oct. 23, 2009. http://www.ncbr.com/article.asp?id=102674

Q and A on China's Scientist Premier Wen Jiabao. Science Vol 322. 16 October, 2008. http://www.sciencemag.org/cgi/reprint/322/5900/362.pdf

Qiu J. 2008. Is China ready for GM rice? Nature 455(16): 850. http://www.nature.com/news/2008/081015/pdf/455850a.pdf

Qingjun N. 2007. Experience of Mr. Niu Qingjun, a small Bt cotton farmer who grows approximately 0.6 hectares of Bt cotton in China.

Rajya Sabha. 2003. Pesticides in Fruits and Vegetables, Unstarred Question No. 1112, Rajya Sabha, the Parliament of India, New Delhi.

Ramesh J. 2009. The Q&A "Introduction of Bt Brinjal", the Rajya Sabha (Upper house) of the Parliament of India is available at:http://164.100.47.4/newrsquestion/ShowQn.aspx and the press release from the Press Information Bureau (PIB) is available at: http://www.pib.nic.in/release/release.asp?relid=54401 The Press Information Bureau press release "Extensive Evaluation and Regulatory Approval Process before Approval for Commercial Cultivation of GM Plant" based on the Q&A in the Lok Sabha of the Parliament of India is available at: http://pib.nic.in/release/release.asp?relid=54567

Ramasamy C, KN Selvaraj and GW Norton. 2007. Economic and Environmental Benefits and Costs of Transgenic Crops: Ex-Ante Assessment, Tamil Nadu Agricultural University (TNAU), Coimbatore, Tamil Nadu, India.

Rasquilha JM. 2006. Voices of Plant Biotechnology. Council for Biotechnology Information http://whybiotech.com/html/pdf/Voices.pdf

Ridley M. 2009. The new NUE thing. Nitrogen Use Efficiency, the Next Green Revolution. The World in 2010. The Economist p. 149 http://www.economist.com/theworldin/displaystory.cfm?story_id=14742733

Saez C. 2009. UN eyes next steps on Food Security; Biotech pleased with summit mention. World Summit on Food Security. 26 November, 2009. http://www.ip-watch.org/weblog/2009/11/26/un-eyes-next-steps-on-food-security-biotech-pleased-with-summit-mention/#more-7990

Scottish Crop Research Institute. 2009. Potato Genome Sequencing. http://www.scri.ac.uk/research/genetics/GenomeBiology/potatosequencing

Schattenberg P. 2009. Nobel Peace Price Laureat Dr. Norman Borlaug calls for a second "Green Revolution: asks new generation to join fight against world hunger. March 9, 2009. http://agnews.tamu.edu/showstory.php?id=1054

Shields R. 2009. GM crops have a role in preventing world hunger, chief scientist says. The Independent.19 November, 2009. http://www.independent.co.uk/life-style/food-and-drink/news/gm-crops-have-a-role-in-preventing-world-hunger-chief-scientist-says-1823219.html

Shuping N. 2008. China Approves big budget for GMO amid food worries. 10 July 2008. Reuters. http://www.reuters.com/article/environmentNews/idUSPEK11727520080710?feedType=RSS&feedName=environmentNews&sp=true

Singh M. 2009. PM Inagurates the 97th Indian Science Congress in Thiruvanthapuran, Kerala, 3rd January, 2010. http://pmindia.nic.in/speeches.ht

Smil V. 2004. Enriching the Earth: Fritz Haber, Carl Bosch and the Transformation of World Food Production. The MIT Press, Cambridge, MA. xvii + 411 pp. Paperback edition.

Smith J. 2008. EU clashes on authorizing Monsanto GM soybean. Reuters 19 Nov, 2008 http://www.reuters.com/article/idUSTRE4AI71C20081119

Stein AJ, HPS Sachdev and M Qaim. 2006. Potential impact and cost-effectiveness of Golden Rice. Nature Biotechnology. 24:1200-01.

Stone R. 2008. China plans $3.5 billion GM Crops Initiative. Science 321:1279. Retrieved on Sept. 5, 2008. http://science-mag.aaas.org/cgi/content/summary/321/5894/1279

Swaminathan MS. 2009. Prof. M. S. Swaminathan in his article "GM: Food for Thought" published in the Asian Age, Delhi, 26th August 2009:

Syngenta. 2009. Syngenta Foundation for Sustainable Agriculture launches Syngenta and CIMMYT wheat Ug99 stem rust resistance research partnership, August 26, 2009 http://www.syngentafoundation.org/db/1/821.pdf

Takanori K, H Nakanishi, M Takahashi, S Mori and N K Nishizawa. 2008. Generation and Field Trials of Transgenic Rice Tolerant to Iron Deficiency. Retrieved 1 August, 2008. http://www.springerlink.com/content/m412wx750257h33l/fulltext.pdf

Tan T. 2008. GM crops a viable option for food crisis. The Strait Times, Singapore. Retrieved. 12 May 2008. http://www.gmac.gov.sg/News/2008/2008_05_12.html

The Age. 2008. Australian First GM grass trial to start. The Age, Melbourne, 28 October 2008. http://www.theage.com.au/national/australianfirst-gm-grass-trials-to-start-in-victoria-20081028-5aai.html

The Economist. 2007. Biotech Crop Plantings in Romania. November 17-23 edition. p. 63

The Economist. 2009a. Food and Farming. The World in 2010. p. 115

The Economist. 2009b. If words were food nobody would be hungry. November 19, 2009. http://www.economist.com/world/international/displaystory.cfm?story_id=14926114

The Economist. 2009c. How to Feed the World. Business as usual will not do it. November 19, 2009. http://www.economist.com/opinion/displaystory.cfm?story_id=14915144

The Economist. 2009d. Drought in Texas, Not a Cloud, 15 August 2009. p. 27-28.

Thomas KV. 2009. India can't oppose GM tech amid current farm crisis, Press Trust of India (PTI), 13th Nov 2009, available at: http://www.ptinews.com/news/375411_India-can-t-oppose-GM-tech-amid-current-farm-crisis

Trigo EJ and EJ Cap. 2006. Ten Years of Genetically Modified Crops in Argentine Agriculture. Argentine Council for Information and Development of Biotechnology (ArgenBio), Buenos Aires, Argentina. December 2006.

Toe A. 2003. Limites maximales de résidus de pesticides dans les produits agricoles d'exportation dans trois pays du CILSS-Etude du Burkina Faso', FAO/CILLS, Rapports Techniques, Projet Gestion des pesticides au Sahel, Bamako, Mali.

Tomich J. 2009. Monsanto Asks Supreme Court to Review Alfalfa Ban. SoyaTech. November 2, 2009. http://www.soyatech.com/news_story.php?id=16057.

Traoré O, D Sanfo, K Traoré and B Koulibaly. 2006. 'The effect of Bt gene on cotton productivity, ginning rate and fiber characteristics under Burkina Faso cropping conditions', A Working Document Written by INERA Staff Members, Bobo Dialasso, Burkina Faso.

UC Davis News and Information. 2008. National report outlines strategies for mitigating alfalfa gene flow. November 3, 2008. http://www.news.ucdavis.edu/search/news_detail.lasso?id=8856.

UNICEF. 2007 United Nations Children's Fund (UNICEF). 2007. The State of the World's Children 2008. New York, NY.

United States Department of Agriculture, National Agricultural Statistics Service (USDA)/FAS. 2007. Cotton: World Markets and Trade Monthly Circular, 1 September 2007. FAS, USDA. http://www.fas.usda.gov/cotton/circular/Current.asp

USDA National Agriculture Statistics Service (NASS) 2009a. Adoption of Genetically Engineered Crops in the. 2009. National Agriculture Statistics http://www.ers.usda.gov/Data/BiotechCrops/

USDA (NASS). 2009b. (http://www.nass.usda.gov/Data_and_Statistics/Quick_Stats/index.asp).

USDA 2009c. USDA Cotton Production Projection. http://www.topenvironnement.net/index2.php?option=com_content&do_pdf=1&id=102

USDA NAAS. 2009d. Acreage. June 30 2009. http://usda.mannlib.cornell.edu/usda/current/Acre/Acre-06-30-2009.pdf

USAID, 2009. Global Development Alliance Supports Use of Biotechnology to Improve Indian Rice and Wheat Production. April 28, 2009. http://www.usaid.gov/our_work/agriculture/biotechnology/gda_indian_rice_wheat.html

University of New Castle Australia. Gene breakthrough secures crops' future. July 21, 2009. http://www.newcastle.edu.au/news/2009/07/genebreakthroughsecurescropsfuture.html:

Future Proofing the World's Food Supply p.18 http://www.newcastle.edu.au/Resources/Research/Research%20publication%202009/Research%202009.pdf

Virk P and G Barry. 2009. Biofortified rice – Towards combating human micronutrient deficiencies, International Rice Research Institute (IRRI), the Philippines, accessed on 7th Dec 2009 from; http://km.fao.org/gipb/images/pdf_files/LiteratureViews/Virk_DOC_apb09.pdf

Vaissayre M and J Cauquil. 2000. 'Principaux ravageurs et maladies du cotonnier en Afrique au Sud du Sahara', A Report Published by CIRAD.

Vitale J, H Glick, J Greenplate, M Abdennadher and O Traoré. 2008. The economic impacts of second generation Bt cotton in West Africa: Empirical evidence from Burkina Faso International Journal of Biotechnology. l10 (2/3).

Vognan G, M Ouédraogo and S Ouédraogo. 2002. Description de la filière cotonnière au Burkina Faso, Rapport intermédiaire, INERA, p.34.

Waugh P. 2009. The Evening Standard, 10th August 2009. http://www.thisislondon.co.uk/standard/article-23730416-details/GM+crops+hold+key+to+our+future+food+supply%2C+says+Benn/article.do

World Bank. 2008. The World Development Report, Agriculture for Development. World Bank, Washington DC.

World Food Program. UN. 2009. http://www/wfp.org/1billion

World Fuel Ethanol Production for 2008. Renewable Fuels Association. http://www.ethanolrfa.org/objects/pdf/outlook/RFA_Outlook_2009.pdf

World Summit on Food Security 2009. WSFS considers biotechnology for food security. http://www.ip-watch.org/weblog/2009/11/26/un-eyes-next-steps-on-food-security-biotech-pleased-with-summit-mention/#more-7990 The full Declaration can be downloaded at: http://www.fao.org/fileadmin/templates/wsfs/Summit/Docs/Final_Declaration/WSFS09_Declaration.pdf

Wu K-M, Y-H Lu, H-Q Feng, Y Jiang and Z Z Jian. 2008. Suppression of cotton bollworm in multiple crops in China in areas with Bt toxin-containing cotton. Science. 321: 1676-1678.

Xinhua. 2009a. China to raise grain output to 540 mln tonnes by 2020. 8 April 2009 http://id2.mofcom.gov.cn/aarticle/chinanews/200904/20090406159327.html

Xinhua. 2009b. Drought affects thousands in China's Inner Mongolia. 25 July 2009.http://www.highbeam.com/doc/1P2-16075902.html

Xinhua. 2009c More than 4 mln hectare crops threatened by drought in NE China. 11 August 2009 www.chinaview.cn. http://news.xinhuanet.com/english/2009-08/11/content_11865170.html

Yorobe JM, Jr and CB Quicoy. 2006. Economic impact of Bt corn in the Philippines. The Philippine Agricultural Scientist, 89(3): 258-67.

Zeigler RS. 2009.The Rice Crisis, Why it happened and what to do, Annual Meeting Symposium 'Protecting our planet against food riots in the future', the American Association for the Advancement of Science (AAAS), 12-16th Feb 2009, Chicago, USA.

Zimmermann R and M Qaim. 2004. Potential health benefits of Golden Rice: A Philippine case study. Food Policy. 29: 147-168.

Biotech Rice – Present Status and Future Prospects

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Introduction

Rice is grown on 157 million ha worldwide and is globally the most important food crop. It is the staple for more than 3 billion people, including 700 million malnourished poor who rely on rice for up to 70% of their daily calories. Because it has a smaller genome than most other cereals, rice is a model for understanding in genetic terms how these important crops grow, withstand stress, and set the seeds on which human nutrition depends. New knowledge gained from rice genome sequencing has led to major improvements in the power and efficiency of rice breeding. One of the techniques used to both generate and exploit this new knowledge is genetic engineering. It allows a single gene to be manipulated in the context of the whole plant with the aim of revealing its biological functions and assessing its value in crop improvement. However, biotech rice (rice varieties containing one or a few additional genes introduced by genetic engineering) cannot currently be grown freely by farmers anywhere in the world. This is in spite of the fact that biotech soybean, maize, canola and cotton are grown on ~125 million ha worldwide, including ~55 million ha in developing countries (James 2008). This prohibition is due principally to governmental and corporate caution when dealing with a largely public-sector crop that accounts for 11% of global arable land and is life itself to the 250 million farmers who grow it. Accordingly, in discussing the present status and future prospects of biotech rice, this article focuses not only on technical breakthroughs and benefits to farmers, consumers and the environment, but also on regulatory innovations that will allow rice-growing countries to harvest their investments in biotech rice.

1. China gives green light to biotech rice

Of the top ten rice-producing countries, all except Brazil are in Asia. Scientific and political events in these countries are crucial to the future of biotech rice. In November 2009, the Biosafety Committee of the Chinese Ministry of Agriculture made two important decisions concerning biotech crops. One was to grant a biosafety certificate to a line of biotech maize for use in animal feed. The line expresses a fungal phytase that releases stored phosphate from the grain and promotes animal growth. The other decision was to grant certificates to two lines of biotech rice intended for human consumption. Each line expresses an insecticidal protein from the bacterium *Bacillus thuringiensis* (Bt) to prevent damage from rice stem borers, increase yield, and reduce pesticide use. When combined with a decision in 1997 to approve Bt cotton (which has since spread to 4 million ha), the latest decisions mean that China has effectively welcomed the use of biotech crops in food, feed and fiber production. These biotech crops are products of China's public sector research system, and both phytase maize and Bt cotton have been licensed to Chinese companies for commercialization.

The most significant decision was the approval of Bt rice, expected to be one of the earliest biotech rices to be grown by farmers for human consumption, with ß-carotene-rich Golden Rice on schedule to be approved and adopted in the Philippines in 2012. The approval of Bt rice by the Chinese government is likely to have reverberations inside and outside China. As it is a decision that has been expected from China for some years, it is intriguing to consider why it has been made now. Two likely factors are (i) the rice crisis of 2008 and (ii) the performance of biotech crops already in farmers' fields in China and around the world.

2. Rice supply and demand

The rice crisis of 2008 persuaded a number of governments in Asia that food security lies in self-sufficiency in rice rather than in reliance on the highly volatile international rice trade. The following seven sub-sections examine briefly (a) the recent history of rice production from 1960 until 2008, (b) the rice production targets for 2010-2030, (c) lessons from existing biotech crops, (d) the need to balance intensification and sustainability in rice production, (e) sources of genetic variation for rice breeding, (f) strategies for irrigated rice breeding, and (g) strategies for rainfed rice breeding.

a. From Green Revolution to Rice Crisis

During the 1950s the population of Asian countries began to climb rapidly as health improvements reduced infant and adult mortality but left fertility rates temporarily unaltered. The rate of population growth peaked at 2.2% in 1964 but declined slowly thereafter as urban parents in particular became aware of the economic costs of raising a large family. The introduction of high-yielding semi-dwarf varieties in temperate and tropical Asia in the 1960s and then high-yielding hybrid rice in China in the 1970s allowed supply to meet demand (Peng et al. 2008). During 1965-85, world rice production increased by 10.7 million metric tons per year (Mt/yr), as the world's population rose by 77 million/yr. However, this rate of gain did not persist. During 1985-2005, rice production rose by only 7.2 Mt/yr, while the population rose by 83 million/yr. Indeed, between 2000 and 2005, production rose by only 6.6 Mt/yr, due chiefly to production shortfalls in China and India.

From the 1960s, international trade in rice amounted to only 4% of total production and it occurred largely within Asia. The real international price of rice fluctuated greatly between 1960 and 1980 but then began a steady decline from US$670 per ton in 1981 to US$200 per ton in 2000. The price decline benefitted the urban poor and led many to believe that the problem of rice production had been solved, but it became a disincentive for farmers to grow rice. Governments relied increasingly on the international market, which reached 7% of production in 2000 and rose further thereafter (Calpe, 2004). Between 2000 and 2006, while global buffer stocks declined from 130 Mt to 60 Mt, the international rice price increased from US$200 to $320 per ton (Pandey, 2008).

Throughout the 1990s, India used a dual pricing system that maintained a high domestic market price to encourage farmers to continue in rice production but provided coupons for the poor to acquire rice at lower prices. As a result, India became a major exporter of rice. It maintained buffer stocks but they were considerably lower than those held in China. As the international rice price continued to climb through 2007, the world's increasing use of maize for biofuel production saw wheat prices rise. Several rice-importing countries began buying rice at whatever price they could get and several rice-exporting countries began to ban exports. The major rice exporter, Thailand, continued to trade and between January and April of 2008 the international rice price jumped from US$375 to US$1100 per ton as consumers, traders and governments in exporting and importing countries alike hoarded rice (Timmer, 2009). By October 2008, the price had retreated to US$575 as record harvests were achieved, but buffer stocks remain at record lows and the International Rice Research Institute (IRRI) warned in September 2009 that prices are likely to remain high for some years.

b. Rice production targets for 2010-2030

It is expected that, during 2010-2030, the world's population will rise by 70 million/yr. IRRI concludes that rice production must increase by 8-10 Mt/yr over that period to keep pace with population growth. However, this rate of increase must be achieved without increasing many of the inputs (water, land, labor, fertilizer, herbicides and pesticides) that characterized the Green Revolution during 1965-1985. Competition for water is now more severe, agricultural land area is shrinking through urbanization and degradation, rural labor has been migrating to cities, and many agrichemicals have been banned for health and environmental reasons. A new Green Revolution is required for 2010-2030, based on exploiting biological knowledge and breeding tools that were unavailable, indeed unimaginable, fifty years ago.

c. Lessons from biotech crops 1996-2007

Brookes and Barfoot (2009) examined specific global economic impacts of biotech soybeans, corn, cotton, and canola on farm income and production from 1996 to 2007. The analysis showed substantial net economic benefits at the farm level, amounting to US$10.1 billion in 2007 and US$44.1 billion for the 12-year period. These biotech crops increased global production levels in 2007 by 14 Mt for soybean (occupying 67 Mha out of 95 Mha) and by 15 Mt for maize (occupying 40 Mha out of 157 Mha). Most of the increased production came from Bt crops, although herbicide-tolerant crops also offered increased yields under specific conditions, in addition to their cost savings and health advantages. Frisvold et al. (2006) examined benefits for China and the US from almost ten years of Bt cotton production. From global economic benefits of US$835 million, China had garnered about 55%. The above examples illustrate the benefits of participating in the production of biotech crops. However, Raney (2006) emphasizes that developing countries reap higher benefits from biotech crops when they have the capacity to conduct scientific research, manage farm inputs and deal with regulatory and IP issues.

d. Balancing intensification and sustainability

The new Green Revolution must achieve a balance between intensification of rice production (to avoid intruding on forests and wetlands) and sustainability (to ensure that the land is available for future generations of rice farmers and consumers). Some major rice production systems have already begun moving towards achieving that balance. For example, the rice-winter wheat cropping system, which occupies large areas of China and the Indo-Gangetic Plain has begun to adopt low-till or no-till agriculture. Out of 13.5 Mha of this system in the Indo-Gangetic Plain, more than 2.5 Mha is no-till (Hobbs et al. 2008). As conservation agriculture has been defined as minimal soil disturbance (no-till) and permanent soil cover (mulch) combined with rotations, the trend in the rice-wheat system is clearly to conservation agriculture.

Another sign that rice production systems are moving towards sustainability is the crop management and post-harvest measures that are being taken to reduce greenhouse gas emissions from rice fields (Li et al. 2002; Pathaka and Wassmann, 2007). These emissions include methane from puddled fields, nitrous oxide from upland fields, and both of the above together with carbon dioxide from the burning of straw. It is up to the new generation of farmers, breeders and agronomists to find ways of increasing yields while minimizing adverse affects of rice production on the environment – from field to water table and atmosphere. However, sustainability is endangered by monoculture, so care must be taken to ensure that the strategy for deployment of biotech rice includes diversification of the engineered varieties and diversification of the genes themselves. We return to this point in connection with the cost of regulatory compliance (section 7).

e. Sources of genetic variation for rice breeding

Genetic variation is the raw material of the breeder's trade. There are 24 species of rice within the genus Oryza and two are cultivated (*Oryza sativa* from Asia and *O. glaberrima* from Africa). *O. sativa* is derived from the wild species *O. rufipogon*, whereas *O. glaberrima* is derived from the wild species *O. barthii. O. sativa* contains two major sub-species (*indica* and *japonica*) which separated from different founding populations of *O. rufipogon* (Sweeney and McCouch, 2007). Indica rice is adapted to tropical lowland environments in the Indian subcontinent, Southeast Asia and Southern China, while japonica rice is adapted to temperate rice in East Asia and tropical areas in the uplands of Southeast Asia. Most breeding activities are conducted within indica germplasm or within japonica germplasm, but *indica/japonica* inter-subspecific crosses have become common. Interspecific crosses are increasingly employed following the development of techniques for wide hybridization (Brar and Khush, 1997). Of course, one of the main advantages of genetic engineering is that it allows breeders to reach beyond the genus Oryza to access new genetic variation (see subsection 3.a).

Rice breeders and agronomists seek to increase yields in four ecosystems: irrigated, rainfed lowland, rainfed upland and deepwater. There is considerable country-to-country variation in the areas of these ecosystems (Table 1). Within each ecosystem major differences can exist in water availability, soil quality, pests and diseases, cropping patterns, farmers' financial resources and population density. The result is that relatively few varieties are widely adopted by farmers. This situation could retard the spread of new biotech traits but may be essential for their sustainability. The next two subsections are devoted to strategies for breeding in the irrigated and rainfed ecosystems and the compatibility of biotech traits with these strategies.

Table 1. Areas of the irrigated, rainfed lowland, uplands and deepwater rice ecosystems varies widely among countries. Data: IRRI World Rice Statistics (consulted 12 January 2010).

Area (mean 2004-06)	China	India	Brazil	Nigeria	Bangla-desh	Indonesia	World	World
							Area	Production
Irrigated (%)	93	53	35	16	40	60	57	75
Rainfed lowland (%)	5	32	3	52	42	25	31	17
Upland (%)	2	12	52	30	7	0	9	5
Deepwater (%)	0	3	0	2	11	15	3	3
Total area (000 ha)	29,037	43,089	3,542	2,522	10,657	11,708	156,688	-
Production 2007 (Mt)	185.5	141.1	11.1	4.7	43.5	57.0	-	650.2

f. Strategies for breeding irrigated rice

Each of the major rice breeding programs of the last 50 years began with a well-defined goal and a clear conception of how to achieve it. The breeding program at IRRI began with a key idea that Norman Borlaug had used in the 1950s in the Rockefeller Foundation's wheat breeding program in Mexico: employ a dwarfing gene to lower the height of cereal plants so that they (i) put more of their biomass into grain rather than straw (high harvest index) and (ii) were less likely to be flattened by wind or rain. IRRI began its program in 1960 with *indica*/*indica* crosses suitable for the tropics and released its first variety IR8 in 1966. It combined high biomass, dwarf stature, high harvest index, and fertilizer responsiveness under irrigated conditions (Jennings, 1966). IR8 was planted on more than 1 Mha in India alone and often doubled farmers yields. Subsequently, pest and disease resistance and improved grain quality were added, along with tolerance of problem soils and abiotic stresses in a complex breeding program involving at least one interspecific cross that transferred resistance to grassy stunt virus from *O. nivara* (Khush, 1999). At their peak, two IRRI varieties (IR36 released in

1976 and IR64 released in 1985) were planted on more than 11 million ha. Breeding institutes and agricultural universities throughout the world employed many IRRI products as parental lines in their own breeding programs (Evenson and Gollin, 2003).

In 1970, Chinese scientists began their hybrid rice program with another key idea – this one derived from hybrid maize. They would form hybrids from markedly different indica parents and exploit the heterotic yield advantage of such hybrids. As was done for maize, they would use as female parent a line with cytoplasmic male sterility to facilitate large-scale hybrid seed production. Hybrid rice was deployed in China from 1976 and continued to be improved in terms of hybrid seed costs and grain quality for many years. It spread eventually to cover about 55% of Chinese rice land and raised yields in China by 30% (Yuan, 2002). In 1979 IRRI began its own hybrid rice program for tropical conditions, not by using the temperate hybrid parents from China but new parents adapted to tropical conditions (Virmani, 1994).

Between 1966 and 1985, IR8 and its derivates set the standard for yield potential among inbred lines, with hybrids yielding ~15% more. The global production increases seen in this period were due to the gradual uptake of the modern varieties and associated crop management tools by farmers. However, it became clear that new efforts would have to be made to increase the yield potential of rice beyond the 10 tons/ha achieved by IR8. In 1982 Japan began its super-high-yielding rice program which employed *indica/japonica* crosses and produced a number of very high-yielding varieties with heavy panicles (Wang et al. 1997). In 1989, IRRI began its New Plant Type (NPT) program to raise yield potentials for tropical irrigated rice to 12 tons/ha. The first crosses were between tall and dwarf tropical japonicas. Later crosses were between tropical japonica NPT lines and elite indicas to improve grain type (Peng et al. 2008). In 1996, China organized its first national project to achieve super high yields with inbred rice derived from *indica/japonica* crosses (Peng et al. 2008). In 1998, the program was expanded to include a super hybrid rice program, also with *indica/japonica* crosses. Seven inbred lines and 44 hybrids were released to farmers and by 2005 they were planted on 13.5 Mha, producing an extra 6.7 million tons of rice annually.

g. *Strategies for breeding rainfed rice*

The irrigated environment was not the only ecosystem to have a substantial breeding program devoted to it. IRRI's headquarters in the Philippines experiences two distinct seasons (wet and dry) and this seasonal variation has aided development of widely adapted irrigated varieties and rainfed lowland varieties. In addition, the rainfed lowland program has used a shuttle breeding approach (Sarkarung, 1995) to link the Philippines, Thailand, Eastern India and other parts of Southeast Asia and their widely divergent environments (Wade et al. 1999). The emphasis in this program has been on abiotic stress tolerance (both climatic and problem soils) and on serious biotic stresses such as the blast fungus (Mackill et al. 1996). Drought tolerance has been a particular focus for Thailand as its major export varieties are grown under rainfed conditions (Jongdee et al. 2006). Asia, Africa and South America share a number of problems connected with upland rice cultivation. A major upland breeding program in South America was conducted by the International Center for Tropical Agriculture in Colombia (Rao et al. 1993). It was focused on acid-soil tolerance, including tolerance of aluminum toxicity. Varieties and methods developed by that program have been widely used elsewhere.

Most of the rice area in Africa is rainfed uplands. In the early 1990s, the African Rice Center and its partners developed inbred lines from a cross between a high-yielding upland *O. sativa* tropical japonica and a locally adapted upland *O. glaberrima* (Jones et al. 1997). The crosses employed wide hybridization technology with embryo rescue of the initial low-fertility hybrid and backcrossing to the sativa parent to restore fertility. These new interspecific lines are called NERICA, which is an acronym for New Rice for Africa. In 2000, seven NERICA varieties were released for the uplands of Africa.

In 2001 IRRI started its aerobic rice program, originally focused on achieving higher yields in the uplands. Based on the success of the water-saving temperate aerobic rice varieties of northern China and the Cerrados of Brazil (Pinheiro et al. 2006), IRRI's aerobic rice was for tropical upland conditions where rainfall could be supplemented with limited irrigation. Unlike traditional low-input upland cultivation, aerobic rice was supported by fertilizer and other inputs. The tropical aerobic rice program has achieved its goals of increasing yields in the uplands and has had major spinoffs in enhancing yields under drought conditions in the uplands (Bernier et al. 2008) and providing aerobic rice for the lowland rice-wheat cropping system so that aerobic wheat does not suffer yield loss by being grown after anaerobic puddled rice (Singh et al. 2008).

Ideotype breeding programs focus initially on plant architecture but acknowledge the requirement to add specific traits at later stages of the program. If those traits are genetically simple, they may be suitable for backcross breeding (e.g., resistance to grass stunt virus). Equally, breeders employ backcrossing to introgress important traits into the products of different breeding programs. Normally, at least six cycles of backcrossing would be required to retrieve the key traits of the recurrent parent, but recently DNA marker-assisted breeding combined with visual phenotypic analysis has enabled this end point to be reached in about 3 backcrosses (Collard and Mackill, 2008).

An example is provided by the introgression of the submergence tolerance allele *Sub1* from landrace FR13A into Swarna, which possesses a submergence intolerance allele *Sub1*. After introgression into Swarna, the allele *Sub1* reduces the yield loss after 2 weeks of partial submergence and recovery (Neeraja et al. 2007). As the *Sub1* locus and *sub1* alleles have been cloned, it has been possible to design markers to identify progeny from Swarna/FR13A backcrosses in which (i) *Sub1* is present and *sub1* is absent (known as foreground selection), (ii) the most closely flanking regions around the introgressed recurrent parent *Sub1* gene are Swarna rather than FR13A (known as recombinant selection), and (iii) DNA markers located elsewhere in the genome detect only Swarna alleles rather than FR13A alleles (known as background selection). This triple selection is the method of choice for introgressing a specific gene from a donor into a recipient and has been used to introgress *Sub1* into other popular submergence-intolerant varieties (Septiningsih et al. 2009). It should be noted, however, that engineering a *Sub1* gene from FR13A into a submergence-intolerant variety achieves a similar goal to backcrossing (Xu et al. 2006; Fukao et al. 2006). Biotech rice might therefore be a useful alternative to DNA marker-assisted backcrossing in introducing valuable new traits into popular cultivars or promising breeding lines.

3. Major contributions of biotech rice

The three most popular traits in existing biotech crops are herbicide tolerance, insect resistance and virus resistance (James, 2008). In each case, the introduced gene is not from a plant genome: (i) a glyphosate-resistant gene from a strain of *Agrobacterium tumefaciens*, (ii) a synthetic version of a lepidopteran-specific insecticidal Crystal Protein (*Cry*) gene from *B. thuringienesis* (Bt), and (iii) viral coat-protein genes. These examples illustrate two major contributions of the biotech approach to plant breeding: (i) enlarging the gene pool to include genes that breeders could not access by conventional or enhanced crossing techniques, and (ii) modifying the gene by recombinant DNA technology to fine-tune a trait, e.g., by changing the codon bias of the Bt *Cry* gene from that in *B. thuringienesis* to that in plants (Stewart et al. 1996). Other major contributions of the biotech approach to plant breeding are in functional genomics and forward and reverse genetics. These contributions are discussed in the following subsections.

a. Exploring the gene pool

In searching for suitable genetic variation, rice breeders look first within accessions of *O. sativa* and then within accessions of *O. rufipogon* and its very close relative *O. nivara*. The next ports of call are accessions of *O. glaberrima* and four other wild species that share the diploid AA genome (2n = 24) with *O. sativa*. These eight species are at least partially interfertile (Doi et al. 2007). Even within *O. sativa*, the *indica* and *japonica* subspecies often display marked sterility but that can be removed with wide compatibility genes. The remaining sixteen species of the genus Oryza have diploid genomes (BB, CC, EE, FF or GG, 2n = 24) or allotetraploid genomes (BBCC, CCDD, HHJJ or HHKK, 2n = 48) and can be crossed with *O. sativa* only with the help of embryo rescue (Brar and Khush, 1997). Thus, in principle, all genes within the genus Oryza can be brought into *O. sativa* for breeding purposes. Intergeneric hybridization has been used frequently to bring genes of related genera into the gene pools of wheat, barley, oats and maize, but intergeneric hybrids are rare for rice. The best studied case is the use of a repeated-pollination procedure to introgress DNA from *Zizania latifolia* into *O. sativa* cv Matsumae (Wang et al. 2005).

Gene cloning gives the rice breeder access to any gene inside or outside the genus Oryza. Genes within Oryza are known as cis-genes because they are also accessible by crossing with or without embryo rescue, while the genes outside Oryza are known as trans-genes (Jacobsen and Schouten, 2009). Access to cis-genes and trans-genes has been greatly facilitated by the extensive programs of genome sequencing across all types of living organisms and viruses. In the case of rice, the genome of *japonica* variety Nipponbare is considered as the reference genome (http://rice.plantbiology.msu.edu/riceInfo/info.shtml#Genes). It contains ~435 million bases of deoxyribonucleic acid (DNA). In rice, as in other plant and algal cells, the genome is found in three compartments: the nucleus, the mitochondria and the chloroplasts, reflecting the role of two endosymbiotic events in the evolutionary origin of algae (Pisani et al. 2007). In Nipponbare, the nuclear genome contains 40,577 protein-coding genes arranged on 12 linear chromosomes, with two copies per nucleus. The mitochondrial and chloroplast genomes are much smaller circular molecules that carry 35 and 106 protein-coding genes, respectively, and present in multiple copies in each organelle. The complete sequencing of the genome of cv Nipponbare, together with sequencing of parent 93-11 of the Chinese Super Hybrid Rice (http://rice.genomics.org.cn/rice/index2.jsp), has provided a platform for comparative sequencing of twenty representative rice accessions from *O. sativa* (McNally et al. 2009), ten representative wild species (Ammiraju et al. 2006) and syntenic regions of rice and other grasses (Buell et al. 2005).

b. Modifying the sequence of cis-genes and trans-genes

The biotech approach is a powerful tool for fine-tuning the function and regulation of a protein or the regulation of the gene encoding the protein. Examples include (i) modification of a site within the drought-responsive DREB2A transcription factor of Arabidopsis to remove a site of proteolytic attack (Sakuma et al. 2006), (ii) use of directed evolution to discover a new glyphosate-resistant form of the rice 5-enolpyruvylshikimate 3-phosphate (EPSP) synthase (Zhou et al. 2006), and (iii) use of a modified maize ADP-glucose pyrophosphorylase to escape feedback inhibition of starch synthesis by inorganic phosphate (Smidansky et al. 2003).

c. Biotech rice for functional genomics

The complete sequencing of the genome of rice *japonica* cv Nipponbare revealed the presence of 56,797 genes: 16,220 genes related to transposable elements (TE) and 40,577 non-TE genes (http://rice.plantbiology.msu.edu/riceInfo/info.shtml#Genes). There are five biotech methods for exploring gene function in more detail. They are: over-expression lines (Chen et al. 2008a), knock-out and activation mutant lines (Krishnan et al. 2009), RNA interference lines (Miki et al. 2005), and artificial microRNA lines (Warthmann et al. 2008). The knock-out and activation mutant lines are generated randomly, but over-expression, RNAi and amiRNA lines are directed to specific genes or gene families. They also offer an important advantage: whereas knockouts inactivate the affected gene through the plant, the other methods can be designed to over-express or down-regulate the gene in specific cell types or in response to specific signals through appropriate choice of the regulatory sequence (promoter) that defines the circumstances of gene expression (Jung et al. 2008). Over-expression of miRNAs provides information on the functions of the miRNAs and the functions of their target transcripts (Zhu et al. 2009).

The 40,577 non-TE genes of the rice genome have an average length of 2,841 base pairs, meaning that ~115 million bases out of ~435 million bases in the nuclear genome comprise the non-TE genes. The number of bases comprising the TE genes amount to ~53 million. The remaining ~267 million bases are known collectively as intergenic DNA, which is highly variable in function. The sequences of the genes and the intergenic DNA of a rice variety constitute its genotype.

Much of the future of biology will be concerned with how genotype and environment determine phenotype. Phenotype is the collection of traits such as architecture, chemical composition and behavior that has traditionally been used by breeders and others to distinguish among a set of breeding lines, varieties or germplasm accessions. The differences in phenotype between two varieties tested in the same environment are assumed to arise from differences in their genotypes. Even before DNA was recognized as the genetic material of life by Avery et al. (1944), the genetic differences between varieties at a given genetic locus were referred to as allelomorphs or alleles. Allelic differences are usually considered to be traceable to sequence differences within a protein-coding gene, but they might also arise within intergenic DNA. An example from plants is the conserved non-coding sequence affecting flowering time in maize and located 70,000 bases upstream from a gene previously implicated in flowering control (Salvi et al. 2007).

4. Production of biotech rice

All three genomes (nuclear, chloroplastic and mitochondrial) have been engineered in the unicellular green alga *Chlamydomonas reinhardtii* by microprojectile bombardment (Remacle et al. 2006). However, in flowering plants, only the nuclear genome has been amenable to transformation in most species where the attempt has been made. The chloroplast genome has been engineered in several dicot plants (Maliga, 2004), beginning 20 years ago with tobacco (Svab et al.,1990), but monocots have proved to be recalcitrant. Nevertheless, engineering of the rice chloroplast genome has progressed significantly in recent years (Lee et al. 2006) and may soon be achieved. Mitochondrial transformation has not been achieved in any flowering plant.

Nuclear transformation is achieved by either Agrobacterium-mediated transformation (Shrawat and Lörz, 2006) or microprojectile bombardment (Christou, 1997). These methods differ principally in how the purified DNA enters the cell and secondarily in how integration into the nuclear genome occurs. With both techniques the aim is to produce biotech rice in which the introduced DNA is integrated in an intact, stable, functional and heritable form and the engineered cell regenerates into a whole, viable and fertile plant.

a. Agrobacterium-mediated transformation of dicots

The first reports of the production of biotech plants appeared in 1983 from three different research groups (Herrera-Estralla et al. 1983; Bevan et al. 1983; Fraley et al. 1983). Each group used recombinant DNA technology to construct a transforming plasmid carrying a gene for antibiotic resistance. The plasmid was then amplified in *Esherichia coli* and then transferred to *Agrobacterium tumefaciens* by transformation. *A. tumefaciens* was then cultivated with plant tissue to allow transfer of a segment of plasmid DNA from a bacterial cell into a neighboring plant cell by a conjugation-like mechanism. The plasmid segment became integrated into the plant nuclear DNA and the cells were challenged with the antibiotic to which only transformed cells would be resistant. Antibiotic-resistant cell masses were transferred to a medium suitable for the inducing regeneration of the cell masses into whole fertile plants.

This method depended on a detailed understanding of how *A. tumefaciens* caused the crown gall disease in a range of dicotyledonous plants. The disease is characterized by formation of a tumor that produces novel metabolites (opines or nopalines) that only Agrobacterium can use for growth. Whether the metabolites are opines or nopalines is determined by the strain of *A. tumefaciens* rather than by the variety of plant, suggesting that the enzymes for synthesizing these molecules are encoded by genes of the bacterium that are transferred to and are active in plant cells. As crown gall disease is not found in cereals and other grasses, it was not surprising that this method did not initially work for rice.

b. Direct DNA uptake by rice

For several years rice scientists tried other methods of forcing DNA into rice cells and succeeded with two of them: (i) protoplast transformation (Toriyama et al. 1988; Zhang et al. 1988), and (ii) microprojectile bombardment of embryogenic tissue (Christou et al. 1991). Protoplasts were produced by treatment with cellulases and other enzymes specific for cell-wall components, but only protoplasts from japonica varieties would frequently regenerate into whole fertile plants; protoplasts from indica varieties were much less amenable. Microprojectile bombardment, by contrast, was applicable to a much wider range of rice varieties, including indicas. It became widely used even for plant species that could already be transformed by Agrobacterium.

c. Agrobacterium-mediated transformation of rice

Detailed studies on Agrobacterium-mediated transformation of dicots revealed that successful transfer of DNA from the bacterial cell to the plant cell was triggered by bacterial recognition of small metabolites released from the plant cells. One such molecule released from potato cells was acetosyringone. Although acetosyringone was not released from rice cells in tissue culture, its addition to the co-cultivation medium for rice and *A. tumefaciens* triggered the bacterium to inject DNA into rice cells and made Agrobacterium-mediated transformation possible (Hiei et al.1994). Japonica rice was initially more amenable to Agrobacterium-mediated transformation but adjustments to the plasmids and the tissue culture media increased the frequencies of indica transformation (Hiei and Komari 2006).

d. Future prospects

Over the next decade, it is likely that biotech rice will continue to be produced by either microprojectile bombardment or *Agrobacterium*-mediated gene transfer. The efficiency of these methods will be improved to aid gene discovery, rice breeding and regulatory approval. Likely improvements include (i) floral dip or floral spray transformation with Agrobacterium, as accomplished for Arabidopsis (Clough and Bent 1998; Davis et al. 2009) and wheat (Zale et al. 2009), (ii) allele replacement by homologous recombination (Yamauchi et al. 2009), and (iii) recovery of marker-free transformants as achieved for maize using cassettes delivered by co-bombardment (Lowe et al. 2009). Homologous replacement will have two important benefits: (i) it will allow gene integration for biotech rice to be targeted to specific genes rather than inserted at random into the genome, and (ii) unwanted alleles will be replaced by new alleles rather than having to co-exist as at present, at different sites in the genome. An example of gene targeting is provided by the work of Endo et al. (2007) on the rice acetolactate synthase gene that is the binding site of the herbicide bispyribac. Endo et al. (2007) were able to replace two amino acids simultaneously in the protein by targeting the gene inside the plant; by this route they obtained a biotech rice that is highly resistant to the herbicide.

5. Key traits for biotech rice

Since biotech rice was first produced in 1988, hundred of genes have been successfully inserted into the rice genome in an intact, functional and heritable form. Some of these biotech genes are shown in Table 2. They are gathered under four areas of impact: yield potential, yield stability, human health and environmental protection. A separate subsection (*f*) deals with the contribution of biotech rice to pharming. However, before discussing individual genes and estimating where they are currently located in the pipeline from laboratory to farmers' fields (Column # in Table 2), we consider the nature of the pipeline itself.

a. The pipeline to biotech rice

Thousands of publications have identified genes with potential utility in biotech crops. However, the chance is extremely low that any given biotech plant reaches its intended destination in farmers' fields. There are several crucial decision points: proof-of-concept, agronomic evaluation, regulatory compliance, corporate or institutional backing, and farmer adoption. During proof-of-concept, the gene must give something like the expected trait impact under a realistic set of circumstances. As most traits are likely to be influenced by the environment, proof-of-concept should be field-based. The prevailing biosafety regulations should allow such tests without undue expense and delay. The field is the best place to evaluate the biotech rice line side-by-side against any competing biotech or non-biotech rice lines, as well as any control lines.

After successful proof-of-concept there are three crucial questions: (i) does the biotech gene work well in the major target varieties, (ii) does it exert any negative side-effects, and (iii) does it work in the population of target environments? These questions are similar to those asked of any non-biotech backcrossed line, and to answer them requires numerous medium-scale field tests. The final stage concerns the function of the biotech gene under farmers' field conditions, where the environment would be considerably more variable and sub-optimal than research station trials.

Table 2. A selection of genes that have enhanced the indicated traits in biotech rice.

Trait type	#	Trait	Gene	Comments	Reference
Yield	3	Wide compatibility	S5 aspartic protease	tri-allelic locus	Chen et al. 2008b
potential	2	Male sterility for hybrids	Superwoman1 repressor	silencing	Mitsuda et al. 2006
	2	Stored starch mobilization	sterol C-22 hydrogenase	tissue-specific	Wu et al. 2008
	2	Grain number	cytokinin oxidase Gn1a	anti-sense	Ashikari et al. 2005
	3	Erect leaves	suppression of OsBR1	RNAi	Morinaka et al. 2006
	2	Grain filling	invertase GIF1	overexpressed	Wang et al. 2008
	3	Starch synthesis	ADPG pyrophosphorylase	Pi insensitive	Smidansky et al 2003
Yield	3	Tungro virus complex	RTSV replicase	synthetic gene	Huet et al. 1999
stability	3	Tungro virus complex	RTBV RF2a/RF2b factors	host-derived	Dai et al. 2008
	3	Tungro virus complex	RTBV coat protein gene	virus-derived	Ganesan et al. 2009
	3	Rice Hoja Blanca Virus	nucleocapsid protein gene	virus-derived	Lentini et al. 2003
	2	Yellow Mottle Virus	translational initiation	virus complex	Albar et al. 2006
	1	Herbicide tolerance	glyphosate-resistant EPSPS	bacterial	Stalker et al. 1985
	1	Herbicide tolerance	glyphosate-resistant EPSPS	mod enzyme	Zhou et al. 2006
	1	Herbicide tolerance	PPT N-acetyltransferase	bacterial	Rathore et al. 1993
	1	Sap-sucking insects	snowdrop lectin	tissue-specific	Foissac et al. 2000
	2	Sap-sucking insects	*Allium* agglutinin lectin	overexpressed	Yarasi et al. 2008
	1	Lepidopteran insects	Bt *Cry1Ab Cry1Ac* proteins	bacterial	Cheng et al. 1998
	1	Lepidopteran insects	potato proteinase inhibitor II	new promoter	Duan et al. 1996
	2	Blast resistance	defensin	overexpressed	Kanzaki et al. 2002
	2	Blast resistance	harpin-encoding gene	bacterial	Shao et al. 2008
	2	Blast resistance	germin-like gene cluster	complex locus	Manoslava et al 2009

Table 2. A selection of genes that have enhanced the indicated traits in biotech rice.

Trait type	#	Trait	Gene	Comments	Reference
	3	Blast/bact. blight resistance	WRKY transcription factors	allele complex	Tao et al. 2009
	3	Bacterial blight resistance	hydroperoxide lyase 2	overexpressed	Gomi et al. 2009
	2	Sheath blight resistance	PR-3 rice chitinase	constitutive	Datta et al. 2001
	3	Drought	ZAT10 and LOS5/ABA3	induced	Xiao et al. 2009
	3	Drought	AP37 transcription factor	overexpressed	Oh et al. 2009
	2	Drought	rice LEA3-1 protein	induced	Xiao et al. 2007
	2	Drought	rice OsDRED2B	overexpressed	Matsukura et al 2009
	2	Salinity	protein kinase SAPK4	overexpressed	Diédhiou et al. 2009
	1	Salinity	rice glyoxylase II	overexpressed	Singla-Pareek 2007
	2	Salinity	vacuolar Na+/H+ antiporter	overexpressed	Ohta et al. 2002
	2	Salinity/cold tolerance	OsDREB1A, OsDREB1B	inducible	Ito et al. 2006
	2	Salinity/cold tolerance	SNAC2 transcription factors	overexpressed	Hu et al. 2008
	2	Thermotolerance	heat shock protein 101	overexpressed	KatiyarAgarwal 2003
Human health	1	Fe content of endosperm	bean ferritin	endosperm	Lucca et al. 2002
	1	Fe bioavailability	thermo-stable phytase	endosperm	Lucca et al. 2002
	1	Fe absorption from gut	cysteine-rich metallothionin	endosperm	Lucca et al. 2002
	3	Fe & Zn	iron-regulated Transporter 1	endosperm	Lee & An 2009
	2	Vitamin A	phytoene desaturase	endosperm	Datta et al. 2003
	2	Vitamin A	ß-carotene desaturase	endosperm	Datta et al. 2003
	2	Vitamin A	lycopene ß-cyclase	endosperm	Datta et al. 2003
	3	Vitamin B	GTP cyclohydrolase	endosperm	Naqvi et al. 2009
	1	Vitamin C	dehydroascorbate reductase	endosperm	Naqvi et al. 2009
	3	Vitamin E	homogentisic acid GGTase	endosperm	Cahoon et al. 2003
	1	Hypoallergenic rice	14-16kD rice seed proteins	anti-sense	Tada et al. 1996
	3	Fructans as prebiotics	wheat SS-1-FT and SF-6-FT	+ cold tol.	Kawakami et al 2008
Environ. protection	3	Nitrogen-use efficiency	early nodulin gene	overexpressed	Bi et al. 2009
	3	Nitrogen-use efficiency	alanine aminotransferase	root-specific	Shrawat et al. 2008
	2	Water-use efficiency	HARDY, AP2 family	+ drought tol.	Karaba et al. 2007
	2	Water-use efficiency	isopenteneyltransferase	+ drought tol.	Rivero et al. 2007

The above data on field performance would also be required for any new non-biotech variety. The additional data demanded about biotech rice relate to food safety and environmental safety. Regulations stipulate the form that the introduced DNA must conform to within the plant genome before approval can be given. It is important to have a plan for satisfying these requirements before the project is initiated to avoid much duplication of efforts. of the publications cited in Table 2 do not allow biotech lines to be assessed from this perspective, so that it is difficult to predict how long it would take for each transgenic event to be rendered acceptable under local regulations and then finally reach farmers' fields.

In a world survey of the pipeline in biotech crops, Stein and Rodríguez-Cerezo (2009) defined four stages. They were:

(i) commercial crop (biotech event currently marketed in at least one country);
(ii) commercial pipeline (biotech event authorized in at least one country but not yet commercialized because of decision of the developer);
(iii) regulatory pipeline (biotech events already in the regulatory process to be marketed in at least one country);
(iv) advanced R&D pipeline (biotech events not yet in the regulatory process but at late stages of development – large-scale multi-location field trials, generation of data for the review process).

Stein and Rodriguez-Cerezo (2009) considered that the numbers of biotech rice lines in these four phases of the pipeline were 0, 1, 4 and 10. They include several different sorts of Bt rice. However, the majority of the entries in Table 2 would not even have reached the advanced R&D pipelines. Accordingly, the entries in Column # of Table 2 are intended as rough estimates of the time to regulatory approval, including research required for proof-of-concept: 1 = 0-5 years to approval, 2 = 6-10 years to approval, and 3 = >10 years to approval.

b. Rice yield potential

Three-line hybrid rice was traditionally confined to *indica/indica* hybrids because of the rarity of restorer genes among japonica germplasm. These intrasubspecific hybrids show a heterotic yield advantage of about 15%. Later, two-line hybrids with temperature- or photoperiod-induced genic male sterility (TGMS or PGMS) allowed *indica/japonica* hybrids to be developed, as in the Chinese Superhybrid Rice Program. The heterotic yield advantage of intersubspecific hybrids can be ~35% if partial intersubspecific sterility is prevented using wide compatibility genes (Ouyang et al. 2009). As shown in Table 2, the cloning of the S5 wide compatibility gene (Chen et al. 2008b) is one step forward, while another is the development of an artificial male sterility system that requires neither restorers nor temperature- or photoperiod-sensitivity (Mitsuda et al. 2006).

It may also be possible to increase yields of inbred lines. This is suggested by the discovery of a number of very different genes that produce significant yield increases when overexpressed, down-regulated or expressed in specific tissues in pre-existing varieties (Table 2). They operate through quite different mechanisms and may therefore show additive effects in yield in biotech rice. The gene act on light interception (Morinaka et al. 2006), mobilization of stored starch (Wu et al. 2008), increased grain number (Ashikari et al. 2005) and increased grain filling (Wang et al. 2008). In the first three cases, the genes directly affect plant hormone levels. It will be intriguing to see whether stacking of these genes enhance yield in a range of already popular varieties.

c. Rice yield stability

Yields in farmers' fields are threatened by a wide range of biotic and abiotic stresses. Genes that protect against these stresses are crucial in protecting the livelihoods of farming families. A single season of drought in Eastern India can send a family into poverty from which they may take five years to recover (Pandey et al. 2000). Savary et al. (2000) studied the biotic stress in tropical Asia and found that yield losses due to weeds averaged 20%, various stem borers were the major insect pests (2.3%), and the only diseases that caused substantial yield loss when averaged over the entire region were *Rhizoctonia solani* sheath blight (6.1%), *Magnaportha grisea* leaf blast (5%) and *Helminthosporium oryzae* brown spot (5%). Rice tungro disease was a very severe Asian disease in particular regions and years, just as rice African yellow mottle virus and rice Hoja Blanca virus are in West Africa and South America, respectively. The justification for enhancing virus resistance in rice hangs not through its impact on global rice production but on benefits brought to the livelihoods of millions of farmers worldwide.

Table 2 shows genes that can be incorporated into biotech rice to confer herbicide tolerance and enhanced resistance to stem borers, blast, sheath blight and tungro disease. Naturally occurring resistance genes against blast are well studied and are used in conventional breeding and DNA marker-assisted breeding (Manoslava et al. 2009; Skamnioti and Gurr, 2009), but it is likely that the biotech mechanisms will be particularly useful in devising broad-spectrum resistance. There is some natural resistance to stem borers but nothing as effective as Bt rice or biotech rice expressing one of the many plant proteinase inhibitors that interfere with insect digestion (Duan et al. 1996). No reliable sources of resistance to sheath blight exist in rice germplasm, but biotech rice expressing rice and other chitinases in a constitutive manner offers effective resistance (Datta et al. 2001), implying that rice is defective in inducing endogenous chitinases in response to infection by sheath blight. Virus resistance may be against the sap-sucking insect vector or the virus itself. Both forms of resistance may occur naturally, and both are available in biotech rice (Table 2).

Resistance to abiotic stresses such as drought, submergence, cold, heat and adverse soil conditions (toxicities and deficiencies) has been intensively studied in rice. Naturally occurring resistance genes can range from major genes to major-effect quantitative trait loci (QTL) to minor-effect QTL. Biotech genes for stress tolerance in rice have been discovered by forward genetics and reverse genetics. In forward genetics the transgenic knockout phenotype leads to the identification of the altered gene. In reverse genetics, differences in allele sequences lead to the discovery of altered phenotype. They have also been discovered by microarray analysis of stress responsiveness or by orthology with stress genes from other plants, fungi and mammals (Salekdeh et al. 2009). Xiao et al. (2009) compared seven drought-tolerant biotech rice lines under identical conditions and found that the best levels of tolerance were delivered by two genes from Arabidopsis (encoding zinc finger protein ZAT10 and LOS5/ABA3). The next key step in the study of stress tolerance in biotech rice will be to stack genes for different mechanisms related to the same trait. The most common way of stacking is by pair-wise crossing of single-gene events.

d. Human health

As the world's largest food crop, especially for the poor, rice is recognized as an excellent vehicle for delivering nutrients for improved health. Parboiled rice is healthier than polished rice because the steaming process forces the nutrients of the pericarp into the endosperm. However, polished rice is the most popular form and lacks both the pericarp and its nutrients. The targeting of micronutrients into the endosperm so that they remain after polishing requires the biotech approach. The most commonly used promoters for directing expression of nutrition-related genes to the endosperm are the promoters that drive accumulation of the major endosperm proteins (prolamin and glutelin).

The health benefits expected from the biofortification of rice with micronutrients extend to large percentages of the human population (Bouis, 2003). The two principal groups are vitamins (Mayer et al. 2008) and minerals (White and Broadley, 2009). Table 2 lists some of the genes contributing to the accumulation of these molecules in the endosperm. The table also mentions fructans. These prebiotics are considered as health-related but are not micronutrients because they are intended for consumption by protective bacteria in the colon and are specifically designed not be consumed by humans (Roberfroid, 2007). Hypoallergenic rice is another health-related feature. It involves down-regulation of genes encoding normal rice seed proteins that are allergenic, especially to workers in the rice products industry.

e. Pharming

Plant-made pharmaceuticals (PMPs) are becoming an important segment of the biotechnology industry because of their considerable advantages including ease of scale-up, low risk of pathogen contamination, eukaryotic protein processing systems for post-translational modification of proteins, and long-term product stability when the genes of interest are expressed in plant grains. A critical objective of PMP research is to increase the expression levels of recombinant protein in transgenic plants/tissues to meet the demands of commercialization. Two rice-based systems are currently employed: (i) cell culture derived from rice callus, and (ii) the endosperm of mature transgenic plants (Table 3). The microprojectile bombardment method is used to introduce the gene constructs into callus-derived cell culture, whereas both engineering methods are used to generate transformed plants. The work of Takagi et al. (2008) used the Agrobacterium-mediated method. Expression in cell culture is driven by the amylase RAmy 3D promoter, which is activated by removal of sugar from the medium. Endosperm-specific expression in whole plants is driven by the promoter of either a rice endoperm strorage protein (Glutelin1) or a wheat puroindoline protein (Tapur). Field cultivation of rice plants expressing recombinant human lactoferrin and human lysozyme is scheduled for 2010. A study in Peru by Zavaleta et al. (2007) found that addition of purified rice-derived recombinant human lactoferrin and human lysozyme to a rice-based oral rehydration solution had beneficial effects on children with acute diarrhea.

Table 3. A selection of human and other genes expressed in biotech rice cells or endosperm

Issues	Protein product	Promoter	Reference
Rice cell culture			
Tumor targeting	Secreted humanized fragment antibody	R*Amy3*D	Hong et al. 2008
Infant formula	Human 1-antitrypsin	R*Amy3*D	Terashima et al. 2001
Immunostimulus	Human granulocyte macrophage colony stimulating factor	R*Amy3*D	Shin et al. 2003
Cell maintenance	Serum albumin	R*Amy3*D	Huang et al. 2005
Cell growth	Human growth hormone	R*Amy3*D	Kim et al. 2008
Seed endosperm			
Iron deficiency	Human lactoferrin	Gt1	Bethell & Huang 2004
Diarrhoea	Human lactoferrin	Gt1	Bethell & Huang 2004
Diarrhoea	Human lysozyme	Tapur,Gt1	Hennegan et al. 2005
Cell growth	Human lactoferrin	Gt1	Huang et al. 2008
Immunostimulus	Human granulocyte macrophage colony stimulating factor	GluB-1	Sardana et al. 2007
Arthritis	Human collage peptides	Glutelin	Hashizume et al. 2008
Immunotherapy	Cholera toxin B subunit + cedar pollen antigens	GluB-1	Takagi et al. 2008
Vaccination	human cytomegalovirus glycoprotein B	Glutelin	Tackaberry et al 2008

f. Environmental protection

Many of the genes listed in Table 2 under yield potential or yield stability will make important contributions to environmental protection if they are deployed. For example, much of the damage caused by slash-and-burn agriculture in the uplands is due to the rapid loss of fertility of upland fields, forcing the poor farmers to cut down more of the forest. If upland rice cultivation were made more sustainable, the forest would be left intact. One key to sustainability in the uplands is likely to be nematode resistance. An alternative is to focus on "the lowlands in the uplands", that is, to confine rice cultivation to the valley bottoms, leaving the slopes for reforrestation. The lowlands in the uplands may require cold tolerance during flowering.

Rice production occurs in a wide range of cropping systems. They include a single rice crop per year, or as many as three rice crops per year, a crop rotation (e.g., rice-wheat, rice-legume, rice-shrimp), as well as irrigated, rainfed lowland, rainfed upland or deep-water. In general, the intensification of these systems in a sustainable manner is preferable to increasing the cultivated area through intrusion into forests and wetlands, but it is difficult to balance intensification and sustainability. Biotech rice already offers some components of a sustainable intensification system. Conservation agriculture has been defined as minimal soil disturbance (no-till) and permanent soil cover (mulch) combined with rotations (Hobbs et al. 2008). It is already clear that herbicide-tolerant crops are compatible with no-till agriculture and the accumulation of mulch (Duke and Powles, 2008) and a soybean-corn rotation using glyphosate-tolerant soybean and glufosinate-tolerant corn can reduce herbicide contamination of groundwater (Shipitalo et al. 2008) and address the problem of the appearance of herbicide-tolerant weeds or volunteers (Gressel and Valverde, 2009).

A similar system could be applied to the 13.5 Mha rice-wheat cropping system in the Indo-Gangetic Plain, which is shifting from transplanted rice to direct-seeded rice as a way of saving water and maintaining the productivity of wheat (Hobbs et al. 2008). Direct-seeded crops suffer much more from weeds than transplanted rice. However, this shift has increased the incidence of root-infesting nematodes, a problem seen also with aerobic rice which is another non-puddled production system (Kreye et al. 2009). A number of transgenic approaches to achieving nematode resistance hold promise (Fuller et al. 2008). The huge rice-rice cropping area in Asia is also shifting to direct seeding and could also benefit from nematode resistance. Thus, the major change of rice cultivation to direct seeding poses major new agronomic challenges for which biotech crops offer solutions, particularly in the form of substitutes for hand weeding, which is not possible in direct seeding.

g. Frontier projects

In the 1990s, IRRI developed a program to fix N_2 within the rice plant. Three approaches were considered: (i) Rhizobium-ready rice, (ii) transfer of a bacterial *nif* operon to the rice chloroplast genome, and (iii) diazotrophic endophytes. Only the third approach is being actively pursued. The concept is based on the situation with sugarcane in Brazil where unidentified endophytes supply fixed N to the crop (Boddey et al. 2003). The diazophyte that is the focus of attention in the rice study is Azoarcus strain BH72. Rice variety IR36 is colonized by strain BH72 as determined by nifH::gusA activity but sister variety IR42 produces a defense reaction (Miché et al. 2006). Jasmonic acid inhibits colonization. It is likely that some degree of genetic engineering of both host and endophyte will be needed to understand this relationship and determine how far it can contribute to N-nutrition in rice.

IRRI has recently expanded its C_4 rice program. The key concept is that C_4 crops such as maize are much more productive and N- and water-efficient than C_3 crops such as rice, and should be copied. C_4 crops have found a way of making the photosynthetic enzyme ribulose-1,5-bisphosphate carboxylase/oxygenase focus more on carboxylation (CO_2-fixation) than on the largely wasteful process of oxygenation (photorespiration). What are the genes required for C4 photosynthesis, and how can they be most effectively be transferred to rice? This question is discussed in more detail by Hibberd et al. (2008).

As many of the genes necessary for N_2-fixation and C_4 photosynthesis in rice have not yet been identified, it is not appropriate to refer to these projects in Table 2.

6. Biotech rice and poverty alleviation

Is biotech rice relevant to the poor? If so, are the costs associated with production, regulatory compliance and IP licensing of biotech rice likely to put these products out of their reach? We shall look at the first question by examining how many of the current biotech traits are likely to benefit the rural poor and the urban poor and whether these traits will help to achieve the UN's Millennium Development Goals. We shall look at the second question in Section 7.

Most of the health-related traits listed in Table 2 will contribute to eliminating micronutrient deficiencies, also known as hidden hunger. Although micronutrient deficiencies are known to extend to the general population on a seasonal basis, they are particularly severe among the poor. Micronutrient deficiencies in children affect them for their whole adult lives, whereas these deficiencies in pregnant women affect the next generation also. The presence of micronutrients in their staple food will bring life-long benefits to a large section of the population. Indeed, Anderson and Jackson (2004) concluded that most of the economic benefits of nutritionally enhanced biotech rice will come from the productivity increase among unskilled laborers.

Visible hunger, a shortage of calories in the diet, is particularly severe in the "hungry months" immediately before harvest. It is usually dealt with by governments through price interventions, release of buffer stocks and emergency imports. However, buffer stocks are currently low and the international rice price is high, so methods to increase the yield potential of hybrids and inbreds are essential to stave off shortages, particularly for urban consumers. Yield stability is more important for the rural poor who rely on their own or their neighbors' harvest. Pharming (Table 3) is also a potential method of ensuring that pharmaceuticals for dealing with diarrhea and other ailments reach those who need them cheaply and safely, without the need for refrigeration.

The UN's Millenium Development Goals are listed in Table 4. Rosegrant et al. (2006) noted that for most of the rural poor, agriculture is a critical component in the successful attainment of the MDGs. As about 70 percent of the MDGs' target group live in rural areas, particularly in Asia and Africa, improvements in the factor productivity and human nutritional qualities of rice are vital. Agriculture is particularly important for achieving MDG 1 but all MDGs have direct or indirect linkages with agriculture. MDG 2, on universal education, is often regarded as only indirectly linked to agriculture, but studies in drought-affected areas of eastern India and salinity-affected areas of Pakistan indicate that the education of children – particularly daughters – is liable to be disrupted by loss of family income through abiotic stresses (Pandey et al. 2000). Agriculture contributes to MDG 3 directly through the empowerment of women farmers and indirectly through reduction of the time burden on women for domestic tasks such as manual weeding. Agriculture contributes to reduced child mortality (MDG 4) indirectly by increasing diversity of food production and making more resources available to manage childhood illnesses. However, Bryce et al. (2005) anticipate direct reductions in the mortality of children up to 5 years in age through interventions that reduce the incidence of several major diseases, most prominent of which are diarrhea, and pneumonia, both of which are exacerbated by undernutrition. In addition, molecular pharming in rice has been used to produce seed expressing two recombinant human proteins (lactoferrin and lysozyme) useful in oral rehydration therapy for diarrhea (Bethall and Huang 2004, Zavaleta et al. 2007).

Table 4. Relevance of biotech rice traits to achieving the UN's Millennium Development Goals

No.	Millennium Development Goals	Relevance of agriculture and biotech rice
1	Eradicate extreme poverty and hunger	Economic growth, yield, nutrition
2	Achieve universal primary education	Yield stability, nutrition
3	Promote gender equality and empower women	Reduction in manual weeding
4	Reduce child mortality	Nutrition, oral rehydration for diarrhoea
5	Improve maternal health	Iron, zinc, vitamin A
6	Combat HIV/AIDS, malaria and other diseases	Nutrition, money for health care
7	Ensure environmental sustainability	Withdrawal from marginal land, sustainable intensification of favorable land
8	Develop a global partnership for development.	Public-private partnerships

7. Regulation of biotech rice

Will the cost of producing pro-poor biotech rice and the costs of regulatory compliance and IP licensing put these novel varieties out of the reach of the target consumers? The cost of regulatory compliance for biotech rice has become prohibitively expensive in the USA. Kalaitzandonakes et al. (2007) estimate the costs to range from US$7,060,000 to US$15,440,000 for Bt maize and from US$6,180,000 to US$14,510,000 for herbicide-tolerant maize. These costs and the difficulties associated with intellectual property protection of key steps in biotech rice production are major disincentives to pursuing the commercialization of biotech crops. However, the rice-growing countries of Asia are not obliged to raise such high hurdles. In this section and Section 8 we examine regulatory compliance and IP licensing in several countries, including China and India, to see if there is room for lowering costs to ensure that biotech rice reaches the poor.

AGBIOS (www.agbios.com) is a very useful site for articles and data on public policy, regulatory, and risk assessment expertise for products of biotechnology. Their website offers access to a database of safety information on all genetically modified plant products that have received regulatory approval, information on the implementation of biosafety systems, including case studies for food and environmental safety assessments, and a searchable library of biosafety-related citations in key topic areas. The following four subsections summarize salient points on biotech regulations for USA, European Union, Japan, China and India.

a. USA and Canada

The cloning of foreign DNA in *E. coli* was first reported by Cohen et al. (1973). The need for regulating this technology was discussed at the Asilomar Conference of 1975. The conference report outlined a peer-reviewed, risk-based regulatory system and recommended a moratorium on further research with the technology until specific guidelines had been put in place (Berg et al. 1975). NIH issued its *Guidelines for Research Involving Recombinant DNA Molecules* in 1976. They focused on the provision of appropriate levels of containment for different levels of perceived risk in research laboratories. The US government decided later that commercialization and environmental release of the products of recombinant DNA technology were to be regulated under existing legislation, with the Food and Drug Administration (FDA), the Animal and Plant Health Inspection Service (APHIS) and the Environmental Protection Agency (EPA) as the lead agencies.

APHIS began operating in 1987, four years after the first reports of successful production of biotech plants by European and US laboratories. Between 1987 and 1996, biotechnology companies and government regulators in the USA, Canada and Argentina discussed issues surrounding deregulation and commercial release of several biotech crops. Biotech soybean was first grown commercially in 1996, followed quickly by biotech maize, canola and cotton. The first approval of commercial production of biotech rice in the US was granted in 1999. It was for herbicide-tolerant rice (Liberty-Link LLRICE06 and LLRICE62). The herbicide was glufosinate ammonium with the active ingredient phosphinothrycin. The herbicide-tolerance gene encoded phosphinothrycin N-acetyltransferase from *Streptomyces hygroscopicus*. The Liberty-Link rice was intended for animal feed and human food but was withdrawn by Bayer. HealthCanada approved LLRICE62 as a food in 2006. USDA and FDA approved LLRICE601 in 2006. LLRICE06 was in a California long-grain cultivar M202, LLRICE62 was in Louisiana medium-grain cv Bengal and LLRICE601 was in Louisiana long-grain Cocodrie but these products were never commercialized.

b. Europe

European participants in the Asiolmar Conference of 1975 recommended that European national governments and the EEC itself should adapt the NIH guidelines to their own circumstances. Most national governments, including those of the UK, France and Germany, did so, but the EEC played an active role only after the mid-1980s when it became clear that EEC-wide regulations were needed to harmonize the marketing and deliberate release of recombinant DNA products within the Community. The Single European Act of 1987 gave enhanced prominence to environmental issues. The final draft directives on biotechnology had a strong environmental emphasis and came into force in 1990.

After the USA, Canada and Argentina approved the commercialization of biotech crops in 1996, the companies concerned applied to the European Commission for approval to import biotech seeds for processing or planting. Several approvals were issued, but in 1999 the European Union imposed a moratorium, which it justified by invoking the precautionary principle. One widely accepted statement of this ethical principle appeared as Principle 15 of the 1992 Rio Declaration on Environment and Development: "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." The moratorium lasted until 2004, when the World Trade Organization (WTO) upheld a challenge against the moratorium brought by the US. However, the moratorium has continued in other forms, owing in part to use of the national safeguard clauses and to an ongoing tussle between the European Commission and the Council of Ministers for predominance in decision making (Tiberghien 2009). The basis of that tussle may change significantly under the Treaty of Lisbon which was ratified by all member countries in 2009 and will come into force in 2010, but how biotech crops will emerge remains to be seen.

One continuing issue is the role of the European Food Safety Authority (EFSA). It was established in 2003 as an advisory body responsible for delivering scientific advice to EU institutions. Although EFSA has recommended the granting of import permits for several biotech crops over the last six years, the advice has usually been overruled by the Council of Ministers, which is not obliged to accept EFSA's assessments as binding (Szajkowska, 2009). However, a body of case law is accumulating in the European Court of Justice and the Court of First Instance that promises to enhance operational clarity. While the Council may override its own scientific advice, it must do so using scientific evidence at least as cogent as that provided by ESFA and similar bodies (De Sadeleer, 2006; Szajkowska, 2009). The Courts have already stated that they do not have the expertise to adjudicate between conflicting scientific assessments, prompting EFSA to broaden its consultations with environmentalists, risk-benefit experts and other stakeholders. The EU-funded SAFE FOODS project (2004-2008) aims to develop an improved risk governance framework for foods that explicitly incorporates stakeholder consultation, public participation, and risk–benefit assessment (Wentholt et al. 2009).

c. Japan

Industrialized countries attempted to harmonize their biosafety regulations through the publication of *Recombinant DNA: Safety Considerations* (OECD 1986). These guidelines put forward key safety concepts for development and commercialization of biotech crops. They included advice on risk assessment, agriculture and the environment, and how to build understanding of the behavior of the biotech plants.

Japan was one of the countries that used OECD guidelines to help the development of national regulations: for industry in 1986, for agriculture, forestry and fisheries in 1989, and for feed in 1992 (Hayashi 2006). In the case of agriculture, 114 biotech events in 16 crops were approved for cultivation in Japan, including low-allergen rice, low-protein rice and virus-resistant rice. However, all of the Japanese guidelines on environmental biosafety were terminated with the adoption of the Cartagena Protocol in 2003 and previously approved events and new events had to be evaluated under the new regulations. As of July 2006, the total number of approvals under the new protocols was 75, involving 25 of Japanese origin (USDA-FAS 2009).

Japan is the world's largest per capita importer of biotech foods and feeds, and has approved annual imports of ~16 million metric tons of corn and ~4.2 million metric ton of soybeans, both of which are mainly biotech crops. Japan also imports billions of dollars worth of processed foods that contain biotech-derived oils, sugars, yeasts, enzymes, and other ingredients. In spite of this, Japanese consumers remain wary about consuming biotech foods. In response, the Japanese government has over the years taken extensive regulatory measures to address public concerns, including mandatory biotech labeling.

In 2008, Agriculture, Forestry and Fisheries Research Council (AFFRC) published a report titled *Committee for the Research and Development Plan for GMO Crops*. The report lays out a goal that biotech events researched and developed in Japan will be grown, distributed and consumed in Japan. The report sets out a five year time line with the earliest product launch coming in 2012. The events for initial release would mostly come from Japanese public sector researchers. Traits could include high yield multi-disease resistant rice, drought tolerant rice and wheat, nutritionally altered rice and heavy metal accumulating rice (USDA-FAS, 2009). Industry sources estimate that a single food approval in Japan costs millions of dollars and can take up to three years. Since most of the likely products would have to be labeled, there would remain the possibility of consumer rejection.

d. China and India

China and India have gained most of their experience in regulating biotech crops through their growth of Bt cotton, which has been a success in both countries. China granted permits in 1997 to two transgenic events, one from Monsanto and the other from the Chinese public sector (Chinese Academy of Agricultural Sciences). India granted permits to Monsanto-MAHYCO in 2002. Pray et al. (2006) examined two issues in both countries: the cost of regulatory compliance and the effectiveness of enforcement. They found that costs were lower in China, probably because it was in the interest of the public sector participants to keep them low. Costs were higher in India because there was no government pressure to keep them low, although they were low by American standards, where regulatory compliance for a single event can cost in excess of US$6 million (Kalaitzandonakes et al. 2007). In relation to enforcement, a number of unlicensed, low-cost events were circulating in both countries. In China, the illegal events appeared to lack positive benefits and were easily controlled through farmers' choice. In India, the illegal events were probably as effective as those marketed by Monsanto-MAHYCO but were cheaper than the original, making eradication more difficult.

Keeley (2006) examined several issues related to governance of agricultural biotechnology in China. Two major concerns were (i) the clear limits on the degree of debate and transparency around controversial issues, and (ii) the roles of the state as promoter, producer and regulator of biotech crops. However, the state system is not a monolith; it is made up of different actors with their own expectations and responsibilities (Paarlberg and Pray, 2007). Their interactions with international actors may contribute to disagreements, encourage the system's natural tendency to grind to a halt through disagreements between and within government ministries, over such issues as the application of the precautionary principle in China.

The five stages of the Chinese regulatory system are based on decreasing levels of confinement and larger scale plantings, and have a strong environmental emphasis. It is far from clear how the system handles food safety issues. The announcement in 2009 that food safety laws will be strengthened provides an opportunity to include biotech crops in the new system. The key to progress may be three-fold: (i) to have a greater number of events flowing through the regulatory system, preferably from a number of different national, provincial and university research institutes and featuring novel events that require local regulators to make their own decisions; (ii) to simplify the allocation of responsibility among government departments for operating the system; and (iii) to promote private-sector analytical laboratories that use nationally mandated food safety tests that are subject to regular state oversight.

The Food Safety and Standards Authority of India (FSSAI) has been established under the Food Safety and Standards Act, 2006 as a statutory body for laying down science based standards for articles of food and regulating manufacturing, processing, distribution, sale and import of food so as to ensure safe and wholesome food for human consumption. In 2009, it was announced that FSSAI would assume responsibility for evaluating the food safety of biotech crops. It remains to be seen how FSSAI carries out their responsibility.

8. Intellectual property protection

In developing countries, rice research and seed distribution are largely in the public sector. When the private sector participates, it is mostly in hybrid seed research and production. A clear business plan can be built on the fact that farmers need to purchase fresh hybrid seed every season. Public sector scientists need to have access to information on IPP, whether as prospective patent holders or licensees. Three trends are emerging: (i) various agencies and journals are helping to educate public-sector scientists in IPP and how they can assess their freedom-to-operate, (ii) the public sector research institutes are engaging directly in IPP, and (iii) public-private cooperation is expanding.

a. IPP resources for the public sector

ISAAA was an early source of information on IPP, as illustrated by their commissioning Kryder et al. (2000) to prepare a freedom-to-operate review on Golden Rice. Atkinson et al. (2003) described a public sector consortium to improve access to agricultural IP needed to release new varieties for humanitarian purposes. Graff and Zilberman (2001) and Graff et al. (2003) discuss how an IP clearinghouse for agricultural biotechnology would operate and outline the IP covering a range of enabling technologies used in producing biotech crops. Li et al. (2010) summarize recent trends in how to search patent records for sequence information.

A major web-based resource for patent searches is Patent Lens (www.patentlens.net). It is provided free by Cambia (www.cambia.org). It describes how to achieve freedom-to-operate and allows database searches of 80 million nucleotide and protein sequences disclosed in patents. Patent Lens also features a series of patent landscapes for special topics including the rice genome, Agrobacterium-mediated transformation of plants, promoters, and selectable marker genes.

The Public Intellectual Property Resources for Agriculture (PIPRA, www.pipra.org) supports innovation in agriculture, health, water, and energy technologies. In collaboration with more than 50 universities and research centers and a *pro bono* attorney network, PIPRA provides services in the areas of intellectual property rights and commercialization strategy with the goal of increasing the impact of public sector innovation, particularly for developing countries and specialty markets. PIPRA's ipHandbook of Best Practices contains a range of important case studies, including those dealing with Golden Rice and Bt Eggplant in India.

b. Case study: Golden Rice

The IP aspects of Golden Rice are summarized at the website of the Golden Rice Project (http://www.goldenrice.org/Content2-How/how9_IP.html). The project is a public-private humanitarian partnership to which holders of IP for the enabling technologies have given royalty-free licenses under specific conditions. These IP holders included not only the inventors of Golden Rice (Ingo Potrykus and Peter Beyer) but also Syngenta Seeds AG, Bayer AG, Monsanto Co, Orynova BV, and Zeneca Mogen BV. A freedom-to-operate review conducted for Golden Rice by Kryder et al. (2000) provided unique insights into the diversity of the owners of Proprietary Property connected with production of biotech rice. Proprietary Property consists of Intellectual Property (e.g., patent rights, plant variety protection certificates, trade secrets, research results) and technical property (e.g., germplasm, computer software, plasmids and information). Many of the items of proprietary property were invented in the public sector and either retained by them or licensed to the private sector. The 15 technical property items associated with Golden Rice related to the construction and use of three transformation vectors (one for each gene: phytoene synthase, phytoene desaturase, and lycopene cyclase) and many other processes and components. There were 44 intellectual property items, almost all of which were patents that had been granted in the USA and most European countries; 21 of the patents had also been granted in Japan. By contrast, no more than 11 items would apply in the 10 top rice-producing countries and the 10 top rice-importing countries.

c. Public-private collaboration in China and India

In 1997, China granted commercial licenses to two Bt cotton technologies, one developed by Monsanto and the other developed by the Chinese Academy of Agricultural Sciences (CAAS). Both technologies were marketed and licensed through local seed companies. The Chinese Academy of Sciences (CAS) developed a novel glyphosate-resistance gene in rice through directed evolution (Zhou et al. 2006). This modified gene was jointly patented in China and the USA by CAS and Sichuan Biotech Engineering Ltd and was exclusively licensed to Origin Biotechnology, a wholly owned subsidiary of China's third largest seed company, Origin Agritech Ltd. Origin Biotechnology has the right to develop and sell corn, soybean, rice, cotton and canola products that contain this gene worldwide. Origen Agritech Ltd has also licensed technology from CAAS for production of phytase maize as an animal food.

India approved the commercialization of Bt cotton in 2001 and Bt eggplant in 2009. The IP issues surrounding Bt cotton were dealt with by a partnership between Monsanto and the local seed company MAHYCO. USAID funded a rather different arrangement for Bt eggplant: MAHYCO sub-licensed Monsanto's technology on a royalty-free basis to five public research institutes, three in India and one each in Bangladesh and the Philippines (Medakker and Vijayaraghavan, 2007).

9. Conclusions

There are no technical impediments to the widespread adoption of biotech rice by rice-growing countries. Recombinant DNA technology and methods for generating biotech rice are widely available. Indeed, over the next decade the efficiency of biotech rice production may see further increases, with the likely introduction of (i) floral spray inoculation of Agrobacterium to avoid tissue culture, (ii) homologous recombination to insert genes in a targeted rather than random manner, and (iii) plastome transformation to permit alteration of key photosynthetic genes in the chloroplast. In addition, enormous improvements will be made in our understanding of the function of rice genes, not only individually but also within the networks that control key aspects of plant behavior. There are, however, several potential impediments arising from regulation of biotech crops in the major rice-growing countries.

a. Regulatory impediments to the adoption of biotech rice

The two major rice-growing countries, China and India, are currently modernizing rapidly across all sectors including agriculture, to the obvious satisfaction and benefit of their citizens. Biotech rice is likely to meet with public approval if it contributes to food security and is supported by transparent, rigorous, focused and independent evaluation of food safety and environmental protection.

It is currently difficult to judge how well the Chinese and Indian regulatory systems are operating. They would benefit from more transparency in devising and costing the tests for food safety and environmental protection. At present there is great reliance on data already assembled overseas for well-established biotech traits. While that is not a problem in itself, it means that some areas in regulatory oversight are not yet adequately developed. Homegrown biotech rice with novel traits will be helpful in this context. It is to be hoped that China and India introduce simplified regulatory systems for (i) cis-genes, (ii) stacked genes, and (iii) introgression of genes into multiple varieties to avoid monoculture and recognize the ecological diversity of rice. Costs of regulation should be kept at a level that would maintain the integrity of the process while allowing the public sector to make a strong contribution to biotech crops.

b. Benefits of biotech rice

Rice production employs about 0.5 billion people and feeds another 2.5 billion, including 0.7 billion below the poverty line. It also occupies 157 Mha. This situation creates huge opportunities for rice science to contribute to human health and livelihoods, poverty alleviation, and environmental protection. Many of the benefits will come through improved crop management and conventional breeding, but many will come from focused applications of biotech rice. Health benefits will come from two biotech applications that cannot be achieved through conventional breeding: increasing the micronutrient content of polished rice and generating safe, cheaper pharmaceuticals through rice pharming. A major challenge that may be more easily achieved through biotech rice than any other approach is to fine-tune key components of the complex networks connecting genotype to phenotype to enhance yield potential and yield stability in already popular varieties. Among the changes that will be given high priority are those that will help to mitigate and adapt to global climate change, which is expected to be most adverse in the tropics. Finally, the biotech approach will be essential to confer on rice the traits of endophytic N-supply and C_4 photosynthesis.

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References

Albar L, M Bangratz-Reyser, E Hébrard, MN Ndjiondjop, M Jones and A Ghesquière. 2006. Mutations in the eIF(iso)4G translation initiation factor confer high resistance of rice to Rice yellow mottle virus. Plant J. 47(3): 417-426.

Ammiraju JS, M Luo, Jl Goicoechea, W Wang, D Kudrna, C Mueller, J Talag, H Kim, NB Sisneros, B Blackmon, E Fang, JB Tomkins, D Brar, D MacKill, S McCouch, N Kurata, G Lambert, DW Galbraith, K Arumuganathan, K Rao, JG Walling, N Gill, Y Yu, P SanMiguel, C Soderlund, S Jackson and RA Wing. 2006. The Oryza bacterial artificial chromosome library resource: construction and analysis of 12 deep-coverage large-insert BAC libraries that represent the 10 genome types of the genus Oryza. Genome Res. 2006 Jan;16(1):140-7.

Anderson K and L Jackson. 2005. Some implications of GM food technology policies for sub-Saharan Africa. J Af Economies. 14: 385-410.

Ashikari M, S Hakakibara, S Lin, T Yamamoto, T Takashi, A Nishimura, ER Angeles, Q Qian, K Hitano and M Matsuoka. 2005. Cytokinin oxidase regulates rice grain production. Science. 309: 741-745.

Atkinson RC, RN Beachy, G Conway, FA Cordova, MA Fox, KA Holbrook, DF Klessig, RL McCormick, PM McPherson, HR Rawlings III, R Rapson, LN Vanderhoef, JD Wiley and CE Young. 2003. Intellectual Property Rights: Public Sector Collaboration for Agricultural IP Management. Science. 301: 174-175.

Avery OT, CM MacLeod, M McCarty. 1944. Studies on the chemical nature of the substance inducing transformation of pneumococcal types. Induction of transformation by a desoxyribonucleic acid fraction isolated from Pneumococcus Type III. J Exp Med. 79:137–158

Berg P, D Baltimore, S Brenner, RO Roblin III and MR Singer. 1975. Summary Statement of the Asilomar Conference on Recombinant DNA Molecules. Proc. Nat. Acad. Sci. USA. 72(6): 1981-1984.

Bernier JJ, GN Atlin, R Serraj, Kumar A and D Spaner. 2008. Breeding upland rice for drought resistance. Journal of the Science of Food and Agriculture. 88: 927-939.

Bethell DR and J Huang. 2004. Recombinant human lactoferrin treatment for global health issues: iron deficiency and acute diarrhea. Biometals. 17(3): 337-342.

Bevan MW, RB Flavell, MD Chilton. 1983. A chimaeric antibiotic resistance gene as a selectable marker for plant cell transformation. Nature. 304: 184–187.

Bi YM, S Kant, J Clark, S Gidda, F Ming, J Xu, A Rochon, BJ Shelp, L Hao, R Zhao, RT Mullen, T Zhu and SJ Rothstein. 2009. Increased nitrogen-use efficiency in transgenic rice plants over-expressing a nitrogen-responsive early nodulin gene identified from rice expression profiling. Plant Cell Environ. 32: 1749-1760.

Boddey RMS, B Urquiaga, JR Alves and Veronica Reis. 2003. Endophytic nitrogen fixation in sugarcane: present knowledge and future applications. Plant and Soil. 252: 139-149.

Bouis HE. 2003. Micronutrient fortification of plants through plant breeding: can it improve nutrition in man at low cost? Proc Nutr Soc. 62(2): 403-411.

Brar DS and GS Khush. 1997. Alien introgression in rice. Plant Mol Biol. 35(1-2): 35-47.

Brookes G and P Barfoot. 2009. Global Impact of Biotech Crops: Income and Production Effects, 1996-2007. AgBioForum, 12(2): 184-208.

Bryce J, C Boschi-Pinto, K Shibuya and RE Black. 2005. WHO estimates of the causes of death in children. WHO Child Health Epidemiology Reference Group. 365(9465): 1147-1152.

Buell CR, Q Yuan, S Ouyang, J Liu, W Zhu, A Wang, R Maiti, B Haas, J Wortman, M Pertea, KM Jones, M Kim, L Overton, T Tsitrin, D Fadrosh, J Bera, B Weaver, S Jin, S Johri, M Reardon, K Webb, J Hill, K Moffat, L Tallon, S Van Aken, M Lewis, T Utterback, T Feldblyum, V Zismann, S Iobst, J Hsiao, AR de Vazeille, SL Salzberg, O White, C Fraser, Y Yu, H Kim, T Rambo, J Currie, K Collura, S Kernodle-Thompson, F Wei, K Kudrna, JS Ammiraju, M Luo, JL Goicoechea, RA Wing, D Henry, R Oates, M Palmer, G Pries, C Saski, J Simmons, C Soderlund, W Nelson, M de la Bastide, L Spiegel, L Nascimento, E Huang, R Preston, T Zutavern, L Palmer, A O'Shaughnessy, S Dike, WR McCombie, P Minx, H Cordum, R Wilson, W Jin, HR Lee, J Jiang and S Jackson. 2005. Sequence, annotation, and analysis of synteny between rice chromosome 3 and diverged grass species. Rice Chromosome 3 Sequencing Consortium. Genome Res. 15(9): 1284-1291.

Cahoon EB, SE Hall, KG Ripp, TS Ganzke, WD Hitz and SJ Coughlan. 2003. Metabolic redesign of vitamin E biosynthesis in plants for tocotrienol production and increased antioxidant content. Nat Biotechnol. 21(9): 1082-1087.

Calpe C. 2004. International Trade in Rice, Recent Developments and Prospects. www.fao.org/es/esc/en/15/70/81/highlight_79.html

Chen J, J Ding, Y Ouyang, H Du, J Yang, K Cheng, J Zhao, S Qiu, X Zhang, J Yao, K Liu, L Wang, C Xu, X Li, Y Xue, M Xia, Q Ji, J Lu, M Xu and Q Zhang. 2008b. A triallelic system of S5 is a major regulator of the reproductive barrier and compatibility of indica-japonica hybrids in rice. Proc Natl Acad Sci USA. 105(32): 11436-11441.

Chen JQ, XP Meng, Y Zhang, M Xia and XP Wang. 2008a. Over-expression of OsDREB genes lead to enhanced drought tolerance in rice. Biotechnol Lett. 30: 2191-2198.

Cheng, X, R Sardana, H Kaplan, and I Altosaar. 1998. Agrobacterium transformed rice plants expressing synthetic *cry1Ab* and *cry1Ac* genes are highly toxic to striped stem borer and yellow stem borer. Proc. Natl. Acad. Sci. USA. 95: 2767-2772.

Christou P, TL Ford and M Kofron. 1992. The development of a variety-independent gene-transfer method for rice. Trends Biotechol 10: 239-246

Christou P. 1997. Rice transformation: bombardment. Plant Mol Biol. 35: 197-203

Clough SJ and AF Bent. 1998. Floral dip: a simplified method for Agrobacterium-mediated transformation of Arabidopsis thaliana. Plant J. 16(6): 735-743.

Cohen SN, AC Chang, HW Boyer and RB Helling. 1973. Construction of biologically functional bacterial plasmids in vitro. Proc Natl Acad Sci USA. 70(11): 3240–3244.

Collard BC and DJ Mackill. 2008. Marker-assisted selection: an approach for precision plant breeding in the twenty-first century. Philos Trans R Soc Lond B Biol Sci. 363(1491): 557-72.

Dai S, X Wei, AA Alfonso, L Pei, UG Duque, Z Zhang, GM Babb and RN Beachy. 2008. Transgenic rice plants that overexpress transcription factors RF2a and RF2b are tolerant to rice tungro virus replication and disease. Proc Natl Acad Sci USA. 105(52): 21012-21016.

Datta K, N Baisakh, N Oliva, L Torrizo, E Abrigo, J Tan, M Rai, S Rehana, S Al-Babili, P Beyer, I Potrykus and SK Datta. 2003. Bioengineered 'golden' indica rice cultivars with beta-carotene metabolism in the endosperm with hygromycin and mannose selection systems. Plant Biotechnol J. 1(2): 81-90.

Datta K, J Tu, N Oliva, I Oña, R Velazhahan, TW Mew, S Muthukrishnan and SK Datta. 2001. Enhanced resistance to sheath blight by constitutive expression of infection-related rice chitinase in transgenic elite indica rice cultivars. Plant Sci. 160(3): 405-414.

Davis AM, A Hall, AJ Millar, C Darrah and SJ Davis. 2009. Protocol: Streamlined sub-protocols for floral-dip transformation and selection of transformants in *Arabidopsis thaliana*. Plant Methods. 27(5): 3.

De Sadeleer N. 2006. The precautionary principle in EC health and environment law. European Law Journal. 12(2): 139-172.

Diédhiou CJ, OV Popova, KJ Dietz and D Golldack. 2008. The SNF1-type serine-threonine protein kinase SAPK4 regulates stress-responsive gene expression in rice. BMC Plant Biol. 28(8): 49.

Doi K, H Yasui and A. Yoshimura. 2008. Genetic variation in rice. Curr Opin Plant Biol. 2008 11(2): 144-148.

Duan X, X Li, Q Xue, M Abo-el-Saad, D Xu and R Wu. 1996. Transgenic rice plants harboring an introduced potato proteinase inhibitor II gene are insect resistant. Nat Biotechnol. 14(4): 494-498.

Duke SO and SB Powles. 2008. Glyphosate: a once-in-a-century herbicide. Pest Manag Sci. 64: 319-325.

Endo M, K Osakabe, K Ono, H Handa, T Shimizu and S Toki. 2007. Molecular breeding of a novel herbicide-tolerant rice by gene targeting. Plant J. 52(1): 157-166.

Evenson RE and D Gollin. 2003. Assessing the Impact of the Green Revolution, 1960 to 2000. Science. 300(5620): 758-762.

Foissac X, N Thi Loc, P Christou, AM Gatehouse and JA Gatehouse. 2000. Resistance to green leafhopper (*Nephotettix virescens*) and brown planthopper (*Nilaparvata lugens*) in transgenic rice expressing snowdrop lectin (*Galanthus nivalis* agglutinin; GNA). J Insect Physiol. 46(4): 573-583.

Fraley RT, SG Rogers, RB Horsch, PR Sanders, JS Flick, SP Adams, ML Bittner, LA Brand, CL Fink, JS Fry, GR Galluppi, SB Goldberg, NL Hoffmann and SC Woo. 1983. Expression of bacterial genes in plant cells. Proc Natl Acad Sci USA. 80: 4803-4807.

Frisvold GB, JM Reeves and R Tronstad. 2006. Bt cotton adoption in the united states and China: international trade and welfare effects. AgBioForum. 9(2): 69-78.

Fukao T, K Xu, PC Ronald and J Bailey-Serres. 2006. A variable cluster of ethylene response factor–like genes regulates metabolic and developmental acclimation responses to submergence in rice. Plant Cell. 18: 2021-2034.

Fuller VL, CJ Lilley and PE Urwin. 2008. Nematode resistance. New Phytol. 180: 27-44.

Ganesan U, SS Suri, S Rajasubramaniam, MV Rajam and I Dasgupta. 2009. Transgenic expression of coat protein gene of Rice tungro bacilliform virus in rice reduces the accumulation of viral DNA in inoculated plants. Virus Genes. 39(1): 113-119.

Gomi K, M Satoh, R Ozawa, Y Shinonaga, S Sanada, K Sasaki, M Matsumura, Y Ohashi, H Kanno, K Akimitsu and J Takabayashi. 2009. Role of hydroperoxide lyase in white-backed planthopper (*Sogatella furcifera* Horváth)-induced resistance to bacterial blight in rice, *Oryza sativa* L. Plant J. Sep 26.

Graff G and Zilberman D. 2001. An intellectual property clearinghouse for agricultural biotechnology. Nat Biotechnol. 19(12): 1179-1180.

Graff GD, SE Cullen, KJ Bradford, D Zilberman and AB Bennett. 2003. The public-private structure of intellectual property ownership in agricultural biotechnology. Nat Biotechnol. 21(9): 989-995.

Gressel J and BE Valverde. 2009. A strategy to provide long-term control of weedy rice while mitigating herbicide resistance transgene flow, and its potential use for other crops with related weeds. Pest Manag Sci. 65: 723-731.

Hashizume F, S Hino, M Kakehashi, T Okajima, D Nadano, N Aoki and T Matsuda. 2008. Development and evaluation of transgenic rice seeds accumulating a type II-collagen tolerogenic peptide. Transgenic Res. 17(6): 1117-1129.

Hayashi K. 2006. The Japanese experience with the Blue Book and subsequent activities in environmental biosafety of GM crops. Environ. Biosafety Res. 5(4): 237-238

Hennegan K, DC Yang, D Nguyen, LY Wu, J Goding, JM Huang, FL Guo, N Huang and S Watkins. 2005. Improvement of human lysozyme expression in transgenic rice grain by combining wheat (*Triticum aestivum*) puroindoline b and rice (*Oryza sativa*) Gt1 promoters and signal peptides. Transgenic Res. 14: 583-592.

Herrera-Estrella L, M De Block, E Messens, JP Hernalsteens, M Van Montagu and J Schell. 1983. Chimeric genes as dominant selectable markers in plant cells. EMBO J. 2: 987-995.

Hibberd JM, Sheehy JE and JA Langdale. 2008. Using C4 photosynthesis to increase the yield of rice-rationale and feasibility. Curr Opin Plant Biol. 11(2): 228-231.

Hiei, Y, S Ohta, T Komari and T Kumashiro. 1994. Efficient transformation of rice (*Oryza sativa*) mediated by *Agrobacterium* and sequence analysis of the boundaries of the T-DNA. Plant J. 6: 271-282.

Hiei Y and T Komari. 2006. Improved protocols for transformation of indica rice mediated by *Agrobacterium tumefaciens.* Plant cell, Tissue Organ Culture. 85: 271-283.

Hobbs PR, K Sayre and R Gupta. 2008. The role of conservation agriculture in sustainable agriculture. Philos Trans R Soc Lond B Biol Sci. 363: 543-55.

Hu H, J You, Y Fang, Z Xhu, Z Qi and L Xiong. 2008. Characterization of transcription factor gene SNAC2 conferring cold and salt tolerance in rice. Plant Mol Biol. 2008 67(1-2): 169-181.

Hong SY, TS Lee, J Kim, JH Jung, CW Choi, TG Kim, TH Kwon, YS Jang and MS Yang. 2008. Tumor targeting of humanized fragment antibody secreted from transgenic rice cell suspension culture. Plant Mol Biol. 68(4-5): 413-422.

Huang N, D Bethell, C Card, J Cornish, T Marchbank, D Wyatt, K Mabery and R Playford. 2008. Bioactive recombinant human lactoferrin, derived from rice, stimulates mammalian cell growth. In Vitro Cell Dev Biol Anim. 44(10): 464-471.

Huang LF, YK Liu, CA Lu, SL Hsieh and SM Yu. 2005. Production of human serum albumin by sugar starvation induced promoter and rice cell culture. Transgenic Res. 14: 569-581.

Huet H, S Mahendra, J Wang, E Sivamani, CA Ong, L Chen, RN A de Kochko, RN Beachy, and C Fauquet. 1999. Near immunity to rice tungro spherical virus achieved in rice by a replicase-mediated resistance strategy. Phytopathology. 89(11): 1022-1027.

Ito Y, K Katsura, K Maruyama, T Taji, M Kobayashi, M Seki, K Shinozaki and K Yamaguchi-Shinozaki. 2006. Functional analysis of rice DREB1/CBF-type transcription factors involved in cold-responsive gene expression in transgenic rice. Plant Cell Physiol. 47(1): 141-153.

Jacobsen E and HJ Schouten. 2009. Cisgenesis: an important sub-invention for traditional plant breeding companies. Euphytica. 170: 235-247.

James C. 2008. Global Status of Commercialized Biotech/GM Crops: 2008. ISAAA Brief No. 39. ISAAA: Ithaca, NY.

Jennings PR. 1964. Plant type as a rice breeding objective. Crop Sc. 4: 13-15.

Jones MP, M Dingkuhn, GK Aluko and M Semon. 1997. Interspecific *Oryza sativa* L. x *O. glaberrima* Steud. progenies in upland rice improvement. Euphytica. 92: 237-246.

Jongdee B, G Pantuwan, S Fukai and K Fischer. 2006. Improving drought tolerance in rainfed lowland rice: An example from Thailand. Agricultural Water Management. 80(1-3): 225-240.

Jung KH, G An and PC Ronald. 2008. Towards a better bowl of rice: assigning function to tens of thousands of rice genes. Nat Rev Genet. 9: 91-101.

Kalaitzandonakes N, JM Alston and KJ Bradford. 2007. Compliance costs for regulatory approval of new biotech crops. Nat Biotechnol. 25(5): 509-511.

Kanzaki H, S Nirasawa, H Saitoh, M Ito, M Nishihara, R Terauchi and I Nakamura. 2002. Overexpression of the wasabi defensin gene confers enhanced resistance to blast fungus (*Magnaporthe grisea*) in transgenic rice. Theor Appl Genet. 105(6-7): 809-814.

Karaba A, S Dixit, R Greco, A Aharoni, KR Trijatmiko, N Marsch-Martinez, A Krishnan, KN Nataraja, M Udayakumar and A Pereira. 2007. Improvement of water use efficiency in rice by expression of HARDY, an Arabidopsis drought and salt tolerance gene. Proc Natl Acad Sci USA. 104(39): 15270-15275.

Kawakami A, Y Sato and M Yoshida. 2008. Genetic engineering of rice capable of synthesizing fructans and enhancing chilling tolerance. J Exp Bot. 59(4): 793-802.

Katiyar-Agarwal S, M Agarwal and A Grover. 2003. Heat-tolerant basmati rice engineered by over-expression of hsp101. Plant Mol Biol. 51(5): 677-686.

Keeley J. 2006. Balancing technological innovation and environmental regulation: an analysis of Chinese agricultural biotechnology governance. Environmental Politics. 15: 293-309.

Khush GS. 1999. Green revolution: Preparing for the 21st century. Genome 42(4): 646-655.

Kim TG, MY Baek, EK Lee, TH Kwon and MS Yang. 2008. Expression of human growth hormone in transgenic rice cell suspension culture. Plant Cell Rep. 27(5): 885–891.

Kreye C, BAM Bouman, A Castañeda, R Lampayan, JE Faronilo, AT Lactaoen and L Fernandez. 2009. Possible causes of yield failure in tropical aerobic rice. Field Crops Research. 111: 197-206.

Krishnan A, E Guiderdoni, G An, YI Hsing, CD Han, MC Lee, SM Yu, N Upadhyaya, S Ramachandran, Q Zhang, V Sundaresan, H Hirochika, H Leung and A Pereira. 2009. Mutant resources in rice for functional genomics of the grasses. Plant Physiol. 149(1):165-70.

Kryder DR, SP Kowalski and AF Krattiger. 2000 The intellectual and technical property components of pro-vitamin A rice (Golden Rice): a preliminary freedom-to-operate review. In International Service for the Acquisition of Agri-biotech Applications (ISAAA) Brief No. 20. ISAAA, Ithaca, NY. Pp. 68.

Lee S and G An. 2009. Over-expression of OsIRT1 leads to increased iron and zinc accumulations in rice. Plant, Cell and Environment 32: 408–416

Lee SM, K Kang, H Chung, SH Yoo, XM Xu, SB Lee, JJ Cheong, H Daniell and M Kim. 2006. Plastid transformation in the monocotyledonous cereal crop rice (Oryza sativa) and transmission of transgenes to their progeny. Mol Cells 21: 401-410.

Lentini Z, I Lozano, E Tabares, L Fory, J Domínguez, M Cuervo and L Calvert. 2003. Expression and inheritance of hypersensitive resistance to rice hoja blanca virus mediated by the viral nucleocapsid protein gene in transgenic rice. Theor Appl Genet. 106(6): 1018-1026.

Li C, J Qiu, S Frolking, X Xiao, W Salas, B Moore III, S Boles, Y Huang and R Sass. 2002. Reduced methane emissions from large-scale changes in water management in China's rice paddies during 1980–2000, Geophys. Res. Lett. 29 (20): 1972, doi:10.1029/2002GL015370

Li W, HC McWilliam, AR de la Torre, A Grodowski, I Benediktovich, M Goujon, S Nauche and R Lopez. 2010. Non-redundane patent sequence databases with value-added annotations at two levels. Nucleic Acids Research. 38(D):52-56.

Lowe BA, N Shiva Prakash, Way, MT Mann, TM Spencer and RS Boddupalli. 2009. Enhanced single copy integration events in corn via particle bombardment using low quantities of DNA. Transgenic Res. 18: 831-40.

Lucca P, R Hurrell and I Potrykus. 2002. Fighting iron deficiency anemia with iron-rich rice. J Am Coll Nutr. 21(3 Suppl): 184S-190S.

Mackill DJ, WR Coffman and DP Garrity. 1996. Rainfed lowland rice improvement. International Rice Research Institute, Los Baños. Philippines.

Miché L, B Federico, G Sabrina, B Maya and B Reinhold-Hurek. 2006. Upregulation of jasmonate-inducible defense proteins and differential colonization of roots of *Oryza sativa* cultivars with the endophyte *Azoarcus* sp. Molec. Plant-Microbial Interactions. 19: 502–511.

Maliga P. 2004. Plastid transformation in higher plants. Annu Rev Plant Biol. 55: 289-313.

Manosalva PM, RM Davidson, B Liu, X Zhu, SH Hulbert, H Leung and JE Leach. 2009. A germin-like protein gene family functions as a complex quantitative trait locus conferring broad-spectrum disease resistance in rice. Plant Physiol. 149: 286-296.

Matsukura S, J Mizoi, T Yoshida, D Todaka, Y Ito, K Maruyama, K Shinozaki and K Yamaguchi-Shinozaki. 2010. Comprehensive analysis of rice *DREB2*-type genes that encode transcription factors involved in the expression of abiotic stress-responsive genes. Mol Genet Genomics. 2010 Jan 5. [Epub ahead of print].

Mayer JE, WH Pfeiffer and P Beyer. 2008. Biofortified crops to alleviate micronutrient malnutrition. Curr Opin Plant Biol. 11(2): 166-170.

McNally KL, KL Childs, R Bohnert, RM Davidson, K Zhao, VJ Ulat, G Zeller, RM Clark, DR Hoen, TE Bureau, R Stokowski, DG Ballinger, KA Frazer, DR Cox, B Padhukasahasram, CD Bustamante, D Weigel, DJ Mackill, RM Bruskiewich, G Rätsch, CR Buell, H Leung and JE Leach. 2009. Genomewide SNP variation reveals relationships among landraces and modern varieties of rice. Proc Natl Acad Sci USA. 106(30): 12273-12278.

Medakker A and V Vijayaraghavan. 2007. Successful Commercialization of Insect-Resistant Eggplant by a Public–Private Partnership: Reaching and Benefiting Resource-Poor Farmers. In Intellectual Property Management in Health and Agricultural Innovation: A Handbook of Best Practices (eds. A Krattiger, RT Mahoney, L Nelsen, et al.). MIHR: Oxford, U.K., and PIPRA: Davis, USA. pp 1829-1831.

Miki D, R Itoh and K Shimamoto. 2005. RNA silencing of single and multiple members in a gene family of rice. Plant Physiol. 138: 1903-13.

Mitsuda N, K Hiratsu, D Todaka, K Nakashima, K Yamaguchi-Shinozaki and M Ohme-Takagi 2006. Efficient production of male and female sterile plants by expression of a chimeric repressor in Arabidopsis and rice. Plant Biotechnol J. 4(3): 325-332.

Morinaka Y, T Sakamoto, Y Inukai, M Agetsuma, H Kitano, M Ashikari and M Matsuoka. 2006. Morphological alteration caused by brassinosteroid insensitivity increases the biomass and grain production of rice. Plant Physiol. 141(3): 924-931.

Naqvi S, C Zhu, G Farre, K Ramessar, L Bassie, J Breitenbach, D Perez Conesa, G Ros, G Sandmann, T Capell and P Christou. 2009. Transgenic multivitamin corn through biofortification of endosperm with three vitamins representing three distinct metabolic pathways. Proc Natl Acad Sci USA. 106: 7762-7767.

Neeraja CN, R Maghirang-Rodriguez, A Pamplona, S Heuer, BCY Collard, EM Septiningsih, G Vergara, D Sanchez, K Xu, AM Ismail and DJ Mackill. 2007. A marker-assisted backcross approach for developing submergence-tolerant rice cultivars. Theoretical and Applied Genetics. 115: 767-776.

OECD. 1986. Recombinant-DNA: Safety Considerations, Paris: OECD. 74 pp.

Oh SJ, YS Kim, CW Kwon, HK Park, JS Jeong and JK Kim. 2009. Overexpression of the transcription factor AP37 in rice improves grain yield under drought conditions. Plant Physiol. 150(3): 1368-1379.

Ohta M, Y Hayashi, A Nakashima, A Hamada, A Tanaka, T Nakamura and T Hayakawa. 2002. Introduction of a Na+/H+ antiporter gene from *Atriplex gmelini* confers salt tolerance to rice. FEBS Lett. 532(3): 279-82.

Ouyang YD, JJ Chen, JH Ding and QF Zhang. 2009. Advances in the understanding of inter-subspecific hybrid sterility and wide-compatibility in rice. Chinese Sci Bull. 54: 2332-2341, doi: 10.1007/s11434-009-0371-4.

Paarlberg R and C Pray. 2007. Political actors on the landscape. AgBioForum, 10(3): 144-153.

Pandey S, DD Behura, R Villano and D Naik. 2000. Economic costs of drought and farmers' coping mechanisms: a study of rainfed rice systems in eastern India. International Rice Research Institute (IRRI) Discussion Paper Series 39, IRRI, Los Baños, Philippines.

Pandey S. 2008. The true price of rice. Rice Today (January-March) pp. 36-37

Pathaka H and R Wassmann. 2007. Introducing greenhouse gas mitigation as a development objective in rice-based agriculture: I. Generation of technical coefficients. Agricultural Systems. 94: 807-825.

Peng S, GS Khush, P Virk, Q Tang and YB Zou. 2008. Progress in ideotype breeding to increase rice yield potential. Field Crops Research. 108: 32-38.

Pinheiro B da S, E da M de Castro and CM Guimarães. 2006. Sustainability and profitability of aerobic rice production in Brazil. Field Crops Research. 97: 34-42.
Pisani D, JA Cotton and JO McInerney. 2007. Supertrees disentangle the chimerical origin of eukaryotic genomes. Mol Biol Evol. 24, 1752-1760.
Pray CE, B Ramaswami, J Huang, R Hu, P Bengali and H Zhang. 2006. Costs and enforcement of biosafety regulation in India and China. Int. J. Technology and Globalisation. 2: 137-157.
Raney T. 2006. Economic impact of transgenic crops in developing countries. Curr Opin Biotechnol. 17(2): 174-178.
Rao IM, RS Zeigler, R Vera and S Sarkarung. 1993. Selection and Breeding for Acid-Soil Tolerance in Crops. BioScience. 43(7): 454-465.
Rathore KS, VK Chowdhury and TK Hodges. 1993. Use of *bar* as a selectable marker gene and for the production of herbicide-resistant rice plants from protoplasts. Plant Mol Biol. 21(5): 871-874.
Remacle C, P Cardol, N Coosemans, M Gaisne and N Bonnefoy. 2006. High-efficiency biolistic transformation of Chlamydomonas mitochondria can be used to insert mutations in complex I genes. Proc Natl Acad Sci USA. 103(12): 4771-4776.
Rivero RM, M Kojima, A Gepstein, H Sakakibara, R Mittler, S Gepstein and E Blumwald. 2007. Delayed leaf senescence induces extreme drought tolerance in a flowering plant. Proc Natl Acad Sci USA. 104(49): 19631-19636.
Roberfroid MB. 2007. Prebiotics: The concept revisited. J Nutr. 137: 830S.
Rosegrant MW, C Ringler, T Benson, X Diao, D Resnick, J Thurlow, M Torero and D Orden. 2006. Agriculture and Achieving the Millennium Development Goals. International Food Policy Research Institute, Washington. pp 1-9.
Sakuma Y, K Maruyama, Y Osakabe, F Qin, M Seki, K Shinozaki and K Yamaguchi-Shinozaki. 2006. Functional analysis of an Arabidopsis transcription factor, DREB2A, involved in drought-responsive gene expression. Plant Cell. 18(5): 1292-1309.
Salekdeh GH, M Reynolds, J Bennett and J Boyer. 2009. Conceptual framework for drought phenotyping during molecular breeding. Trends Plant Sci. 14(9): 488-96.
Salvi S, G Sponza, M Morgante, D Tomes, X Niu, KA Fengler, R Meeley, EV Ananiev, S Svitashev, E Bruggemann, B Li, H CF ainey, S Radovic, G Zaina, JA Rafalski, Tingey, GH Miao, RL Phillips and R Tuberosa. 2007. Conserved noncoding genomic seq SV uences associated with a flowering-time quantitative trait locus in maize. Proc Natl Acad Sci USA. 104(27): 11376-11381.
Sardana R, AK Dudani, E Tackaberry, Z Alli, S Porter, K Rowlandson, P Ganz and I Altosaar. 2007. Biologically active human GM-CSF produced in the seeds of transgenic rice plants. Transgenic Res. 16(6): 713-721.
Sarkarung S. 1995. Shuttle breeding for rainfed lowland rice improvement. In: K.T. Ingram (Ed.), Rainfed Lowland Rice Agricultural Research for High Risk Environments, IRRI, Manila, Philippines. pp. 119–126.
Savary S, L Willocquet, FA Elazegui, N P Castilla and PS Teng. 2000. Rice pest constraints in tropical Asia: Quantification of yield losses due to rice pests in a range of production situations. Plant Dis. 84: 357-369.
Septiningsih EM, AM Pamplona, DL Sanchez, CN Neeraja, GV Vergara, S Heuer, AM Ismail and DJ Mackill. 2009. Development of submergence-tolerant rice cultivars: the Sub1 locus and beyond. Ann Bot. 103: 151-60.
Shao M, J Wang, RA Dean, Y Lin, X Gao and S Hu. 2008. Expression of a harpin-encoding gene in rice confers durable nonspecific resistance to *Magnaporthe grisea*. Plant Biotechnol. J. 6: 73–81.
Shin YJ, SY Hong, TH Kwon, YS Jang and MS Yang. 2003. High level of expression of recombinant human granulocyte-macrophage colony stimulating factor in transgenic rice cell suspension culture. Biotechnol Bioeng. 82: 778-783.
Shipitalo MJ, RW Malone and LB Owens. 2008. Impact of glyphosate-tolerant soybean and glufosinate-tolerant corn production on herbicide losses in surface runoff. J Environ Qual. 37: 401-408.
Shrawat AK and H Lörz. 2006. Agrobacterium-mediated transformation of cereals: a promising approach crossing barriers. Plant Biotechnol J. 4: 575-603.

Shrawat AK, RT Carroll, M DePauw, GJ Taylor and AG Good. 2008. Genetic engineering of improved nitrogen use efficiency in rice by the tissue-specific expression of alanine aminotransferase. Plant Biotechnol J. 6(7): 722-732.
Singh S, JK Ladha, RK Gupta, L Bhushan and AN Rao. 2008. Weed management in aerobic rice systems under varying establishment methods. Crop Protection 27: 660-671.
Singla-Pareek SL, SK Yadav, A Pareek, MK Reddy and SK Sopory 2007. Enhancing salt tolerance in a crop plant by overexpression of glyoxalase II. Transgenic Res. 17(2): 171-80.
Skamnioti P and SJ Gurr. 2009. Against the grain: safeguarding rice from rice blast disease. Trends Biotechnol. 27(3): 141-150.
Smidansky ED, JM Martin, LC Hannah, AM Fischer, MJ Giroux. 2003. Seed yield and plant biomass increases in rice are conferred by deregulation of endosperm ADP-glucose pyrophosphorylase. Planta. 216(4): 656-64.
Stalker DM, WT Hyatt and L Comai. 1985. A single amino acid substitution in the enzyme 5-enolpyruvlshikimate-3-phosphate synthase confers resistance to the herbicide glyphosate. J. Biol. Chem. 260: 4724-4728.
Stein AJ and E Rodríguez-Cerezo. 2009. The global pipeline of new GM crops: introduction to the database. Luxembourg: Office for Official Publications of the European Communities. http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=2199
Stewart CN Jr, MJ Adang, JN All, HR Boerma, G Cardineau, D Tucker and WA Parrott. 1996. Genetic transformation, recovery, and characterization of fertile soybean transgenic for a synthetic *Bacillus thuringiensis cryIAc* gene. Plant Physiol. 112: 121-129.
Svab Z, P Hajdukiewicz and P Maliga. 1990. Stable transformation of plastids in higher plants. Proc Natl Acad Sci USA. 87(21): 8526-8530.
Sweeney M and S McCouch. 2007. The complex history of the domestication of rice. Ann Bot. 100(5): 951-957.
Szajkowska A. 2009. From mutual recognition to mutual scientific opinion? Constitutional framework for risk analysis in EU food safety law. Food Policy 34: 529-538.
Tackaberry ES, FA Prior, K Rowlandson, M Tocchi, J Mehic, S Porter, M Walsh, MR Schleiss, PR Ganz, RK Sardana, I Altosaar and AK Dudani. 2008. Sustained expression of human cytomegalovirus glycoprotein B (UL55) in the seeds of homozygous rice plants. Mol Biotechnol. 40: 1-12.
Tada Y, M Nakase, T Adachi, R Nakamura, H Shimada, M Takahashi, T Fujimura and T Matsuda. 1996. Reduction of 14-16 kDa allergenic proteins in transgenic rice plants by antisense gene. FEBS Lett. 391(3): 341-345.
Takagi H, T Hiroi, L Yang, K Takamura, R Ishimitsu, H Kawauchi and F Takaiwa. 2008. Efficient induction of oral tolerance by fusing cholera toxin B subunit with allergen-specific T-cell epitopes accumulated in rice seed. Vaccine. 26(48): 6027-6030.
Tao Z, H Liu, D Qiu, Y Zhou, X Li, C Xu and S Wang. 2009. A pair of allelic WRKY genes play opposite roles in rice-bacteria interactions. Plant Physiol. 151(2): 936-948.
Terashima M, Y Ejiri, N Hashikawa and H Yoshida. 2001. Utilization of an alternative carbon source for efficient production of human alpha (1)-antitrypsin by genetically engineered rice cell culture. Biotechnol Prog. 17: 403-406.
Tiberghien Y. 2009. Competitive Governance and the Quest for Legitimacy in the EU: the Battle over the regulation of GMOs since the mid-1990s',Journal of European Integration. 31:(3)389- 407.
Timmer CP. 2009. Reflections on food crises past. Food Policy 2. October 17, 2009.
Toriyama K, Y Arimoto, H Uchimiya and K Hinata. 1988. Transgenic rice plants after direct gene transfer into protoplasts. Bio/Tech 6: 1072-1074.
USDA-FAS. 2009. http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biotechnology%20Report_Tokyo_Japan_6-12-2009.pdf.
Virmani SS. 1994. Heterosis and Hybrid Rice Breeding. Springer-Verlag, New York. 106 pp.
Wade LJ, CG McLaren, L Quintana, D Harnpichitvitaya, S Rajatasereekul, AK Sarawgi, A Kumar, HU Ahmed,

AK Singh Sarwoto, R Rodriguez, J Siopongco, and S Sakarung. 1999. Genotype by environment interactions across diverse rainfed lowland rice environments. Field Crops Res. 64: 35-50.

Wang E, J Wang, X Zhu, W Hao, L Wang, Q Li, L Zhang, W He, B Lu, H Lin, H Ma, G Zhang and Z He. 2008. Control of rice grain-filling and yield by a gene with a potential signature of domestication. Nat Genet. 40(11): 1370-1374.

Wang Y, E Kuroda, M Hirano and T Murata. 1997. Analysis of high yielding mechanism of rice varieties belonging to different plant types. I. Comparison of growth and yield characteristics and dry matter production. Jpn. J. Crop Sci. 66: 293-299.

Wang YM, ZY Dong, ZJ Zhang, XY Lin, Y Shen, D Zhou and B Liu. 2005. Extensive de Novo genomic variation in rice induced by introgression from wild rice (Zizania latifolia Griseb.). Genetics. 170(4): 1945-56.

Warthmann N, H Chen, S Ossowski, D Weigel and P Hervé. 2008. Highly specific gene silencing by artificial miRNAs in rice. PLoS One. 3(3): 1829.

Wentholt MTAa, G Rowe, A König, HJP Marvin, LJ Frewer. 2009. The views of key stakeholders on an evolving food risk governance framework: Results from a Delphi study. Food Policy. 34 (2009): 539-548.

White PJ and MR Broadley. 2009. Biofortification of crops with seven mineral elements often lacking in human diets--iron, zinc, copper, calcium, magnesium, selenium and iodine. New Phytol. 182(1): 49-84.

Wu CY, A Trieu, P Radhakrishnan, SF Kwok, S Harris, K Zhang, J Wang, J Wan, H Zhai, S Takatsuto, S Matsumoto, S Fujioka, KA Feldmann and RI Pennell. 2008. Brassinosteroids regulate grain filling in rice. Plant Cell. 20: 2130-2145.

Xiao B, Y Huang, N Tang and L Xiong. 2007. Over-expression of a LEA gene in rice improves drought resistance under the field conditions. Theor Appl Genet. 115: 35-46.

Xiao BZ, X Chen, CB Xiang, N Tang, QF Zhang and LZ Xiong. 2009. Evaluation of seven function-known candidate genes for their effects on improving drought resistance of transgenic rice under field conditions. Mol Plant. 2: 73-83.

Xu K, X Xu, T Fukao, P Canlas, R Maghirang-Rodriguez, S Heuer, AM Ismail, J Bailey-Serres, PC Ronald and DJ Mackill. 2006. Nature. 442: 705-708.

Yamauchi T, Y Johzuka-Hisatomi, S Fukada-Tanaka, R Terada, I Nakamura and Iida S. 2009. Homologous recombination-mediated knock-in targeting of the MET1a gene for a maintenance DNA methyltransferase reproducibly reveals dosage-dependent spatiotemporal gene expression in rice. Plant J. 60(2): 386-396.

Yarasi B, V Sadumpati, CP Immanni, DR Vudem and VR Khareedu. 2008. Transgenic rice expressing A*llium sativum* leaf agglutinin (ASAL) exhibits high-level resistance against major sap-sucking pests. BMC Plant Biol. 14(8): 102.

Yuan LP. 2002. The second generation of hybrid rice in China. In: Sustainable rice production for food security Proceedings of the 20th session of the International Rice Commission. Bangkok, Thailand. 23-26 July 2002.

Zale JM, S Agarwal, S Loar and CM Steber. 2009. Evidence for stable transformation of wheat by floral dip in Agrobacterium tumefaciens. Plant Cell Rep. 28(6): 903-913.

Zavaleta N, D Figueroa, J Rivera, J Sánchez, S Alfaro and BJ Lönnerdal. 2007. Efficacy of rice-based oral rehydration solution containing recombinant human lactoferrin and lysozyme in Peruvian children with acute diarrhea. Pediatr Gastroenterol Nutr. 44: 258-264.

Zhang HM, H Yang, EL Rech, TJ Golds, AS Davis, BJ Mulligan, EC Cocking and MR Davey. 1988. Transgenic rice plants produced by electroporation-mediated plasmid uptake into protoplasts. Plant Cell Rep. 7: 379-384.

Zhou M, H Xu, X Wei, Z Ye, L Wei, W Gong, Y Wang and Z Zhu. 2006. Identification of a glyphosate-resistant mutant of rice 5-enolpyruvylshikimate 3-phosphate synthase using a directed evolution strategy. Plant Physiol. 140: 184-195.

Zhu QH, NM Upadhyaya, F Gubler and CA Helliwell. 2009. Over-expression of miR172 causes loss of spikelet determinacy and floral organ abnormalities in rice. BMC Plant Biol. 9: 149.

Appendix 1

Global Status of Regulatory Approvals*

* This is an overview of the global status of regulatory approvals for import for food and feed use and for release into the environment through December 2009. Regulatory approval processes for biotech products vary from country to country and therefore, countries should be consulted for specific details.

Appendix 1. Global Status of Regulatory Approvals

Compiled by M. Escaler, ISAAA 2006; RR Aldemita, ISAAA 2007, 2008, 2009

ARGENTINA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Cotton	*Gossypium hirsutum* L.	HT	MON1445	Monsanto Company	2001	✓	2001		
Cotton	*Gossypium hirsutum* L.	IR	MON531	Monsanto Company	1998	✓	1998		
Cotton	*Gossypium hirsutum* L.	IR/HT	Mon 531 x Mon 1445	Monsanto Company	2009	✓		2009	2009
Maize	*Zea mays* L.	HT	T14,T25	Bayer CropScience	1998	✓	1998		
Maize	*Zea mays* L.	HT	GA21	Monsanto Company	2005	✓	2005		
Maize	*Zea mays* L.	HT	NK603	Monsanto Company	2004	✓	2004		
Maize	*Zea mays* L.	HT + IR	176	Syngenta Seeds	1996	✓	1998		
Maize	*Zea mays* L.	HT + IR	Bt11	Syngenta Seeds	2001	✓	2001		
Maize	*Zea mays* L.	IR	MON810	Monsanto Company	1998	✓	1998		
Maize	*Zea mays* L.	IR	DBT 418	DeKalb Genetics Corporation	1998				
Maize	*Zea mays* L.	HT + IR	TC1507	Mycogen (Dow AgroSciences); Pioneer (Dupont)	2005	✓	2005		
Maize	*Zea mays* L.	IR + HT	MON-ØØ6Ø3-6 x MON-ØØ81Ø-6	Monsanto Company	2007	✓	2005		
Maize	*Zea mays* L.	IR + HT	MON-ØØ15Ø7-1 x MON-ØØ6Ø3-6	Dow Agro Sciences Inc	2008	✓	2006		
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company	1996	✓	1996		

AUSTRALIA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Alfalfa	*Medicago sativa*	HT	MonØØ1Ø1-8 x Mon -ØØ163-7 (J101 x J163)	Monsanto Co. & Forage Genetics International				2007	
Argentine Canola	*Brassica napus*	HT	HCN92	Bayer CropScience	2003	✓		2002	
Argentine Canola	*Brassica napus*	HT	T45 (HCN28)	Bayer CropScience	2003	✓	2002		
Argentine Canola	*Brassica napus*	HT	GT73,RT73	Monsanto Company	2003	✓		2000	
Argentine Canola	*Brassica napus*	HT + F	MS1, RF1 PGS1	Bayer CropScience	2003	✓	2002		
Argentine Canola	*Brassica napus*	HT + F	MS1, RF2 PGS2	Bayer CropScience	2003	✓	2002		
Argentine Canola	*Brassica napus*	HT + F	MS8xRF3	Bayer CropScience	2003	✓	2002		
Argentine Canola	*Brassica napus*	HT	OXY 235	Bayer CropScience				2002	
Carnation	*Dianthus caryophyllus*	DR	66	Florigene Pty Ltd.	1995	✓			
Carnation	*Dianthus caryophyllus*	FC	4, 11, 15, 16	Florigene Pty Ltd.	1995	✓			
Carnation	*Dianthus caryophyllus*	FC + HT	Moonlite (123.2.38)	Florigene Pty Ltd.	2007	✓			
Carnation	*Dianthus caryophyllus*	FC + HT	Moonshade (123.2.2)	Florigene Pty Ltd.	2007	✓			
Carnation	*Dianthus caryophyllus*	FC + HT	Moonshadow 11363	Florigene Pty Ltd.	2007	✓			
Carnation	*Dianthus caryophyllus*	FC + HT	Moonvista (123.8.8)	Florigene Pty Ltd.	2007	✓			
Cotton	*Gossypium hirsutum* L.	IR	COT102	Syngenta Seeds				2005	
Cotton	*Gossypium hirsutum* L.	HT + IR	MON-ØØ531-6 x MON-Ø1445-2	Monsanto Company	2003	✓			
Cotton	*Gossypium hirsutum* L.	IR	DAS-21Ø23-5 x DAS-24236-5	Dow AgroSciences LLC				2005	
Cotton	*Gossypium hirsutum* L.	HT	MON1445	Monsanto Company	2000	✓		2000	
Cotton	*Gossypium hirsutum* L.	IR	MON15985	Monsanto Company	2002	✓		2002	
Cotton	*Gossypium hirsutum* L.	IR	MON531	Monsanto Company	1996	✓		1996	1996
Cotton	*Gossypium hirsutum* L.	HT	BXN	Calgene Inc.			2002		
Cotton	*Gossypium hirsutum* L.	HT	MON88913	Monsanto Company	2006	✓		2006	
Cotton	*Gossypium hirsutum* L.	HT + IR	MON88913/15985	Monsanto Company	2006	✓			
Cotton	*Gossypium hirsutum* L.	HT + IR	MON15985/1445	Monsanto Company	2006	✓			

<u>LEGEND</u>

HT	Herbicide Tolerance
IR	Insect Resistance
VR	Virus Resistance
FC	Modified flower color
DR	Delayed ripening/altered shelf life
Oil Content	Modified oil content
Lys	Enhanced Lysine content
NIC	Nicotine reduction
F	Fertility restored
CPP	Cedar pollen peptide
Plt Quality	Mod Amylase
Flav Path	Flavonoid Biosynthetic Pathway
*	The product has been approved for planting/cultivation but it is not necessarily in commercial production at present

Sources:
http://www.agbios.com
http://www.fas.usda.gov/itp/biotech/countries.html
http://www.ogtr.gov.au
http://www.mhlw.go.jp/english/topics/food/pdf/sec01-2.pdf
http://www.bch.biodic.go.jp
http://www.gmo-compass.org
http://www.bpi.da.gov.ph
http://bch.biodiv.org

AUSTRALIA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Cotton	*Gossypium hirsutum* L.	HT	LLCotton25	Bayer CropScience				2006	
Cotton	*Gossypium hirsutum* L.	IR	SYN-IR67B-1 (COT67B)	Syngenta Seeds				2009	
Cotton	*Gossypium hirsutum* L.	HT	BCS-GHØØ2-5 (GHB614)	Bayer Crop Science				2009	
Cotton	*Gossypium hirsutum* L.	IR/HT	Widestrike	Dow Agro Sciences Au	2009	✓			2009
Maize	*Zea mays* L.	HT + IR	TC1507	Mycogen (Dow AgroSciences); Pioneer (Dupont)				2003	
Maize	*Zea mays* L.	HT	T25	Bayer CropScience			2002		
Maize	*Zea mays* L.	HT	GA21	Monsanto Company				2000	
Maize	*Zea mays* L.	HT	NK603	Monsanto Company				2002	
Maize	*Zea mays* L.	HT + IR	176	Syngenta Seeds			2001		
Maize	*Zea mays* L.	HT + IR	Bt11	Syngenta Seeds			2001		
Maize	*Zea mays* L.	HT + IR	DBT418	Dekalb Genetics Corporation				2002	
Maize	*Zea mays* L.	IR	MON810	Monsanto Company				2000	
Maize	*Zea mays* L.	IR	MON863	Monsanto Company				2003	
Maize	*Zea mays* L.	HT + IR	DAS-59122-7	Dow AgroSciences LLC/Pioneer				2005	
Maize	*Zea mays* L.	HT + IR	MON88017	Monsanto Company				2006	
Maize	*Zea mays* L.	IR	MIR604	Syngenta Seeds				2006	
Maize	*Zea mays* L.	Lys	REN-ØØØ38-3 (LY038)	Monsanto Company			2007		
Maize	*Zea mays* L.	Plt Quality	Event 3272	Syngenta Seeds			2008		
Maize	*Zea mays* L.	IR	MIR162	Syngenta Seeds			2009		
Potato	*Solanum tuberosum* L.	IR	ATBT04-6, ATBT04-27, ATBT04-30, ATBT04-31, ATBT04-36, SPBT02-5, SPBT02-7	Monsanto Company			2001		
Potato	*Solanum tuberosum* L.	IR + VR	RBMT15-101, SEMT15-02, SEMT15-15	Monsanto Company			2001		
Potato	*Solanum tuberosum* L.	IR + VR	RBMT21-129, RBMT21-350, RBMT22-082	Monsanto Company			2001		
Soybean	*Glycine max* L.	HT	A2704-12, A2704-21, A5547-35	Aventis Crop Science				2004	
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company				2000	
Soybean	*Glycine max* L.	Oil content	G94-1, G94-19, G168	DuPont Canada Agricultural Products				2000	
Soybean	*Glycine max* L.	HR	MON 89788	Monsanto			2008		
Sugar Beet	*Beta vulgaris*	HT	GTSB77	Novartis Seeds; Monsanto Company			2002		
Sugar Beet	*Beta vulgaris*	HT	H7-1	Monsanto Company				2005	
Rose	*Rosa hybrida*	MdFlwrCol	WKS82/130-4-1	Florigene/Japan Suntory	2009	✓			

BOLIVIA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company	2008	✓	2008		

BRAZIL

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Cotton	*Gossypium hirsutum* L.	IR	MON531/757/1076	Monsanto Company	2005	✓		2005	2005
Cotton	*Gossypium hirsutum* L.	HT	LL Cotton 25	Bayer CropScience	2008	✓		2008	2008
Cotton	*Gossypium hirsutum* L.	HT	CP4 EPSPS/NPT 11 (Mon 1445)	Monsanto Company	2008	✓	2008		
Cotton	*Gossypium hirsutum* L.	IR	Mon 15985 Bollgard II Cotton	Monsanto Company	2009	✓	2009		
Cotton	*Gossypium hirsutum* L.	IR/HT	event 281-24-236/3006-210-23 (Widestrike)	Dow Agro Sciences	2009	✓	2009		
Cotton	*Gossypium hirsutum* L.	IR/HT	Mon 531 x Mon 1445	Monsanto Company	2009	✓	2009		
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company	1998	✓		1998	1998
Maize	*Zea mays* L.	HT + IR	Cry1Ac/Cri1AB, Cry9c, mEPSPS, PAT, BAR	AVIPE					2005
Maize	*Zea mays* L.	HT	T14, T25	Bayer CropScience	2008	✓	2008		
Maize	*Zea mays* L.	IR	Mon 810	Monsanto Company	2008	✓	2008		
Maize	*Zea mays* L.	HT + IR	BT11	Syngenta Seeds Inc	2008	✓	2008		
Maize	*Zea mays* L.	HT	GA21	Monsanto Company	2008	✓	2008		
Maize	*Zea mays* L.	HT	NK 603	Monsanto Company	2008	✓	2008		
Maize	*Zea mays* L.	HT/IR	PAT/ cry1Fa2	Pioneer/Dow AgroSciences	2008	✓	2008		
Maize	*Zea mays* L.	IR	TC1507 (Herculex Corn)	Dow AgroSciences	2009	✓	2009		

BRAZIL

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Maize	*Zea mays* L.	IR/HT/HT	MIR162 corn	Syngenta Seeds	2009	✓	2009		
Maize	*Zea mays* L.	IR/HT/HT	MON 810 X NK 603	Monsanto Company	2009	✓	2009		
Maize	*Zea mays* L.	IR	Bt11 X GA21	Syngenta Seeds	2009	✓	2009		
Maize	*Zea mays* L.	IR	Mon 89034	Monsanto Company	2009	✓	2009		
Maize	*Zea mays* L.	IR/HT	TC1507 x NK603	Dow Agro Sciences	2009	✓	2009		

BURKINA FASO

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Cotton	*Gossypium hirsutum L.*	IR	MON 15985	Monsanto Company	2008	✓	2008		

CANADA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Alfalfa	*Medicago sativa*	HT	J101, J163	Monsanto Company and Forage Genetics International	2005			2005	2005
Argentine Canola	*Brassica napus*	HT	HCN10	Aventis Crop Science	1995	✓		1995	1995
Argentine Canola	*Brassica napus*	HT	HCN92	Bayer CropScience	1995	✓		1995	1995
Argentine Canola	*Brassica napus*	HT	T45 (HCN28)	Bayer CropScience	1996	✓		1997	1995
Argentine Canola	*Brassica napus*	HT	GT200	Monsanto Company	1996			1997	
Argentine Canola	*Brassica napus*	HT	GT73,RT73	Monsanto Company	1995	✓		1994	1995
Argentine Canola	*Brassica napus*	HT +F	MS1, RF1 PGS1	Aventis Crop Science	1995	✓		1995	1995
Argentine Canola	*Brassica napus*	HT +F	MS1, RF2 PGS2	Aventis Crop Science	1995	✓		1995	1995
Argentine Canola	*Brassica napus*	HT +F	MS8xRF3	Bayer CropScience	1996	✓		1997	1996
Argentine Canola	*Brassica napus*	Oil content	23-18-17,23-198	Calgene Inc.	1996	✓		1996	1996
Argentine Canola	*Brassica napus*	HT	OXY 235	Aventis Crop Science	1997	✓		1997	1997
Cotton	*Gossypium hirsutum* L.	IR	281-24-236	Dow AgroSciences LLC				2005	2005
Cotton	*Gossypium hirsutum* L.	IR	3006-210-23	Dow AgroSciences LLC				2005	2005
Cotton	*Gossypium hirsutum* L.	HT	MON1445/1698	Monsanto Company				1996	1996
Cotton	*Gossypium hirsutum* L.	IR	15985	Monsanto Company				2003	2003
Cotton	*Gossypium hirsutum* L.	IR	MON531/757/1076	Monsanto Company				1996	1996
Cotton	*Gossypium hirsutum* L.	HT	LLCotton 25	Bayer CropScience				2004	2004
Cotton	*Gossypium hirsutum* L.	HT	MON88913	Monsanto Company				2005	2005
Cotton	*Gossypium hirsutum* L.	HT + IR	31807 x 31808	Calgene Inc.				1998	
Cotton	*Gossypium hirsutum* L.	HT	BXN	Calgene Inc.				1996	1996
Cotton	*Gossypium hirsutum* L.	HT	BCS-GHØØ2-5 (GHB614)	Bayer CropScience				2009	2009
Flax, Linseed	*Linum usitatissimum* L.	HT	FP967	Univ of Saskatchewan	1996	✓		1998	1996
Maize	*Zea mays* L.	IR + HT	MON802	Monsanto Company	1997	✓		1997	1997
Maize	*Zea mays* L.	IR + HT	MON809	Pioneer Hi-Bred International Inc.	1996	✓		1996	1996
Maize	*Zea mays* L.	HT	B16 (DLL25)	Dekalb Genetics Corporation	1996	✓		1996	1996
Maize	*Zea mays* L.	HT	T14,T25	Bayer CropScience	1996	✓		1997	1996
Maize	*Zea mays* L.	HT	GA21	Monsanto Company	1998	✓		1999	1998
Maize	*Zea mays* L.	HT	MON832	Monsanto Company	1997	✓		1997	1997
Maize	*Zea mays* L.	HT	NK603	Monsanto Company	2001	✓		2001	2001
Maize	*Zea mays* L.	HT + F	MS3	Bayer CropScience	1996	✓		1997	1998
Maize	*Zea mays* L.	HT + IR	176	Syngenta Seeds	1996	✓		1995	1996
Maize	*Zea mays* L.	HT + IR	Bt11	Syngenta Seeds	1996	✓		1996	1996
Maize	*Zea mays* L.	HT + IR	DBT418	Dekalb Genetics Corporation	1997	✓		1997	1997
Maize	*Zea mays* L.	HT + IR	TC1507	Mycogen (c/o Dow AgroSciences); Pioneer (c/o Dupont)	2002	✓		2002	2002
Maize	*Zea mays* L.	IR	MON810	Monsanto Company	1997	✓		1997	1997
Maize	*Zea mays* L.	IR	MON863	Monsanto Company	2003	✓		2003	2003
Maize	*Zea mays* L.	HT + IR	MON88017	Monsanto Company	2006	✓		2006	2006
Maize	*Zea mays* L.	HT + IR	DAS-59122-7	Dow AgroSciences LLC/Pioneer	2005	✓		2005	2005
Maize	*Zea mays* L.	LYS	LY038	Monsanto Company	2006	✓		2006	2006
Maize	*Zea mays* L.	IR	DAS-06275-8	Dow AgroSciences LLC	2006	✓		2006	2006

CANADA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Maize	*Zea mays* L.	IR	SYN-IR6Ø4-5 (MIR604)	Syngenta Seeds Inc	2007	✓		2007	2007
Maize	*Zea mays* L.	IR	Mon 89034	Monsanto Company and Forage Genetics International	2008	✓			
Maize	*Zea mays* L.	Plt Qual	Event 3272	Syngenta Seeds	2008	✓		2008	2008
Maize	*Zea mays* L.	HT	DP 98140	Dupont/ PHI				2009	2009
Maize	*Zea mays* L.	IR/HT	Mon89034 x TC1507x Mon88017 x DAS59122-7	Monsanto	2009	✓		2009	2009
Papaya	*Carica papaya*	VR	55-1/63-1	Cornell University				2003	
Polish canola	*Brassica rapa*	HT	HCR-1	Bayer CropScience	1998	✓			1998
Polish canola	*Brassica rapa*	HT	ZSR500/502	Monsanto Company	1997	✓			1997
Potato	*Solanum tuberosum* L.	IR	ATBT04-6, ATBT04-27, ATBT04-30, ATBT04-31, ATBT04-36, SPBT02-5, SPBT02-7	Monsanto Company	1997	✓		1996	1997
Potato	*Solanum tuberosum* L.	IR	BT6, BT10, BT12, BT16, BT17, BT18, BT23	Monsanto Company	1995	✓		1995	1995
Potato	*Solanum tuberosum* L.	IR + VR	RBMT15-101, SEMT15-02, SEMT15-15	Monsanto Company	1999	✓		1999	1999
Potato	*Solanum tuberosum* L.	IR + VR	RBMT21-129, RBMT21-350, RBMT22-082	Monsanto Company	1999	✓		1999	1999
Rice	*Oryza sativa*	HT	LLRICE06, LLRICE62	Aventis Crop Science				2006	2006
Soybean	*Glycine max* L.	HT	ACS-GMØØ5-3 (A2704-12, A2704-21, A5547-35)	Aventis Crop Science	1999			2000	2000
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company	1995	✓		1996	1995
Soybean	*Glycine max* L.	HT	MON89788	Monsanto Company	2007	✓		2007	2007
Soybean	*Glycine max* L.	Oil content	G94-1, G94-19, G168	DuPont Canada Agricultural Products	2000	✓		2000	2000
Soybean	*Glycine max* L.	HT	DP356043	Pioneer Hi-bred				2009	2009
Soybean	*Glycine max* L.	High Oleic Acid	DP-305423-1	Pioneer Hi-bred	2009	✓		2009	2009
Soybean	*Glycine max* L.	HO/ HT	DP305423XGTS 40-30-2	Pioneer Hi-bred				2009	2009
Squash	*Cucurbita pepo*	VR	ZW20	Seminis Vegetable Seeds (Upjohn/Asgrow)				1998	
Squash	*Cucurbita pepo*	VR	CZW-3	Asgrow (USA); Seminis Vegetable Inc. (Canada)				1998	
Sugar Beet	*Beta vulgaris*	HT	H7-1	Monsanto Company	2005	✓		2005	2005
Sugar Beet	*Beta vulgaris*	HT	T120-7	Bayer CropScience	2001	✓		2000	2001
Tomato	*Lycopersicon esculentum*	DR	1345-4	DNA Plant Technology Corporation				1995	
Tomato	*Lycopersicon esculentum*	DR	B, Da, F	Zeneca Seeds				1996	
Tomato	*Lycopersicon esculentum*	DR	FLAVR SAVR	Calgene Inc.				1995	
Tomato	*Lycopersicon esculentum*	IR	5345	Monsanto Company				2000	
Wheat	*Tricitcum aestivum*	HT	BW 7	BASF	2007	✓		2007	2007

CHILE

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Argentine Canola	*Brassica napus*	HT	GT200	Monsanto Company	2007	✓			
Maize	*Zea mays* L.	IR + HT	Bt810	Monsanto Company	2007	✓			
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company	2007	✓			

CHINA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Argentine Canola	*Brassica napus*	HT	GT73, RT73	Monsanto Company			2004		
Argentine Canola	*Brassica napus*	HT	Topas 19/2 (HCN92)	Bayer Crop Science			2004		
Argentine Canola	*Brassica napus*	HT	MS1, RF1 PGS1	Bayer Crop Science			2004		
Argentine Canola	*Brassica napus*	HT	MS1, RF2 PGS2	Bayer Crop Science			2004		
Argentine Canola	*Brassica napus*	HT	MS8xRF3	Bayer CropScience			2004		
Argentine Canola	*Brassica napus*	HT	OXY 235	Bayer Crop Science			2004		
Argentine Canola	*Brassica napus*	HT	T45 (HCN28)	Bayer CropScience			2004		
Cotton	*Gossypium hirsutum* L.	IR	MON531/757/1076 (33B)	Monsanto Company	1997	✓		1997	1997
Cotton	*Gossypium hirsutum* L.	IR	Fusion Cry1ab/Cry1Ac (GK12)	Chinese Academy of Agricultural Sciences	1997	✓			
Cotton	*Gossypium hirsutum* L.	IR	CpTi/Bt (SGK321)	Chinese Academy of Agricultural Sciences	1999	✓			
Cotton	*Gossypium hirsutum* L.	HT	MON1445/1698	Monsanto Company			2004		
Maize	*Zea mays* L.	HT + IR	Bt11	Syngenta Seeds			2004		
Maize	*Zea mays* L.	HT	GA21	Monsanto Company			2004		

CHINA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Maize	*Zea mays* L.	IR	MON810	Monsanto Company			2004		
Maize	*Zea mays* L.	HT + IR	176	Syngenta Seeds			2004		
Maize	*Zea mays* L.	IR	MON863	Monsanto Company			2004		
Maize	*Zea mays* L.	HT	NK603	Monsanto Company			2005		
Maize	*Zea mays* L.	HT	T25	Bayer CropScience			2004		
Maize	*Zea mays* L.	HT + IR	TC1507	Mycogen (c/o Dow AgroSciences); Pioneer (c/o Dupont)			2004		
Maize	*Zea mays* L.	High Phytase	High Phytase	Origin Agritech	2009	✓			2009
Tomato	*Lycopersicon esculentum*	DR	D2 x A53 (Huafan No. 1)	Huazhong Agricultural University	1997	✓		1997	
Tomato	*Lycopersicon esculentum*	DR	Da Dong No.9	Institute of Microbiology, CAS	2000	✓		2000	
Tomato	*Lycopersicon esculentum*	VR	PK-TM8805R	Beijing University	1998	✓		1998	
Papaya	*Carica papaya*	VR		South China Agricultural University	2006	✓			
Petunia	*Petunia*	FC	CHS gene	Beijing University	1998	✓			
Poplar	*Populus nigra*	Bt		Research Institute of Forestry, Beijing, China	2005	✓			
Rice	*Oryza sativa*	Bt	cry IAC event in Huahui and Shanyou hybrid	Huazhong Agricultural Uni	2009			2009	2009
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company			2004		
Soybean	*Glycine max* L.	HT	Mon 89788	Monsanto Company				2008	2008
Sweet pepper	*Capsicum annuum*	VR	PK-SP01	Beijing University	1998	✓		1998	

COSTA RICA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Cotton	*Gossypium hirsutum* L.	IR	MON-00531-6	Monsanto Company	2009	✓			
Cotton	*Gossypium hirsutum* L.	IR	MON 15985-7	Monsanto Company	2009	✓			
Cotton	*Gossypium hirsutum* L.	IR/HT	MON-15985-7 x MON-01445-2	Monsanto Company	2009	✓			
Cotton	*Gossypium hirsutum* L.	IR/HT	MON-15985-7 x MON-88913-8	Monsanto Company	2009	✓			
Cotton	*Gossypium hirsutum* L.	IR/HT	MON-00531-6 x MON-01445-2	Monsanto Company	2009	✓			
Cotton	*Gossypium hirsutum* L.	HT	MON-01445-2	Monsanto Company	2009	✓			
Cotton	*Gossypium hirsutum* L.	HT	MON-88913-8	Monsanto Company	2009	✓			
Cotton	*Gossypium hirsutum* L.	IR	Widestrike	Dow Agro Sciences	2009	✓			
Cotton	*Gossypium hirsutum* L.	IR/HT	Widestrike x Mon 88913-8	Dow Agro Sciences	2009	✓			
Cotton	*Gossypium hirsutum* L.	IR	GEM 1 (T303-3 and T304-40	Bayer S.A., en Costa Rica	2009	✓			
Cotton	*Gossypium hirsutum* L.	HT	GHB614	Bayer S.A., en Costa Rica	2009	✓			
Cotton	*Gossypium hirsutum* L.	IR	SYN-IR102-7	Syngenta Seeds	2009	✓			
Cotton	*Gossypium hirsutum* L.	IR	SYN-IR67B-1	Syngenta Seeds	2009	✓			
Cotton	*Gossypium hirsutum* L.	IR/IR	SYN-IR102-7 X SYN-IR67B-1	Syngenta Seeds	2009	✓			
Cotton	*Gossypium hirsutum* L.	IR/IR	SYN-IR102-7 x SYN-IR67B-1 x MON-88913	Syngenta Seeds	2009	✓			
Cotton	*Gossypium hirsutum* L.	HT	Dicamba and Glufosinate	Monsanto Company	2009	✓			
Soybean	*Glycine max* L.	HT	MON89788	Monsanto Company	2009	✓			
Soybean	*Glycine max* L.	HT	MON-04032-6	Monsanto Company	2009	✓			

CZECH REPUBLIC

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Soybean	*Glycine max* L.	HR	Mon-Ø4Ø32-6	Monsanto Company				2001	2001
Maize	*Zea mays* L.	IR	MON 810	Monsanto Company	2005	✓	2005		2005

EL SALVADOR

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Maize	*Zea mays* L.	HT	NK603	Monsanto			2009		
Maize	*Zea mays* L.	IR/HT	NK603 x Mon 810	Monsanto			2009		
Maize	*Zea mays* L.	IR	TC1507	Dow AgroSciences/PHI			2009		

EUROPEAN UNION (27 MEMBER STATES)

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Argentine canola	*Brassica napus*	HT	TOPAS 19/2 (HCN 92)	AgrEvo				1997	1998
Argentine canola	*Brassica napus*	HT	MS1/RF2	Plant Genetic Systems	1997	✓		1997	1997
Argentine canola	*Brassica napus*	HT	MS1/RF1	Plant Genetic Systems	1996	✓		1997	1996
Argentine canola	*Brassica napus*	HT	GT73	Monsanto	2005			1997	1996
Argentine canola	*Brassica napus*	HT	T45	Bayer Crop Science				1998	1998
Argentine canola	*Brassica napus*	HT	MS8/RF3	Bayer Crop Science/ Plant Genetic Systems	2007		2007	1999	2000
Carnation	*Dianthus caryophyllus*	DR	66	Florigene Pty Ltd.	1998	✓			
Carnation	*Dianthus caryophyllus*	FC	4, 11, 15, 16	Florigene Pty Ltd.	1997	✓			
Carnation	*Dianthus caryophyllus*	FC	Moonlite (123.2.38) (Flo 40644-4)	Florigene Pty Ltd.	2007				
Carnation	*Dianthus caryophyllus*	FC	959A, 988A, 1226A, 1351A, 1363A, 1400A	Florigene Pty Ltd.	1998	✓			
Chicory	*Chichorium intybus*	HT + F	RM3-3, RM3-4, RM3-6	Bejo Zaden BV	1996	✓			
Cotton	*Gossypium hirsutum* L.	HT	1445	Monsanto				2002	1997
Cotton	*Gossypium hirsutum* L.	IR	531	Monsanto				2002	1996
Cotton	*Gossypium hirsutum* L.	IR + HT	531 x 1445	Monsanto				2005	2005
Cotton	*Gossypium hirsutum* L.	IR	15985	Monsanto Company				2005	2005
Cotton	*Gossypium hirsutum* L.	IR + HT	15985 x 1445	Monsanto				2005	2005
Cotton	*Gossypium hirsutum* L.	HT	LL 25	Bayer Crop Science			2008		
Maize	*Zea mays* L.	IR + HT	Bt 176	Syngenta Seeds	1997	✓		1997	1997
Maize	*Zea mays* L.	IR	MON810	Monsanto	2004	✓		1998	1998
Maize	*Zea mays* L.	HT	T25	AgrEvo	1998	✓		1998	1998
Maize	*Zea mays* L.	IR + HT	Bt11	Novartis				1998	1998
Maize	*Zea mays* L.	IR + HT	DAS-Ø15Ø7-1 x MON-ØØ6Ø3-6	DOW AgroSciences LLC	2007		2007		
Maize	*Zea mays* L.	HT	NK603	Monsanto				2004	2004
Maize	*Zea mays* L.	IR	MON863	Monsanto Company				2006	2005
Maize	*Zea mays* L.	HT	GA21	Monsanto Company			2008	2006	2006
Maize	*Zea mays* L.	HT + IR	DAS1507 (TC 1507)	Pioneer Hi-Bred International Inc.				2006	2005
Maize	*Zea mays* L.	HT + IR	NK603 X MON810	Monsanto Company				2005	2005
Maize	*Zea mays* L.	HT + IR	GA21 x MON810	Monsanto Company				2005	2005
Maize	*Zea mays* L.	IR	Mon 863 x Mon 810	Monsato Company					2005
Maize	*Zea mays* L.	HT + IR	Mon 863 x NK603	Monsanto				2005	2005
Maize	*Zea mays* L.	HT + IR	DAS 59122	Dow-AgroSciences / Pioneer Hybrid	2007		2007	2007	2007
Maize	*Zea mays* L.	IR/HT	DAS 59122 x NK603	Pioneer Hi-bred			2009		
Maize	*Zea mays* L.	IR/HT	Mon 88017	Monsanto			2009		
Maize	*Zea mays* L.	IR	Mon 89034	Monsanto			2009		
Maize	*Zea mays* L.	IR	MIR604	Syngenta Seeds			2009		
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company				1996	1996
Soybean	*Glycine max* L.	HT	Liberty Link A2704-12	Bayer Crop Science			2008		
Soybean	*Glycine max* L.	HT	Mon 89788	Monsanto Company				2008	2008
Sugar beet	*Beta vulgaris*	HT	KM 00071-4 (H7-1)	KWS SAAT AG / Monsanto			2008	2007	2007
Tobacco	*Nicotiana tabacum* L.	HT	C/F/93/08-02	Societe National d'Exploitation des Tabacs et Allumettes	1994	✓			

EGYPT

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Maize	*Zea mays* L.	IR	Mon 810	Monsanto Company	2008	✓		2008	

HONDURAS

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Maize	*Zea mays* L.	IR	MON810	Monsanto	2002	✓		2002	2002
Maize	*Zea mays* L.	HT	NK603	Monsanto Company	2008	✓			
Maize	*Zea mays* L.	IR	TC1507 (Herculex Corn)	Dow AgroSciences/PHI	2009	✓		2009	2009

INDIA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Cotton	*Gossypium hirsutum* L.	IR	MON531	Mahyco/Monsanto Company	2002	✓		2002	2002
Cotton	*Gossypium hirsutum* L.	IR	MON 15985	Mahyco/Monsanto Company	2006	✓		2006	2006
Cotton	*Gossypium hirsutum* L.	IR	GFM	Nath Seeds	2006	✓		2006	2006
Cotton	*Gossypium hirsutum* L.	IR	Event-1	JK Agrigenetics	2006	✓		2006	2006
Cotton	*Gossypium hirsutum* L.	IR	BNLA-601	CICR (ICAR) & UAS, Dharwad	2008	✓		2008	2008
Cotton	*Gossypium hirsutum* L.	IR	MLS-9124	Metahelix Life Sciences	2009	✓		2009	2009

INDONESIA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Cotton	*Gossypium hirsutum* L.	IR	MON531/757/1076	Monsanto Company	2001	✓			

IRAN

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Rice	*Oryza sativa*	IR	Tarom molaii + *cry1ab*	Agricultural Biotech Research Institute	2005	✓		2005	2005

JAPAN

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Alfalfa	*Medicago sativa*	HT	J101	Monsanto Company	2006	✓		2005	2006
Alfalfa	*Medicago sativa*	HT	J101 X J163	Monsanto Company	2006	✓		2005	2006
Alfalfa	*Medicago sativa*	HT	J163	Monsanto Company	2006	✓		2005	2006
Argentine Canola	*Brassica napus*	HT	HCN10	Bayer CropScience	1997			1997	1998
Argentine Canola	*Brassica napus*	HT	HCN92	Bayer CropScience	1996			1996	1996
Argentine Canola	*Brassica napus*	HT	T45 (HCN28)	Bayer CropScience	1997			1997	1997
Argentine Canola	*Brassica napus*	HT	GT73,RT73	Monsanto Company	1996	✓		1996	1996
Argentine Canola	*Brassica napus*	HT	MON89249-2 (GT200)	Monsanto Company	2006			2001	2001
Argentine Canola	*Brassica napus*	HT +F	MS1, RF1 PGS1	Bayer CropScience	1996			1996	1996
Argentine Canola	*Brassica napus*	HT +F	MS1, RF2 PGS2	Bayer CropScience	1997			1997	1997
Argentine Canola	*Brassica napus*	HT +F	MS8	Bayer CropScience	1998	✓		1997	1998
Argentine Canola	*Brassica napus*	HT +F	RF3	Bayer CropScience	1998	✓		1997	1998
Argentine Canola	*Brassica napus*	HT +F	MS8xRF3	Bayer CropScience	1998	✓		1997	1998
Argentine Canola	*Brassica napus*	HT + F	PHY35	Bayer CropScience	1997			2001	1998
Argentine Canola	*Brassica napus*	HT + F	PHY14	Bayer CropScience	1997			2001	1998
Argentine Canola	*Brassica napus*	HT + F	PHY23	Bayer CropScience	1997			2001	1999
Argentine Canola	*Brassica napus*	HT + F	PHY-36	Bayer CropScience	1997			1997	1997
Argentine Canola	*Brassica napus*	HT	OXY 235	Bayer CropScience	1998			1999	1999
Argentine Canola	*Brassica napus*	HT	ACS - BN007-1	Bayer CropScience	2007	✓		2007	2007
Carnation	*Dianthus caryophyllus* L.	HT	FLO-40689-6	Suntory Limited	2007	✓			
Carnation	*Dianthus caryophyllus* L.	FC	123.2.38, 123.2.2, 11363, 123.8.8	Florigene Pty Ltd.	2004	✓			
Cotton	*Gossypium hirsutum* L.	IR	DAS-21Ø23-5 x DAS-24236-5	Dow AgroSciences LLC			2005		
Cotton	*Gossypium hirsutum* L.	HT + IR	MON-15985-7 x MON-Ø1445-2	Monsanto Company			2005	2003	2003
Cotton	*Gossypium hirsutum* L.	HT	MON1445/1698	Monsanto Company	1997			1997	1998
Cotton	*Gossypium hirsutum* L.	IR	15985	Monsanto Company				2002	2003
Cotton	*Gossypium hirsutum* L.	HT	LLCotton 25	Bayer CropScience				2004	2006
Cotton	*Gossypium hirsutum* L.	IR	MON531/757/1076	Monsanto Company	1997			1997	1997
Cotton	*Gossypium hirsutum* L.	IR + HT	1445 X 531	Monsanto Company			2004	2003	2003
Cotton	*Gossypium hirsutum* L.	HT + IR	31807/31808	Calgene Inc.	1998			1999	1999
Cotton	*Gossypium hirsutum* L.	HT	BXN	Calgene Inc.	1997			1997	1998
Cotton	*Gossypium hirsutum* L.	HT	MON88913	Monsanto Company				2005	2006
Cotton	*Gossypium hirsutum* L.	IR	281 (DAS 24236-5)	Dow AgroSciences LLC				2005	
Cotton	*Gossypium hirsutum* L.	IR	SYN - IR67B-1	Syngenta Seeds Inc	2007	✓			
Cotton	*Gossypium hirsutum* L.	IR	SYN-IR102-7	Syngenta Seeds Inc	2007	✓			
Cotton	*Gossypium hirsutum* L.	IR	DAS-21Ø23-5 (3006-210-23)	Dow AgroSciences LLC				2005	

JAPAN

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Cotton	*Gossypium hirsutum* L.	HT + IR	281 X 3006 x 1445	Dow AgroSciences LLC				2006	
Cotton	*Gossypium hirsutum* L.	HT + IR	281 X 3006 X MON88913	Dow AgroSciences LLC				2006	
Cotton	*Gossypium hirsutum* L.	HT + IR	MON88913 X 15985	Monsanto Company				2005	2006
Cotton	*Gossypium hirsutum* L.	HT + IR	LLCotton25 x 15985	Bayer CropScience	2007			2006	2007
Maize	*Zea mays* L.	HT + IR	ACS-ZMØØ3-2 (T25) x MON-ØØ81Ø-6	Bayer CropScience	2005	✓	2003		
Maize	*Zea mays* L.	HT + IR	MON-ØØ6Ø3-6 x MON-ØØ81Ø-6	Monsanto Company	2004	✓	2004		
Maize	*Zea mays* L.	HT + IR	MON-ØØ863-5 x MON-ØØ6Ø3-6	Monsanto Company	2004	✓	2004		
Maize	*Zea mays* L.	IR	MON-ØØ863-5 x MON-ØØ81Ø-6	Monsanto Company	2004	✓	2004		
Maize	*Zea mays* L.	HT + IR	MON-ØØØ21-9 x MON-ØØ81Ø-6	Monsanto Company	2005	✓	2003		
Maize	*Zea mays* L.	IR + HT	MON802	Monsanto Company	1997				
Maize	*Zea mays* L.	IR + HT	MON809	Pioneer Hi-Bred International Inc.	1997				1998
Maize	*Zea mays* L.	IR +HT	DAS-59122-7 x NK603	DOW AgroSciences LLC / Pioneer Hi-Bred International Inc.	2006			2005	2006
Maize	*Zea mayz* L.	IR + HT	SYN - EV176-9	Syngenta Seeds Inc.	2007	✓	2007		
Maize	*Zea mays* L.	HT	B16 (DLL25)	Dekalb Genetics Corporation	1999	✓		1999	2000
Maize	*Zea mays* L.	HT	T14	Bayer CropScience	2006			1997	2001
Maize	*Zea mays* L.	HT	T25	Bayer CropScience	2004	✓		2001	2003
Maize	*Zea mays* L.	HT	GA21	Monsanto Company	1998	✓		1999	1999
Maize	*Zea mays* L.	HT/ HT	DP-098140-6	DuPont Inc.	2007	✓			
Maize	*Zea mays* L.	HT	NK603	Monsanto Company	2001	✓		2001	2001
Maize	*Zea mays* L.	HT + IR	176	Syngenta Seeds	1996			2001	1996
Maize	*Zea mays* L.	HT + IR	Bt11	Syngenta Seeds	1996			2001	1996
Maize	*Zea mays* L.	HT + IR	DBT418	Dekalb Genetics Corporation	1999			1999	
Maize	*Zea mays* L.	HT + IR	TC1507	Mycogen (c/o Dow AgroSciences); Pioneer (c/o Dupont)	2002	✓		2002	2002
Maize	*Zea mays* L.	IR	MON810	Monsanto Company	1996	✓		1997	1997
Maize	*Zea mays* L.	HT + IR	DAS-59122-7	Dow AgroSciences LLC/Pioneer	2006	✓		2006	2006
Maize	*Zea mays* L.	HT + IR	MON88017	Monsanto Company	2006	✓		2006	2006
Maize	*Zea mays* L.	HT + IR	MON863 x MON810 x NK603	Monsanto Company	2004	✓		2004	
Maize	*Zea mays* L.	HT + IR	1507 X NK603	Monsanto Company	2005	✓		2004	
Maize	*Zea mays* L.	IR	MON863	Monsanto Company	2004	✓		2002	2003
Maize	*Zea mays* L.	IR	DAS-Ø6275-8 (DAS-06275-8)	Dow AgroSciences LLC	2008	✓		2007	
Maize	*Zea mays* L.	IR	SYN-IR6Ø4-5 (MIR604)	Syngenta Seeds Inc	2007	✓		2007	
Maize	*Zea mays* L.	IR	SYN IR162-4	Syngenta Seeds Inc.	2007	✓		2007	
Maize	*Zea mays* L.	HT + IR	SYN-IR6Ø4-5 x MON-00021-9	Syngenta Seeds Inc	2007	✓		2007	
Maize	*Zea mays* L.	HT + IR	TC1507 x DAS59122-7	Dow AgroSciences LLC	2006	✓		2005	2006
Maize	*Zea mays* L.	HT + IR	MON810 x MON88017	Monsanto Company	2006	✓		2005	
Maize	*Zea mays* L.	HT + IR	SYN-BTØ11-1 x MON-ØØØ21-9	Syngenta Seeds Inc.	2007	✓		2007	
Maize	*Zea mays* L.	HT + IR	TC1507 x DAS59122-7 x NK603	Dow AgroSciences LLC	2006	✓		2005	2006
Maize	*Zea mays* L.	HT + IR	MON89034	Monsanto Company	2008	✓		2007	
Maize	*Zea mays* L.	LYS	LY038	Monsanto Company	2007	✓		2007	
Maize	*Zea mays* L.	Lys + IR	MON-ØØ81Ø-6 x LY038	Monsanto Company	2007	✓		2007	2007
Maize	*Zea mays* L.	IR	DAS 07275-8	Dow Agro Sciences LLC	2008	✓		2007	2008
Maize	*Zea mays* L.	IR	Mon 89034	Monsanto Company	2008	✓		2007	2008
Maize	*Zea mays* L.	IR	BT11 x MIR164x GA21	Syngenta Seeds Inc				2007	
Maize	*Zea mays* L.	IR + HT	MIR 604 x GA21	Syngenta Seeds Inc.	2007	✓		2007	
Maize	*Zea mays* L.	IR + HT	Mon 89034 x Mon 88017	Monsanto Company				2008	
Maize	*Zea mays* L.	IR + HT	Mon 89034 x NK603	Monsanto Company				2008	
Maize	*Zea mays* L.	IR + HT	BT 11 x MIR604	Syngenta Seeds				2007	
Maize	*Zea mays* L.	IR/HT	Mon89034 x TC1507x Mon88017 x DAS59122-7	Monsanto Company	2009	✓	2009	2009	
Potato	*Solanum tuberosum* L.	IR	ATBT04-6, ATBT04-27, ATBT04-30, ATBT04-31, ATBT04-36, SPBT02-5, SPBT02-7	Monsanto Company				2001	

JAPAN

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Potato	*Solanum tuberosum* L.	IR	BT6, BT10, BT12, BT16, BT17, BT18, BT23	Monsanto Company				2001	
Potato	*Solanum tuberosum* L.	IR + VR	RBMT21-129	Monsanto Company				2001	
Potato	*Solanum tuberosum* L.	IR + VR	New Leaf Y SEMT15-02	Monsanto Company				2003	
Potato	*Solanum tuberosum* L.	IR + VR	RBMT21-350	Monsanto Company				2001	
Potato	*Solanum tuberosum* L.	IR + VR	RBMT22-082	Monsanto Company				2001	
Potato	*Solanum tuberosum* L.	IR + VR	New Leaf Y RBMT15-101	Monsanto Company				2003	
Potato	*Solanum tuberosum* L.	IR + VR	New Leaf Y SEMT15-15	Monsanto Company				2003	
Poplar	*Populus alba*	High Cell	AaXEG2	Incorporated Administrative Agency Forest Tree Breeding Center, Japan	2007	✓			
Rice	*Oryza sativa* L.	CPP	7CRP# 242-95-7	National Institute of Agrobiological Sciences (NIAS)	2007	✓			
Rice	*Oryza sativa* L.	CPP	7 Crp#10	National Institute of Agrobiological Sciences (NIAS)	2007	✓			
Rose	*Rosa hybrida*	Flav Path	IFD-52401-4	Suntory Limited	2008	✓			
Rose	*Rosa hybrida*	Flav Path	IFD-52901-9	Suntory Limited	2008	✓			
Rose	*Rosa hybrida*	MdFlwrCol	WKS82/130-4-1	Florigene/ Japan Suntory	2009	✓			
Soybean	*Glycine max* L.	HT	A5547-127	Aventis Crop Science	1999			2002	2003
Soybean	*Glycine max* L.	HT	A2704-12	Aventis Crop Science	1999			2002	2003
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company	1996	✓		1996	2003
Soybean	*Glycine max* L.	HT	MON89788	Monsanto Company				2007	
Soybean	*Glycine max* L.	Oil content	DD-026005-3	Du Pont	2007	✓		2007	
Soybean	*Glycine max* L.	Oil content	G94-1, G94-19, G168	DuPont Canada Agricultural Products	1999			2001	1996
Soybean	*Glycine max* L.	OC + HT	DP 305423-1	Du Pont	2007	✓			
Soybean	*Glycine max* L.	HT	Mon 89788	Monsanto Company	2008	✓		2007	2008
Soybean	*Glycine max* L.	HT	DP-356043-5	Dupont	2009	✓	2009	2009	
Sugar Beet	*Beta vulgaris*	HT	H7-1	Monsanto Company	2007	✓		2003	2007
Sugar Beet	*Beta vulgaris*	HT	GTSB77	Monsanto Company				2003	
Sugar Beet	*Beta vulgaris*	HT	T120-7	Bayer CropScience				2001	2003
Tomato	*Lycopersicon esculentum*	DR	FLAVR SAVR	Calgene Inc.	1996			1997	1999
Carnation	*Dianthus caryophyllus* L.	ModFloClr	(123.8.12, OECD UI : FLO-40689-6)	Suntory Ltd	2009	✓			

MALAYSIA

Crop	**Latin Name**	**Trait**	**Event**	**Developer**	**Environment**	*** Planting**	**Food/Feed**	**Food**	**Feed**
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company			1997		

MEXICO

Crop	**Latin Name**	**Trait**	**Event**	**Developer**	**Environment**	*** Planting**	**Food/Feed**	**Food**	**Feed**
Alfafa	*Medicago sativa*	HT	MON-ØØ1Ø1-8, MON-ØØ163-7, o J101, J163	Monsanto Company				2005	
Argentine Canola	*Brassica napus*	HT	T45 (HCN28)	Bayer CropScience				2001	
Argentine Canola	*Brassica napus*	HT	GT73,RT73	Monsanto Company			1996		
Argentine Canola	*Brassica napus*	HT	HCN92 (TOPAS 19/2)	Bayer CropScience				1999	
Argentine Canola	*Brassica napus*	HT + F	MS8 x RF3	Aventis Crop Science &Agrevo			2004		
Cotton	*Gossypium hirsutum* L.	IR	281-24-236	Dow AgroSciences LLC				2004	
Cotton	*Gossypium hirsutum* L.	IR	3006-210-23	Dow AgroSciences LLC			2004		
Cotton	*Gossypium hirsutum* L.	IR	DAS-21Ø23-5 x DAS-24236-5	Dow AgroSciences LLC				2004	
Cotton	*Gossypium hirsutum* L.	HT	BXN	Calgene Inc.				1996	
Cotton	*Gossypium hirsutum* L.	HT + IR	DAS-21Ø23-5 x DAS-24236-5 x MON-Ø1445-2	Dow AgroSciences LLC				2005	
Cotton	*Gossypium hirsutum* L.	IR	MON531/757/1076	Monsanto Company	1997	✓		1997	1997
Cotton	*Gossypium hirsutum* L.	IR	15985	Monsanto Company				2003	
Cotton	*Gossypium hirsutum* L.	HT	MON1445/1698	Monsanto Company	2000	✓		2000	
Cotton	*Gossypium hirsutum* L.	HT	MON88913	Monsanto Company				2006	
Cotton	*Gossypium hirsutum* L.	HT	ACS-GHØØ1-3 (LLCotton25)	Bayer CropScience (Aventis CropScience(AgrEvo))			2006		
Cotton	*Gossypium hirsutum* L.	HR + IR	DAS-21Ø23-5 x DAS-24236-5 x MON88913	Dow AgroSciences LLC & Pioneer Hi-Bred International Inc.			2006		
Cotton	*Gossypium hirsutum* L.	HR + IR	MON-15985-7 x MON-Ø1445-2	Monsanto			2006		

MEXICO

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Cotton	*Gossypium hirsutum* L.	HT + IR	MON88913/ 15985	Monsanto Company				2006	
Cotton	*Gossypium hirsutum* L.	HT + IR	1445 x 531	Monsanto Company	2000	✓		2002	
Cotton	*Gossypium hirsutum* L.	HT	BCS-GHØØ2-5 (GHB614)				2009		
Maize	*Zea mays* L.	IR	MON810	Monsanto Company				2002	
Maize	*Zea mays* L.	IR	MON863	Monsanto Company				2003	
Maize	*Zea mays* L.	IR	MON88017	Monsanto Company			2006		
Maize	*Zea mays* L.	IR	SYN-IR6Ø4-5 (MIR604)	Syngenta Seeds Inc			2007		
Maize	*Zea mays* L.	IR+ HT	MON88017/MON810	Monsanto Company				2006	
Maize	*Zea mays* L.	IR + HT	MON810/NK603	Monsanto Company				2004	
Maize	*Zea mays* L.	IR+ HT	MON863/NK603	Monsanto Company				2004	
Maize	*Zea mays* L.	IR+ HT	MON863/MON810	Monsanto Company			2006		
Maize	*Zea mays* L.	IR-HT	MON863/MON810/NK603	Monsanto Company				2004	
Maize	*Zea mays* L.	IR+ HT	SYN-BTØ11-1 (BT11 (X4334CBR, X4734CBR))	Syngenta Seeds Inc.				2007	
Maize	*Zea mays* L.	IR +HT	DAS-59122-7 x NK603)	Dow AgroSciences LLC/Pioneer Hi-Bred International Inc.			2006		
Maize	*Zea mays* L.	IR + HT	DAS-59122-7 x TC1507 x NK603	Dow AgroSciences LLC/Pioneer Hi-Bred International Inc.			2007		
Maize	*Zea mays* L.	HT	DAS-59122-7 (DAS-59122-7)	Dow AgroSciences LLC/Pioneer Hi-Bred International Inc.			2004		
Maize	*Zea mays* L.	HT + IR	DAS-Ø15Ø7-1 x MON-ØØ6Ø3-6	Dow AgroSciences LLC			2004		
Maize	*Zea mays* L.	HT	NK603	Monsanto Company				2002	
Maize	*Zea mays* L.	HT	GA21	Monsanto Company				2002	
Maize	*Zea mays* L.	HT + IR	TC1507	Mycogen (c/o Dow AgroSciences); Pioneer (c/o Dupont)				2003	
Maize	*Zea mays* L.	HT	ACS-ZMØØ2-1 / ACS-ZMØØ3-2 (T14, T25)	Bayer CropScience (Aventis CropScience(AgrEvo))			2007		
Maize	*Zea mays* L.	HT + IR	TC1507 x DAS-59122-7)	Dow AgroSciences LLC/Pioneer Hi-Bred International Inc.				2006	
Maize	*Zea mays* L.	LYS	LY038	Monsanto Company				2007	
Maize	*Zea mays* L.	IR + HT	MIR 604 x GA 21	Syngenta Seeds			2007		
Maize	*Zea mays* L.	IR + HT	SYN-BTØ11-1 (BT11) x MON ØØØ21-9	Syngenta Seeds			2007		
Maize	*Zea mays* L.	IR + HT	SYN-BTØ11-1 (BT11) x MIR604	Syngenta Seeds			2007		
Maize	*Zea mays* L.	HT	DP98140	Pioneer Hi-bred			2009		
Tomato	*Lycopersicon esculentum*	DR	1345-4	DNA Plant Technology Corporation				1998	
Tomato	*Lycopersicon esculentum*	DR	FLAVR SAVR	Calgene Inc.	1995			1995	1995
Tomato	*Lycopersicon esculentum*	DR	B,Da, F	Zeneca + Petoseed				1996	
Potato	*Solanum tuberosum* L.	IR	ATBT,SPBT,BT	Monsanto Company				1996	
Potato	*Solanum tuberosum* L.	IR + VR	RBmT,SEMT	Monsanto Company				2001	
Potato	*Solanum tuberosum* L.	IR + VR	RBmT	Monsanto Company				2001	
Rice	*Oryza sativa*	HT	LLRICE06, LLRICE62	Aventis Crop Science			2007		
Soybean	*Glycine max* L.	HT	A2704-12 X A5547	Bayer CropScience				2003	
Soybean	*Glycine max* L.	HT	MON-Ø4Ø32-6 (GTS 40-3-2)	Monsanto Company	1998	✓		1998	1998
Soybean	*Glycine max* L.	HT	ACS-GMØØ6-4 (A5547-127)	Bayer Crop Science			2003		
Soybean	*Glycine max* L.	High Oleic	DP-305423-1	Pioneer Hi-bred			2009		
Sugarbeet	*Beta vulgaris*	HT	KM-ØØØ71-4 (H7-1)	Monsanto Company				2006	

** After Biosafety Law was in place (2005) Food Safety Clearances cover Feed use for GM crops.*

NETHERLANDS

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Maize	*Zea mays* L.	HT + IR	SYN-EV176-9 (176)	Syngenta Seeds Inc.				1997	1997

NEW ZEALAND

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Alfalfa	*Medicago sativa*	HT	J101 x J163	Monsanto Co. & Forage Genetics International				2007	
Argentine Canola	*Brassica napus*	HT	OXY 235	Bayer CropScience				2002	
Argentine Canola	*Brassica napus*	HT +F	MS1, RF1 PGS1	Bayer CropScience				2002	
Argentine Canola	*Brassica napus*	HT +F	MS1, RF2 PGS2	Bayer CropScience				2002	
Argentine Canola	*Brassica napus*	HT +F	MS8xRF3	Bayer CropScience				2002	

NEW ZEALAND

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Argentine Canola	*Brassica napus*	HT	HCN92	Bayer CropScience				2002	
Argentine Canola	*Brassica napus*	HT	T45 (HCN28)	Bayer CropScience				2002	
Argentine Canola	*Brassica napus*	HT	GT73,RT73	Monsanto Company				2000	
Cotton	*Gossypium hirsutum* L.	IR	MON531/757/1076	Monsanto Company				2000	
Cotton	*Gossypium hirsutum* L.	HT	MON1445/1698	Monsanto Company				2000	
Cotton	*Gossypium hirsutum* L.	IR	MON15985	Monsanto Company				2002	
Cotton	*Gossypium hirsutum* L.	HT	MON88913	Monsanto Company				2006	
Cotton	*Gossypium hirsutum* L.	HT	BXN	Calgene Inc.				2002	
Cotton	*Gossypium hirsutum* L.	IR	COT102	Syngenta Seeds				2005	
Cotton	*Gossypium hirsutum* L.	HT	LLCotton25	Bayer CropScience				2006	
Maize	*Zea mays* L.	HT + IR	TC1507	Mycogen (c/o Dow AgroSciences); Pioneer (c/o Dupont)				2003	
Maize	*Zea mays* L.	HT + IR	DBT418	Monsanto Company				2002	
Maize	*Zea mays* L.	HT	NK603	Monsanto Company				2002	
Maize	*Zea mays* L.	HT	T25	Bayer CropScience				2002	
Maize	*Zea mays* L.	IR	MON810	Monsanto Company				2000	
Maize	*Zea mays* L.	HT	GA21	Monsanto Company				2000	
Maize	*Zea mays* L.	HT + IR	Bt 11	Syngenta Seeds				2001	
Maize	*Zea mays* L.	IR	Bt176	Syngenta Seeds				2001	
Maize	*Zea mays* L.	IR	MON863	Monsanto Company				2003	
Maize	*Zea mays* L.	HT + IR	DAS59122-7	Pioneer Company				2005	
Maize	*Zea mays* L.	HT + IR	MON88017	Monsanto Company				2006	
Maize	*Zea mays* L.	IR	MIR604	Syngenta Seeds				2006	
Maize	*Zea mays* L.	Lys	Ly308	Monsanto Company			2008	2008	
Potato	*Solanum tuberosum* L.	IR	ATBT04-6, ATBT04-27, ATBT04-30, ATBT04-31, ATBT04-36, SPBT02-5, SPBT02-7	Monsanto Company				2001	
Potato	*Solanum tuberosum* L.	IR + VR	RBMT15-101, SEMT15-02, SEMT15-15	Monsanto Company				2001	
Potato	*Solanum tuberosum* L.	IR + VR	RBMT21-129, RBMT21-350, RBMT22-082	Monsanto Company				2001	
Soybean	*Glycine max* L.	HT	A2704-12, A2704-21, A5547-35	Bayer CropScience				2004	
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company				2000	
Soybean	*Glycine max* L.	Oil content	G94-1, G94-19, G168	DuPont Canada Agricultural Products				2000	
Sugarbeet	*Beta vulgaris*	HT	H7-1	Monsanto Company				2005	
Sugarbeet	*Beta vulgaris*	HT	GTS B77	Monsanto Company				2002	

PAKISTAN

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Cotton	*Gossypium hirsutum* L.	IR	CEMB-01	Centre of Excellence in Molecular Biology (CEMB)	2009		✓	1997	1997
Cotton	*Gossypium hirsutum* L.	IR/IR	CEMB-02	Centre of Excellence in Molecular Biology (CEMB)	2009		✓		

PARAGUAY

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company	2004	✓	2004		

PHILIPPINES

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Alfalfa	*Medicago sativa*	HT	J101, J163	Monsanto Company and Forage Genetics International				2006	2006
Argentine Canola	*Brassica napus*	HT	GT73,RT73	Monsanto Company				2003	2003
Cotton	*Gossypium hirsutum* L.	IR	MON531	Monsanto Company				2004	2004
Cotton	*Gossypium hirsutum* L.	HT	MON88913	Monsanto Company				2005	2005
Cotton	*Gossypium hirsutum* L.	HT + IR	MON-15985-7 x MON-Ø1445-2	Monsanto Company				2004	2004
Cotton	*Gossypium hirsutum* L.	HT + IR	MON-ØØ531-6 x MON-Ø1445-2	Monsanto Company				2004	2004
Cotton	*Gossypium hirsutum* L.	HT	MON1445/1698	Monsanto Company				2003	2003
Cotton	*Gossypium hirsutum* L.	IR	15985	Monsanto Company				2003	2003

PHILIPPINES

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Cotton	*Gossypium hirsutum* L.	HT + IR	MON 15985 x MON 88913	Monsanto Company				2006	2006
Maize	*Zea mays* L.	HT + IR	MON-ØØ6Ø3-6 x MON-ØØ81Ø-6	Monsanto Company	2005	✓		2004	2004
Maize	*Zea mays* L.	HT + IR	MON-ØØ863-5 x MON-ØØ6Ø3-6	Monsanto Company				2004	
Maize	*Zea mays* L.	IR	MON-ØØ863-5 x MON-ØØ81Ø-6	Monsanto Company				2004	2004
Maize	*Zea mays* L.	HT + IR	MON-ØØ863-5 x MON-ØØ81Ø-6 x MON-ØØ6Ø3-6	Monsanto Company				2005	2004
Maize	*Zea mays* L.	HT + IR	MON-ØØØ21-9 x MON-ØØ81Ø-6	Monsanto Company				2004	2004
Maize	*Zea mays* L.	HT	B16 (DLL25)	Dekalb Genetics Corporation				2003	2003
Maize	*Zea mays* L.	HT	T25	Bayer CropScience				2003	2003
Maize	*Zea mays* L.	HT	GA21	Monsanto Company		2009		2003	2003
Maize	*Zea mays* L.	HT	NK603	Monsanto Company	2005	✓		2003	2003
Maize	*Zea mays* L.	HT + IR	176	Syngenta Seeds				2003	2003
Maize	*Zea mays* L.	HT + IR	Bt11	Syngenta Seeds	2005	✓		2003	2003
Maize	*Zea mays* L.	HT + IR	DBT418	Dekalb Genetics Corporation				2003	2003
Maize	*Zea mays* L.	HT + IR	TC1507	Mycogen (c/o Dow AgroSciences); Pioneer (c/o Dupont)				2003	2003
Maize	*Zea mays* L.	IR	MON810	Monsanto Company	2002	✓		2002	2002
Maize	*Zea mays* L.	HT + IR	MON88017	Monsanto Company				2006	2006
Maize	*Zea mays* L.	HT + IR	DAS59122-7	Pioneer Company				2006	2006
Maize	*Zea mays* L.	Lys	LY038	Monsanto Company				2006	2006
Maize	*Zea mays* L.	IR	MON863	Monsanto Company				2003	2003
Maize	*Zea mays* L.	IR +HT	DAS-59122-7 x NK603)	Dow AgroSciences LLC/Pioneer Hi-Bred International Inc.			2006		
Maize	*Zea mays* L.	HT + IR	SYN-BTØ11-1 x MON-ØØØ21-9	Syngenta Seeds Inc			2007		
Maize	*Zea mays* L.	HT+IR	TC1507 x DAS 59122	Pioneer Hi-Bred			2006	2006	2006
Maize	*Zea mays* L.	HT + IR	TC1507 x NK603	Pioneer Hi-Bred				2006	2006
Maize	*Zea mays* L.	HT + IR	DAS 59122 x TC1507 x NK603	Pioneer Hi-Bred			2007	2007	2007
Maize	*Zea mays* L.	R	MIR 604	Syngenta Seeds Inc			2007	2007	2007
Maize	*Zea mays* L.	HT + IR	MIR604 x GA21	Syngenta Seeds Inc			2007	2007	2007
Maize	*Zea mays* L.	HT + IR	MON88017 x MON810	Monsanto Company				2006	2006
Maize	*Zea mays* L.	Lys + IR	LY038 + MON810	Monsanto Company				2006	2006
Maize	*Zea mays* L.	Plt Qual	Event 3272	Syngenta Seeds			2008	2008	2008
Maize	*Zea mays* L.	IR + HT	BT11 x MIR604 x GA21	Syngenta Seeds Inc			2008	2008	2008
Maize	*Zea mays* L.	HT + IR	BT11 x MIR604	Syngenta Seeds			2007	2007	2007
Maize	*Zea mays* L.	IR/HT	MON89034 x NK603	Monsanto Company				2009	2009
Maize	*Zea mays* L.	IR	Mon 89034	Monsanto Company				2009	2009
Maize	*Zea mays* L.	IR/HT	Mon 89034 x Mon 88017	Monsanto Company			2009		
Potato	*Solanum tuberosum* L.	IR + VR	RBMT21-129, RBMT21-350, RBMT22-082	Monsanto Company				2004	2004
Potato	*Solanum tuberosum* L.	IR	Bt6 (RBBT 02-06 and SPBT02-5	Monsanto Company				2003	2003
Potato	*Solanum tuberosum* L.	IR + VR	RBMT15-101, SEMT15-02, SEMT15-15	Monsanto Company				2003	2003
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company				2003	2003
Soybean	*Glycine max* L.	HT	Mon 89788	Monsanto Phils			2007	2007	2007
Sugarbeet	*Beta vulgaris*	HT	H7-1	Monsanto Company				2005	2005
Sugarbeet	*Beta vulgaris*	HT	GTS B77	Novartis Seeds; Monsanto Company				2004	2004

ROMANIA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company	2004	✓		2004	2004
Maize	*Zea mays* L.	IR	MON810	Monsanto Company	2007	✓			

RUSSIAN FEDERATION

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Maize	*Zea mays* L.	HT + IR	Bt11	Syngenta Seeds				2003	
Maize	*Zea mays* L.	IR	MON810	Monsanto Company				2000	2003

RUSSIAN FEDERATION									
Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Maize	*Zea mays* L.	HT	NK603	Monsanto Company				2002	2003
Maize	*Zea mays* L.	IR	MON863	Monsanto Company				2003	2003
Maize	*Zea mays* L.	HT	GA21	Monsanto Company				2000	2003
Maize	*Zea mays* L.	HT	T25	Bayer CropScience				2001	
Potato	*Solanum tuberosum* L.	IR	SPBT02-05	Monsanto Company	2002			2000	
Potato	*Solanum tuberosum* L.	IR	RBBT02-06	Monsanto Company	2002			2000	
Potato	*Solanum tuberosum* L.	IR	2904/1kgs	Centre Bioengineering RAS, Russia				2005	
Potato	*Solanum tuberosum* L.	IR	1210 amk	Centre Bioengineering RAS, Russia				2006	
Rice	*Oryza sativa*	HT	LLRICE62	Aventis Crop Science				2003	
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company				1999/2002	2003
Soybean	*Glycine max* L.	HT	A2704-12	Aventis CropScience				2002	
Soybean	*Glycine max* L.	HT	A5547-127	Aventis CropScience				2002	
Sugarbeet	*Beta vulgaris*	HT	GTSB77	Novartis Seeds; Monsanto Company				2001	
Sugarbeet	*Beta vulgaris*	HT	H7-1	Monsanto Company				2006	

SINGAPORE									
Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Cotton	*Gossypium hirsutum* L.	HT	MON 88913	Monsanto company				2007	
Maize	*Zea mays* L.	HT	NK603	Monsanto Company				2006	2006
Maize	*Zea mays* L.	IR	MON863	Monsanto Company				2006	2006
Sugarbeet	*Beta v ulgaris*	HT	H7-1	Monsanto Company			2007		

SOUTH AFRICA									
Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Argentine Canola	*Brassica napus*	HT +F	Topas 19/2, HCN92	Bayer Crops Science/Aventis Crop Science			2001		
Argentine Canola	*Brassica napus*	HT	MS1, RF1	Bayer Crops Science/Aventis Crop Science			2001		
Argentine Canola	*Brassica napus*	HT	MS1,RF2	Bayer Crops Science/Aventis Crop Science			2001		
Argentine Canola	*Brassica napus*	HT	MS8RF3	Bayer Crops Science/Aventis Crop Science			2001		
Cotton	*Gossypium hirsutum* L.	HT	MON1445/1698	Monsanto Company	2000	✓			
Cotton	*Gossypium hirsutum* L.	IR	MON531	Monsanto Company	1997	✓		1997	1997
Cotton	*Gossypium hirsutum* L.	IR	MON15985	Monsanto Company	2005	✓		2005	2005
Cotton	*Gossypium hirsutum* L.	HT + IR	MON88913 x MON15985	Monsanto Company	2007	✓	2007		
Cotton	*Gossypium hirsutum* L.	HR	MON88913	Monsanto Company	2007	✓	2007		
Maize	*Zea mays* L.	HT + IR	Bt11	Syngenta Seeds	2003	✓	2003		
Maize	*Zea mays* L.	IR	MON810	Monsanto Company	1997	✓		1997	1997
Maize	*Zea mays* L.	HT	NK603	Monsanto Company	2002	✓	2002		
Maize	*Zea mays* L.	HT + IR	TC1507	Mycogen (c/o Dow AgroSciences); Pioneer (c/o Dupont)			2002		
Maize	*Zea mays* L.	HT + IR	MON81 0 X NK603	Monsanto Company	2007	✓	2004		
Maize	*Zea mays* L.	HT + IR	MON810 X GA21	Monsanto Company			approved		
Maize	*Zea mays* L.	HT	GA21	Monsanto Company			approved		
Maize	*Zea mays* L.	HT	T25	Bayer CropScience			approved		
Maize	*Zea mays* L.	HT + IR	176	Syngenta Seeds			approved		
Maize	*Zea mays* L.	IR + HT	MON00603-6 x MON00810-6	Monsanto Company	2007	✓	2004		
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company	2001	✓		2001	2001
Soybean	*Glycine max* L.	HT	A2704-12	Bayer CropScience			approved		

SOUTH KOREA									
Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Argentine Canola	*Brassica napus*	HT	GT73	Monsanto Company	2005			2003	
Argentine Canola	*Brassica napus*	HT	MS8/RF3	Bayer CropScience	2005			2005	

SOUTH KOREA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Argentine Canola	*Brassica napus*	HT	T45	Bayer CropScience	2005			2005	
Argentine Canola	*Brassica napus*	HT	MS1/RF1	Bayer CropScience				2005	
Argentine Canola	*Brassica napus*	HT	MS1/RF2	Bayer CropScience				2005	
Argentine Canola	*Brassica napus*	HT	Topas1912	Bayer CropScience				2005	
Cotton	*Gossypium hirsutum* L.	IR	531	Monsanto Company	2004			2003	
Cotton	*Gossypium hirsutum* L.	IR	757	Monsanto Company	2004			2003	
Cotton	*Gossypium hirsutum* L.	HT	1445	Monsanto Company	2004			2003	
Cotton	*Gossypium hirsutum* L.	IR	15985	Monsanto Company	2004			2003	
Cotton	*Gossypium hirsutum* L.	HT + IR	MON15985 X 1445	Monsanto Company	--			2004	
Cotton	*Gossypium hirsutum* L.	HT + IR	531 X 1445	Monsanto Company	--			2004	
Cotton	*Gossypium hirsutum* L.	HT + IR	281/3006	Dow Agro				approved	
Cotton	*Gossypium hirsutum* L.	HT + IR	15985 X MON88913	Monsanto Company	--			2006	
Cotton	*Gossypium hirsutum* L.	HT	MON88913	Monsanto Company				2006	
Cotton	*Gossypium hirsutum* L.	HT	LLCotton25	Bayer CropScience	2005			2005	
Cotton	*Gossypium hirsutum* L.	HT + IR	DAS-21Ø23-5 x DAS-24236-5 x MON-Ø1445-2	Dow AgroSciences LLC				2006	
Cotton	*Gossypium hirsutum* L.	HT + IR	DAS-21Ø23-5 x DAS-24236-5 x MON88913	Dow AgroSciences LLC & Pioneer Hi-Bred International Inc.				2006	
Cotton	*Gossypium hirsutum* L.	HT + IR	15985 X LLCotton25	Bayer CropScience				2006	
Maize	*Zea mays* L.	HT	GA21	Monsanto Company	2005			2002	
Maize	*Zea mays* L.	IR	MON810	Monsanto Company	2004			2002	
Maize	*Zea mays* L.	HT + IR	Bt 11	Syngenta Seeds				2003	
Maize	*Zea mays* L.	HT + IR	MON810 x NK603	Monsanto Company	--			2004	
Maize	*Zea mays* L.	HT + IR	1507 X NK603	Dupont Company				2004	
Maize	*Zea mays* L.	HT + IR	TC1507	Dupont Company				approved	
Maize	*Zea mays* L.	HT	NK603	Monsanto Company	2004			2002	
Maize	*Zea mays* L.	HT	T25	Bayer CropScience	2004			2003	
Maize	*Zea mays* L.	IR	MON863	Monsanto Company	2004			2003	
Maize	*Zea mays* L.	IR	Bt176	Syngenta Seeds				approved	
Maise	*Zea mays* L.	IR	SYN-IR6Ø4-5 (MIR604)	Syngenta Seeds Inc				2007	
Maize	*Zea mays* L.	HT	DLL25	Monsanto Company	--			2004	
Maize	*Zea mays* L.	HT + IR	DBT418	Monsanto Company	--			2004	
Maize	*Zea mays* L.	HT + IR	MON863 X NK603	Monsanto Company	--			2004	
Maize	*Zea mays* L.	IR	MON863 X MON810	Monsanto Company	--			2004	
Maize	*Zea mays* L.	HT + IR	MON810 x GA21	Monsanto Company	--			2004	
Maize	*Zea mays* L.	HT + IR	MON810 X MON863 X NK603	Monsanto Company	--			2004	
Maize	*Zea mays* L.	HT + IR	Das-59122-7	Dupont Company				approved	
Maize	*Zea mays* L.	HT + IR	Mon88017	Monsanto Company				2006	
Maize	*Zea mays* L.	HT + IR	Das-59122-7 X 1507 X NK603	Dow AgroSciences LLC/Pioneer Hi-Bred International Inc.				2006	
Maize	*Zea mays* L.	HT + IR	1507 X Das-59122-7	Dupont Company				approved	
Maize	*Zea mays* L.	HT + IR	Das-59122-7 X NK603	Dow AgroSciences LLC/Pioneer Hi-Bred International Inc.				2006	
Maize	*Zea mays* L.	HT + IR	Bt11 X GA21	Syngenta Seeds				approved	
Maize	*Zea mays* L.	HT + IR	MON88017 X MON810	Monsanto Company	--			2006	
Maize	*Zea mays* L.	HT + IR	SYN-BTØ11-1 x MON-ØØØ21-9	Syngenta Seeds Inc				2006	
Maize	*Zea mays* L.	IR/HT	Mon 89034 x NK 603	Monsanto Company					2009
Maize	*Zea mays* L.	IR/HT	Mon 89034 x Mon 88017	Monsanto Company				2009	2009
Maize	*Zea mays* L.	IR	Mon 89034	Monsanto Company				2009	2009
Maize	*Zea mays* L.	IR/HT	Mon89034 x TC1507x Mon88017 x DAS59122-7	Monsanto Company				2009	
Potato	*Solanum tuberosum* L.	IR	SPBT02-05	Monsanto Company	--			2004	
Potato	*Solanum tuberosum* L.	IR	RBBT06	Monsanto Company	--			2004	
Potato	*Solanum tuberosum* L.	IR + VR	New Leaf Y	Monsanto Company	--			2004	
Potato	*Solanum tuberosum* L.	IR + VR	New Leaf Plus	Monsanto Company	--			2004	
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company	2004			2000	

SOUTH KOREA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Soybeean	*Glycine max* L.	HT	A2704-12	Bayer Crop Science					2009
Soybeean	*Glycine max* L.	HT	Mon89788	Monsanto Company				2009	
Soybeean	*Glycine max* L.	HT	Mon89788	Monsanto Company					2009
Sugarbeet	*Beta vulgaris*	HT	H7-1	Monsanto Company	--			2006	

SWITZERLAND

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Maize	*Zea mays* L.	HT + IR	176	Syngenta Seeds				1997	1997
Maize	*Zea mays* L.	HT + IR	Bt11	Syngenta Seeds				1998	1998
Maize	*Zea mays* L.	IR	MON810	Monsanto Company				2000	2000
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company				1996	1996

TAIWAN

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Maize	*Zea mays L.*	HT + IR	176	Syngenta Seeds				2003	2003
Maize	*Zea mays L.*	HT + IR	B16 (DLL25))	Dekalb Genetics Corporation				2003	2003
Maize	*Zea mays L.*	HT + IR	Bt11	Syngenta Seeds				2004	2004
Maize	*Zea mays L.*	HT + IR	DBT418	Dekalb Genetics Corporation				2003	2003
Maize	*Zea mays L.*	HT + IR	GA21	Monsanto Company				2003	2003
Maize	*Zea mays L.*	IR	MON810	Monsanto Company				2002	2002
Maize	*Zea mays L.*	IR	MON863	Monsanto Company				2003	2003
Maize	*Zea mays L.*	HT	NK603	Monsanto Company				2003	2003
Maize	*Zea mays L.*	HT	T25	Bayer CropScience				2002	2002
Maize	*Zea mays L.*	HT + IR	TC1507	Mycogen (Dow AgroSciences); Pioneer (Dupont)				2003	2003
Maize	*Zea mays L.*	HT + IR	Das-59122-7	Dupont Company				2005	2005
Maize	*Zea mays L.*	HT + IR	MON88017	Monsanto Company				2006	2006
Maize	*Zea mays L.*	IR	MIR604	Syngenta Seeds				2007	
Maize	*Zea mays L.*	IR	MON 89034	Monsanto Company				2008	
Maize	*Zea mays L.*	HT	MON 89788	Monsanto Company				2008	
Maize	*Zea mays L.*	Lys	LYO38	Monsanto Company				2006	
Maize	*Zea mays L.*	IR/HT	MON89034 x NK603	Monsanto Company				2009	
Maize	*Zea mays L.*	IR/HT	Mon 89034 x Mon 88017	Monsanto Company				2009	
Maize	*Zea mays L.*	IR/HT	Mon 810 x Mon 88017	Monsanto Company				2009	
Maize	*Zea mays L.*	IR	MIR162 corn	Syngenta Seeds				2009	
Maize	*Zea mays L.*	IR/HT	MON863 x NK603	Monsanto Company				2009	
Maize	*Zea mays L.*	IR/HT	NK603 x Mon 810	Monsanto Company				2009	
Maize	*Zea mays L.*	IR	Bt11 x MIR 162 X MIR 604	Syngenta Seeds				2009	
Soybean	Glycine max *L.*	HT	GTS 40-3-2	Monsanto Company				2002	2002
Soybean	Glycine max *L.*	HT	A2704-12	Bayer CropScience				2007	
Soybean	Glycine max *L.*	HT	DP356043	Dupont/Pioneer Hi-Bred				2009	

THAILAND

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Maize	*Zea mays* L.	HT	NK603	Monsanto Company				2000	2000
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company				2000	2000

UNITED KINGDOM

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Maize	*Zea mays* L.	HT + IR	176	Syngenta Seeds				1997	
Maize	*Zea mays* L.	HT + IR	Bt11	Syngenta Seeds	1996	1996			
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company				2000	2000

URUGUAY

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Maize	*Zea mays* L.	IR	MON810	Monsanto Company	2003	✓		2003	2003
Maize	*Zea mays* L.	HT + IR	Bt11	Syngenta Seeds	2004	✓	2004		
Maize	*Zea mays* L.	HT + IR	TC1507	Mycogen (Dow AgroSciences); Pioneer (Dupont)	2006	✓			
Maize	*Zea mays* L.	HT	NK603	Monsanto Company	2006	✓			
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company	1997	✓		1997	1997

USA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Alfalfa	*Medicago sativa*	HT	J101, J163	Monsanto Company and Forage Genetics International	2005	✓	2004		
Argentine Canola	*Brassica napus*	HT	HCN10	Aventis Crop Science	1995	✓	1995		
Argentine Canola	*Brassica napus*	HT	HCN92	Bayer CropScience	2002	✓		1995	
Argentine Canola	*Brassica napus*	HT	T45 (HCN28)	Bayer CropScience	1998	✓	1998		
Argentine Canola	*Brassica napus*	HT	GT200	Monsanto Company	2003	✓	2002		
Argentine Canola	*Brassica napus*	HT	GT73,RT73	Monsanto Company	1999	✓	1995		
Argentine Canola	*Brassica napus*	HT +F	MS1, RF1 PGS1	Aventis Crop Science	2002	✓	1996		
Argentine Canola	*Brassica napus*	HT +F	MS1, RF2 PGS2	Aventis Crop Science	2002	✓	1996		
Argentine Canola	*Brassica napus*	HT +F	MS8xRF3	Bayer CropScience	1994	✓	1994		
Argentine Canola	*Brassica napus*	Oil content	23-18-17,23-198	Calgene Inc.	1994	✓	1994		
Argentine Canola	*Brassica napus*	HT	OXY 235	Aventis Crop Science				1999	
Chicory	*Chichorium intybus*	HT + F	RM3-3,RM3-4, RM3-6	Bejo Zaden BV	1997	✓	1997		
Cotton	*Gossypium hirsutum* L.	IR	281-24-236	Dow AgroSciences LLC	2004	✓	2004		
Cotton	*Gossypium hirsutum* L.	IR	3006-210-23	Dow AgroSciences LLC	2004	✓	2004		
Cotton	*Gossypium hirsutum* L.	IR	COT102	Syngenta Seeds			2005		
Cotton	*Gossypium hirsutum* L.	IR	DAS-21Ø23-5 x DAS-24236-5	Dow AgroSciences LLC	2004	✓	2004		
Cotton	*Gossypium hirsutum* L.	HT	MON88913	Monsanto Company	2004	✓	2005		
Cotton	*Gossypium hirsutum* L.	HT	LLCotton 25	Bayer CropScience	2003	✓	2003		
Cotton	*Gossypium hirsutum* L.	HT	MON1445/1698	Monsanto Company	1995	✓	1995		
Cotton	*Gossypium hirsutum* L.	IR	15985	Monsanto Company	2002	✓		2002	
Cotton	*Gossypium hirsutum* L.	IR	MON531/757/1076	Monsanto Company	1995	✓	1995		
Cotton	*Gossypium hirsutum* L.	HT + IR	31807/31808	Calgene Inc.	1997	✓	1998		
Cotton	*Gossypium hirsutum* L.	HT	BXN	Calgene Inc.	1994	✓	1994		
Cotton	*Gossypium hirsutum* L.	HT	19-51A	DuPont Canada Agricultural Products	1996	✓	1996		
Cotton	*Gossypium hirsutum* L.	HT	BCS-GHØØ2-5 (GHB614)	Bayer Crop Science	2009	✓		2009	
Cotton	*Gossypium hirsutum* L.	IR	SYN-IR67B-1 (COT67B)	Syngenta			2009		
Creeping Bentgrass	*Agrostis stolonifera*	HT	ASR368	Scotts Seeds					2003
Flax, Linseed	*Linum usitatissimum* L.	HT	FP967	Univ of Saskatchewan	1999	✓	1998		
Maize	*Zea mays* L.	IR	DAS-06275-8	Dow AgroSciences LLC	2004	✓	2004		
Maize	*Zea mays* L.	HT + IR	DAS-59122-7	Dow AgroSciences LLC	2005	✓	2004		
Maize	*Zea mays* L.	HT + IR	MON88017	Monsanto Company	1995	✓	1996		
Maize	*Zea mays* L.	IR	MON80100	Monsanto Company	1995	✓	1996		
Maize	*Zea mays* L.	IR + HT	MON802	Monsanto Company	1997	✓	1996		
Maize	*Zea mays* L.	IR + HT	MON809	Pioneer Hi-Bred International Inc.	1996	✓	1996		
Maize	*Zea mays* L.	HT	B16 (DLL25)	Dekalb Genetics Corporation	1995	✓	1996		
Maize	*Zea mays* L.	HT	T14,T25	Bayer CropScience	1995	✓	1995		
Maize	*Zea mays* L.	HT	GA21	Monsanto Company	1997	✓	1996		
Maize	*Zea mays* L.	HT	NK603	Monsanto Company	2000	✓	2000		
Maize	*Zea mays* L.	HT +F	676, 678, 680	Pioneer Hi-Bred International Inc.	1998	✓	1998		
Maize	*Zea mays* L.	HT + F	MS3	Bayer CropScience	1996	✓	1996		
Maize	*Zea mays* L.	HT + F	MS6	Bayer CropScience	1999	✓	2000		
Maize	*Zea mays* L.	HT + IR	176	Syngenta Seeds	1995	✓	1995		
Maize	*Zea mays* L.	HT + IR	Bt11	Syngenta Seeds	1996	✓	1996		

USA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Maize	*Zea mays* L.	HT + IR	CBH-351	Aventis Crop Science	1998	✓			1998
Maize	*Zea mays* L.	HT + IR	DBT418	Dekalb Genetics Corporation	1997	✓	1997		
Maize	*Zea mays* L.	HT + IR	TC1507	Mycogen (c/o Dow AgroSciences); Pioneer (c/o Dupont)	2001	✓	2001		
Maize	*Zea mays* L.	HT + IR	MON 89034	Monsanto Company	2007	✓		2007	
Maize	*Zea mays* L.	IR	MON810	Monsanto Company	1995	✓	1996		
Maize	*Zea mays* L.	HT	MON832	Monsanto Company			1996		
Maize	*Zea mays* L.	IR	MON863	Monsanto Company	2003	✓	2001		
Maize	*Zea mays* L.	IR	SYN-IR6Ø4-5 (MIR604)	Syngenta Seeds Inc	2007			2007	
Maize	*Zea mays* L.	LYS	LY038	Monsanto Company	2006	✓	2005		
Maize	*Zea mays* L.	IR	MON 89034	Monsanto Company	2008	✓	2007	2008	
Maize	*Zea mays* L.	Plt Qual	Event 3272	Syngenta Seeds			2007		
Maize	*Zea mays* L.	IR/HT	Mon89034-3/DAS1507-1/Das 591	Monsanto	2009	✓			
Maize	*Zea mays* L.	IR	Bt11 x MIR 162 X MIR 604	Syngenta	2009	✓			
Maize	*Zea mays* L.	HT	Event 98140	Pioneer Hi-bred				2009	
Maize	*Zea mays* L.	IR/HT	Mon89034 x TC1507x Mon88017 x DAS59122-7	Monsanto	2009	✓			
Melon	*Cucumis melo*	DR	A.B	Agritope Inc	1996		1997		
Papaya	*Carica papaya*	VR	55-1/63-1	Cornell University	1996	✓	1996		
Papaya	*Carica papaya*	VR	UFL-X17CP-6 (X17-2)	Univ of Florida	2009	✓	2008		
Plum	*Prunus domestica*	VR	ARS-PLMC5-6 (C5)	USDA -Agricultural Research Service,	2007				
Potato	*Solanum tuberosum* L.	IR	ATBT04-6, ATBT04-27, ATBT04-30, ATBT04-31, ATBT04-36, SPBT02-5, SPBT02-7	Monsanto Company	1996	✓	1996		
Potato	*Solanum tuberosum* L.	IR	BT6, BT10, BT12, BT16, BT17, BT18, BT23	Monsanto Company	1995	✓	1994		
Potato	*Solanum tuberosum* L.	IR + VR	RBMT15-101, SEMT15-02, SEMT15-15	Monsanto Company	1999	✓	1998		
Potato	*Solanum tuberosum* L.	IR + VR	RBMT21-129, RBMT21-350, RBMT22-082	Monsanto Company	1998	✓	1998		
Potato	*Solanum tuberosum* L.	IR +VR	HLMT15-3, HLMT15-15, HLMT15-46	Monsanto Company	1999		1998		
Potato	*Solanum tuberosum* L.	IR + VR	SEMT15-07	Monsanto Company	1999		2000		
Rice	*Oryza sativa*	HT	LLRICE06, LLRICE62	Aventis Crop Science	1999	✓	2000		
Rice	*Oryza sativa*	HT	LLRICE601	Bayer Crop Science	2006	✓			
Soybean	*Glycine max* L.	HT	ACS-GMØØ5-3 (A2704-12, A2704-21, A5547-35)	Aventis Crop Science	1996	✓	1998		
Soybean	*Glycine max* L.	HT	A5547-127	Bayer CropScience	1998	✓	1998		
Soybean	*Glycine max* L.	HT	GU262	Bayer CropScience	1998	✓	1998		
Soybean	*Glycine max* L.	HT	W62,W98	Bayer CropScience	1996	✓	1998		
Soybean	*Glycine max* L.	HT	MON89788	Monsanto Company	2007	✓	2007		
Soybean	*Glycine max* L.	HT	GTS 40-3-2	Monsanto Company	1994	✓	1994		
Soybean	*Glycine max* L.	Oil content	G94-1, G94-19, G168	DuPont Canada Agricultural Products	1997	✓	1997		
Soybean	*Glycine max* L.	HT	DP-356Ø43-5 (DP356043)	Pioneer Hi-Bred International Inc.	2008	✓	2007		
Soybean	*Glycine max* L.	High Oleic	DP-305423-1	Pioneer Hi-bred			2009		
Squash	*Cucurbita pepo*	VR	ZW20	Seminis Vegetable Seeds (Upjohn/Asgrow)	1994	✓	1997		
Squash	*Cucurbita pepo*	VR	CZW-3	Asgrow (USA); Seminis Vegetable Inc. (Canada)	1996	✓	1994		
Sugarbeet	*Beta vulgaris*	HT	H7-1	Monsanto Company	2005	✓	2004		
Sugarbeet	*Beta vulgaris*	HT	T120-7	Bayer CropScience	1998	✓	1998		
Sugarbeet	*Beta vulgaris*	HT	GTSB77	Novartis Seeds; Monsanto Company	1998	✓	1998		
Tobacco	*Nicotiana tabacum* L.	Nic	Vector 21-41	Vector Tobacco Inc.	2002	✓			
Tomato	*Lycopersicon esculentum*	DR	1345-4	DNA Plant Technology Corporation	1995	✓	1994		
Tomato	*Lycopersicon esculentum*	DR	35 1 N	Agritope Inc	1996	✓	1996		
Tomato	*Lycopersicon esculentum*	DR	8338	Monsanto Company	1995	✓	1994		
Tomato	*Lycopersicon esculentum*	DR	B, Da, F	Zeneca Seeds	1995	✓	1994		
Tomato	*Lycopersicon esculentum*	DR	FLAVR SAVR	Calgene Inc.	1992	✓	1994		
Tomato	*Lycopersicon esculentum*	IR	5345	Monsanto Company	1998	✓	1998		
Wheat	*Triticum aestivum*	HT	MON71800	Monsanto Company			2004		

Appendix 2

Global Crop Protection Market

Table 1. Global Crop Protection Market, 2008

$M	Herbicides	Insecticides	Fungicides	Others	Biotech	Total
North America	7,152	1,705	1,189	433	7,147	17,626
West Europe	4,121	1,354	3,602	733	13	9,823
East Europe	893	496	455	102	1	1,947
Japan	1,024	1,176	880	97	0	3,177
Industrial Countries	13,190	4,731	6,126	1,365	7,161	32,573
Latin America	4,322	2,505	2,452	365	1,123	10,767
Rest of Far East	2,491	1,900	1,467	164	325	6,347
Rest of World	783	1,522	508	98	435	3,346
Developing Countries	7,596	5,927	4,427	627	1,883	20,460
Total	**20,786**	**10,658**	**10,553**	**1,992**	**9,045**	**53,034**

Source: Cropnosis Agrochemical Service, 2009

Appendix 3

Useful Tables and Charts on the International Seed Trade

Reproduced with the Permission of the International Seed Federation (ISF)

Table 1. Seed Exports (FOB) of Selected Countries, 2008 (with over 100 Million $ Market)*

Country	Agricultural Seeds	Vegetable Seeds	Total
Netherlands	186	854	1040
USA	650	369	1019
France	698	216	914
Germany	442	41	483
Canada	265	82	347
Denmark	281	44	325
Chile	124	80	204
Hungary	186	10	196
Italy	114	70	184
Mexico	162	9	171
Belgium	139	3	142
Argentina	97	21	118
Austria	102	3	105
Japan	30	71	101
Spain	54	35	89
Others	641	319	960
Total	**4,171**	**2,227**	**6,398**

Table 2. Seed Imports (FOB) of Selected Countries, 2008 (with over 100 Million $ Market)**

Country	Agricultural Seeds	Vegetable Seeds	Total
USA	461	211	672
France	331	91	422
Mexico	258	156	414
Netherlands	182	199	381
Germany	304	64	368
Italy	197	130	327
Spain	121	171	292
Canada	181	56	237
Ukraine	204	31	235
United Kingdom	133	65	198
Russian Federation	157	33	190
Belgium	125	27	152
Japan	79	62	141
Poland	98	41	139
China	63	53	116
Others	1281	673	1954
Total	**4,175**	**2,063**	**6,238**

Source: International Seed Federation, 2009
http://www.worldseed.org/cms/medias/file/ResourceCenter/SeedStatistics/SeedExports/Seed_Exports_2007.pdf
http://www.worldseed.org/cms/medias/file/ResourceCenter/SeedStatistics/SeedImports/Seed_Imports_2007.pdf

Appendix 4

Listing of Events, Bt Cotton Variety and Hybrids in India

Table 1. Listing of Events, Bt Cotton Variety and Hybrids in India, 2009

Zone	BG-I Hybrids	BG-II Hybrids	GFM/Event-I/MLS-9124/BNLA-601
North Zone (**164 Hybrids** 5 Events, 26 Companies)	ABCH-3083 Bt, ABCH-3483 Bt, ABCH-1857 Bt, ABCH-172 Bt, ABCH-173 Bt, ABCH-174 Bt, ABCH-177 Bt, ABCH-178 Bt, Ankur 3028 Bt, Ankur 8120 Bt, Ankur-651, Ankur-2226, Ankur-2534, GK-206, IT-905, Jai Bt, KDCHH-507 BG-I, KDCHH-9810, MRC-6025, MRC-6029, MRC-6301, MRC-6304, NAMCOT-402, NCS-138, NCS-913, NCS-950, NCS-901 Bt, NCS-902 Bt, NCS-903 Bt, NCS-904 Bt, NCS-905 Bt, Ole, PCH 401 Bt, PCH 402 Bt, PCH 403 Bt, PCH-406 Bt, RCH-134, RCH-308, RCH-314, RCH-317, SDS-9, SDS-1368, Shakti-9 Bt, Sigma, SP 7007 B1, VBCH-1006 BG, VBCH-1008 BG, VICH-11 BG, 6317 Bt, 6488 Bt	ABCH-1299 Bt (BG-II), ABCH-2099 Bt (BG-II), ABCH-4899 Bt (BG-II), ABCH-7399 Bt (BG-II), ABCH-143 Bt (BG-II), ABCH-146 Bt (BG-II), ABCH-181 Bt (BG-II), ABCH-182 Bt (BG-II), ABCH-191 Bt (BG-II), ABCH-192 Bt (BG-II), ACH 33-2, Ankur 3028 BG-II, ANKUR-5642, ANKUR-8120, GK-212, Jai BG-II, Jassi, KCH-36 BG-II, KCH999 BG-II, KCH-14K59 BGII, KCH-15K39 BGII, KCH-100 BG-II, KCH-172 BG-II, KCH-189 BG-II, KCH-311 BG-II, KCH-707 Bt, KDCHH-541 BGII, KDCHH-441, MRC-7361 BG II, MRC-7365 BG-II, MRC-7017, MRC-7031, MRC-7041, MRC-7045, NAMCOT-616 BGII, NAMCOT-617 BGII, NCS-855 Bt2, NCS-856 Bt2, NCS-857 Bt2, NCS-858 Bt2, NCS-145 (Bunny), PCH-876 Bt2, PCH-877 Bt2, PCH-878 Bt2, PCH-879 Bt2, RCH-602 BGII, RCH-605 BGII, RCH-314 BGII, RCH-134, PRCH-302, PRCH-333, SDS-27 BG II, SDS-6003 BGII, SDS-234 BGII, SDS-9, SDS-36, SOLAR-56 BG-II, SOLAR-64 BG-II, SOLAR-65 BG-II, SOLAR-72 BG II, SOLAR-75 BG-II, SOLAR-76 BG-II, SOLAR-77 BG-II, SO7H878 BGII, SP1169B2, SP 7010B2, SWCH-4707 BG-II, SWCH-4711 BG-II, SWCH-2 BG-II, SWCH-4704 BG-II, SWCH-4713 BG-II, Tulasi-162 BG II, Tulasi-225 BG-II, Tulasi-4, Tulasi-45, VBCH 1515 BGII, VBCH 1516 BGII,VBCH 1517 BGII, VBCH 1518 BGII, VBCH-1501, VBCH-1504, VICH-307 BG-II, VICH-308 BG-II, VICH-309 BG-II, VICH-310 BG-II, VICH-9, VICH-11, 569, 6488-2, 2510-2, 2113-2	Navkar-5 Bt, NCEH-6R, NCEH-26 Bt, NCEH-31 Bt, NCH-1005 Bt, NCH-1085 Bt, NCH-1163 Bt, NCH-1177 Bt, UPLHH-12 Bt, UPLHH-271 Bt, UPL-HH-342 Bt, UPLHH-350 Bt, ZCH-193 Bt, UPLHH-1, JKCH-1950 Bt, *JKCH-99 Bt, JKCH-1145 Bt, JKCH-1923 Bt, JKCH-1945 Bt, JKCH-1947, JK-1050, JKCH-226 Bt,* **BNBt (Variety)**

Table 1 Continued.

Zone	BG-I Hybrids	BG-II Hybrids	GFM/Event-I/MLS-9124/BNLA-601
Central Zone (**296 Hybrids,** 6 Events, 35 Companies)	ABCH-3083 Bt, ABCH-3483 Bt, ABCH-1857 Bt, ABCH-172 Bt, ABCH-173 Bt, ABCH-174 Bt, ABCH-177 Bt, ABCH-178 Bt, ABCH-1165, ABCH-1220, ACH 33-1, ACH 155-1, ACH-177-1, Akka, Ankur 3042 Bt, Ankur-9, Ankur-651, Ankur-3032 Bt, Ankur HxB-1950 Bt, Brahma, Dyna, GK-204, GK-205, Jai Bt, KCH-135, KCH-707, KDCHB-407 BG-I, KDCHH-507 BG-I, KDCHH-786, KDCHH-9632, KD-CHH-9810, KDCHH-9821, Mahasangram BG, MECH-12, MECH-162, MECH-184, MRC-6301, NCS-906 Bt, NCS-907 Bt, NCS-908 Bt, NCS-909 Bt, NCS-910 Bt, NCS-138, NCS-145 (Bunny), NCS-207 (Mallika), NCS-913, NCS-929, NCS- 950, NCS-954, NCS-955, NCHB-991, NCHB-992, NPH-2171, NSPL-36, NSPL-405, NSPL-999, PCH-404 Bt, PCH-405 Bt, PCH-407 Bt, PCH-408 Bt,	ABCH-1299 Bt (BG-II), ABCH-2099 Bt (BG-II), ABCH-4899 Bt (BG-II), ABCH-7399 Bt (BG-II), ABCH-1020 Bt (BG-II), ABCH-143 Bt (BG-II), ABCH-146 Bt (BG-II), ABCH-181 Bt (BG-II), ABCH-182 Bt (BG-II), ABCH-191 Bt (BG-II), ABCH-192 Bt (BG-II), ACH-111-2, ACH-177-2, Ajeet-11-2, Ajeet-155-2, Akka, Amar-1065 Bt, Ankur-3028 BG-II, Ankur-3034 BG II, Ankur-216 BG II, Ankur-257 BG II, Ankur-3070 BG II, Ankur HB 2104 BG-II, Atal, Brahma BGII, GK-218 BGII, GK-221 BGII, GK-224 BGII, GK-231 BGII, GK-235 BGII, GK-205, Jai BG-II, KCH-14K59 BG-II, KCH-15K39 BG-II, KCH-36 BG-II, KCH-999 BGII, KCH-707, KCH-135, KDCHH-541 BGII, KDCHB-407 BG-II, KDCHH-441, KDCHH-621, KDCHH-9632, Krishna BGII, MLBCH6 BGII, MLCH-317, MRC-7373 BG II, MRC-7383 BGII, MRC-7301, MRC-7326, MRC-7347, MRC-7351, MRC- 7918, NAMCOT 614 BGII, NAMCOT 615 BGII, NAMCOT 603 BGII, NAMCOT 605 BGII, NCS-859 Bt2, NCS-860 Bt2, NCS-861 Bt2, NCS-862Bt2, NCS-853Bt2, NCS-145 Bt 2, NCS-207 (Mallika), NCS-854 Bt 2, NCHB-945 Bt, NSPL-333 BGII, NSPL-432 BGII, NSPL-666 BGII, NSPL-36, NSPL-405, NSPL-999, Paras Lakshmi, PCH-115 Bt2, PCH-881 Bt2, PCH-882 Bt2, PCH-2171 Bt 2, PCH-205 Bt2, PRCH-331 Bt II, PRCH-333 Bt II, PRCH-504, PRCH-505, RCH-608 BGII, RCH-377 BGII, RCH-530 BG-II, RCH-2, RCH-515, RCH-578, RCH-584, SARJU BG-II,	ACH 1050 Bt, ACH 1151 Bt, ACH 1171 Bt, ACH-1019, Dhruv Bt, Kashinath, GBCH-07 Bt, GBCH-09 Bt, GBCH-01, Monsoon Bt, Navkar-5, NCEH-2R, NCEH-3R, NCEH-21, NCEH-23, NCEH-14, NCEH-34 Bt, SBCH-286 Bt (Raka Bt), TPHCN07-015 Bt, TPHCN07-005 Bt, TPHCN07-009 Bt, UPLHH-271 Bt, UPLHH-17 Bt, UPLHH-12 Bt, UPLHH-189 Bt, UPLHH-352 Bt, UPLHH-13 Bt,UPLHH-1Bt, UPLHH-10 Bt, UPLHH-2Bt, YRCH-4 Bt, YRCH-9 Bt, YRCH-13 Bt, YRCH-31 Bt, YRCH-45 Bt, YRCH-54 Bt, ZCH-50005, ZCH-50072 Bt, *JK-Chamundi Bt, JK-Gowri Bt, JKCH-2245 Bt, JKCHB-229 Bt, JK-Ishwar (JKCH-634 Bt), JKCH-99, JKCH-226, JKCH-666, JK-Durga Bt, JK-Indra Bt, JK-Varuna, PCH-99 Bt, PCH-77 Bt, PRCH-712 Bt, PRCH-713 Bt, PRCH-714 Bt, PRCH-715 Bt,* **MH-5125Bt, MH-5174Bt, BN Bt (Variety)**

Table 1 Continued.

Zone	BG-I Hybrids	BG-II Hybrids	GFM/Event-I/MLS-9124/BNLA-601
Central Zone (**296 Hybrids,** 6 Events, 35 Companies)	PCH-409 Bt, PCH-115, PCH-207 (PCH-205), PCH-923, PCH-930, PRCHB- 405 BG-I, PRCH-102, PRCH-31, Rudra, RCH-2, RCH-118, RCH-138, RCH-144, RCH-377, RCH-386, RCH-395 Bt, Sarju-BG, Sigma, SP 1136 B1, SP-499, SP-503, SP-504 (Dhanno), SP-904, SP-923, SWCH-4428 Bt, SWCH-4531 Bt, SWCH-4314 Bt, Tulasi-4, Tulasi-5 Bt, Tulasi-9, Tulasi-117, VBCH-101, VBCH-1006,VBCH-1009, VBCH-1010, VBCH-1016, VBCH-1017,VCH-111, VICH-5, VICH-9, VICH-15, 322 Bt, 110 Bt, 6188 Bt, 563 Bt , 311 Bt	SOLAR-66 BG-II, SOLAR-60 BG-II, SP 904B2, SP 1016 B2, SP 1170 B2, SP-504, Super-5 BG-II, Sudarshan BG-II, SWCH-2 BG-II, SWCH-4708 BG-II, SWCH-4715 BG-II, SWCH-1 BG-II, SWCH-5017, SWCH-5011, Tulasi-135 BG-II, Tulasi-144 BG-II, Tulasi-162 BG-II, Tulasi-117 BG-II, Tulasi-4, Tulasi-9, Tulasi-118, VBCH-1511, VBCH-1516, VBCH-1519, VBCH-1520, VBCH-1521, VBCHB-1525, VBCHB-1526, VICH-311 BG-II, VBCH-1501, VBCH-1503, VBCH-1505, VICH-312 BG-II, VICH-313 BG-II, VICH-314 BG-II, VICH-5 Bt, VICH-15, 311-2, 557-2, 110-2, 111-2, 195-2	ACH 1050 Bt, ACH 1151 Bt, ACH 1171 Bt, ACH-1019, Dhruv Bt, Kashi-nath, GBCH-07 Bt, GBCH-09 Bt, GBCH-01, Monsoon Bt, Navkar-5, NCEH-2R, NCEH-3R, NCEH-21, NCEH-23, NCEH-14, NCEH-34 Bt, SBCH-286 Bt (Raka Bt), TPHCN07-015 Bt, TPHCN07-005 Bt, TPHCN07-009 Bt, UPLHH-271 Bt, UPLHH-17 Bt, UPLHH-12 Bt, UPLHH-189 Bt, UPL-HH-352 Bt, UPLHH-13 Bt,UPLHH-1Bt, UPLHH-10 Bt, UPLHH-2Bt, YRCH-4 Bt, YRCH-9 Bt, YRCH-13 Bt, YRCH-31 Bt, YRCH-45 Bt, YRCH-54 Bt, ZCH-50005, ZCH-50072 Bt, *JK-Chamundi Bt, JK-Gowri Bt, JKCH-2245 Bt, JKCHB-229 Bt, JK-Ishwar (JKCH-634 Bt), JKCH-99, JKCH-226, JKCH-666, JK-Durga Bt, JK-Indra Bt, JK-Varuna, PCH-99 Bt, PCH-77 Bt, PRCH-712 Bt, PRCH-713 Bt, PRCH-714 Bt, PRCH-715 Bt,* **MH-5125Bt, MH-5174Bt, BN Bt (Variety)**
South Zone (**294 Hybrids,** 6 Events, 35 Companies)	ABCH-172 Bt, ABCH-173 Bt, ABCH-174 Bt, ABCH-177 Bt, ABCH-178 Bt, ABCH-3083 Bt, ABCH-3483 Bt, ABCH-1165, ABCH-1220, ACHB-901-1 Bt, ACH-1 Bt,	ABCH-143 Bt BG-II, ABCH-146 Bt BG-II, ABCH-147 Bt BG-II, ABCH-148 Bt BG-II, ABCH-1299 Bt BG-II, ABCH-7399 Bt BG-II, ABCH-181 Bt BG-II, ABCH-182 Bt BG-II, ABCH-191 Bt BG-II, ABCH-192 Bt BG-II, ABCH-1065 Bt, ABCH-1020 Bt, ACH-33-2, ACH-177-2, ACH-155-2, Akka,	Dhruv Bt, GBCH-04Bt, GBCH-07 Bt, Kashinath, Monsoon Bt, NCEH-2R, NCEH-3R, NCEH-13 Bt, NCEH-34 Bt, SBCH-310 Bt, SBCH-292 Bt, TPHCN07-015 Bt, TPHCN07-005 Bt, TPHCN07-009 Bt, UPLHH-189 Bt,

Table 1 Continued.

Zone	BG-I Hybrids	BG-II Hybrids	GFM/Event-I/MLS-9124/BNLA-601
South Zone (**294 Hybrids,** 6 Events, 35 Companies)	ACH 21-1, ACH 33-1, ACH 155-1, Akka, Ankur-238 Bt, Ankur-3082 Bt, Ankur HB 1024 Bt, Ankur-3042 Bt, Ankur HB-1902 Bt, Ankur HB-1976 Bt, Brahma, Dyna, GK-207, GK-209, Jai Bt, KCH-135, KCH-707, Mahasangram BG, KDCHH-507 BG-I, KDCHB-407, KD-CHH-9632, KDCHH-9810, MECH-162*, MECH-184*, MRC-6322, MRC-6918, NCS-1911 Bt, NCS-1912 Bt, NCS-1913, NCS-1914 Bt, NCS-145 (Bunny), NCS-207 (Mallika), NCS-913, NCS-929, NCS-950, NCS-954, NCS-906 Bt, NCS-907 Bt, NCS-908 Bt, NCS-909 Bt, NCS-910 Bt, NCHB-940 Bt, NCHB-945 Bt, NCHB-990, NCHB-992, NPH-2171, NSPL-9, NSPL-36, NSPL-603, NSPL-666, NSPL-405, NSPL-999, Ole, PCH-1410 Bt, PCH 1411 Bt, PCH 1412 Bt, PCH-1413 Bt, PCH-115, PCH-207 (PCH 205), PCH-409 Bt, PCH-930,	Ankur-3028 BG-II, Ankur-3034 BG-II, Ankur-257 BG-II, Ankur-356 BG-II, Ankur-3066 BG-II, Ankur HB 2110 BG-II, Ankur-5642, Ankur-10122, Atal BGII, Brahma, GK-218 BGII, GK-221 BGII, GK-223 BGII, GK-224 BGII, GK-231 BGII, GK-235 BGII, GK-217, Jai BG-II, KCH-707 BGII, KCH-14K59 BGII, KCH-15K39 BGII, KCH-36 BGII, KCH-999 BGII, KCH-135 Bt, KDCHH-541 BGII, KDCHB-407 BG-II, KDCHH-441, KDCHH-621, KDCHH-9632, MLBCH6 BGII, MLCH-318, MRC-7373 BGII, MRC-7383 BGII, MRC-7160, MRC-7918, MRC-7201, MRC-7347, MRC-7351, MRC-7929, NAMCOT-612, NAMCOT-607, NAMCOT-604 BG-II, NAMCOT-605 BG-II, NAMCOT-614 BG-II, NAMCOT-615 BG-II, NCS-854, NCS-207, NCS-145 (Bunny), NSPL-432 BGII, NSPL-333 BGII, NSPL-405, NSPL-999, PCH-884 Bt2, PCH-887 Bt2, PCH-888 Bt2, PCH-115 Bt2, PCH-881 Bt2, PCH-882 Bt2, PCH-885 Bt2, PCH-886 Bt2, PCH-205 Bt2, PCH-2171 Bt2, PCH-2270, PCH-105, PRCH-331 BG-II, PRCH-333 BG-II, PRCH-504, PRCH-505, RCH-20 BG-II, RCH-2, RCH-530, RCH-533, RCH-596, SARJU BG-II, SOLAR-66 BG-II, SOLAR-60 BG-II, SP-1171 B2, SP 504 B2 (Dhanno) BG II, SP911B2, SP904B2, SP-1037, Sudarshan BGII, Super-5 BG-II, SWCH-2 BG-II, SWCH-4708 BG-II, SWCH-4703 BG-II, SWCH-4715 BG-II, SWCH-4720 BG-II, SWCH-5017 BG-II, SWCH-5011 BG-II,Tulasi-135 BG-II, Tulasi-144 BG-II,	UPLHH-7 Bt, UPLHH-295 Bt, UPLHH-355 Bt, UPLHH-358 Bt, UPLHH-360 Bt, UPLHH-347 Bt, UPLHH-265 Bt, UPLHH-271 Bt, UPLHH-10 Bt, YRCH-4 Bt, YRCH-9 Bt, YRCH-13 Bt, YRCH-31 Bt, YRCH-45 Bt,YRCH-54 Bt, UPLHH-12 Bt, UPLHH-5 Bt, ZCH-50072 Bt, *JKCH-1305 Bt, JKCHB-229 Bt, JK-Durga, JKCH-99, JKCH-634 (JK-Iswar), JKCH-2245 Bt, JK Chamundi Bt, JK-Indra Bt, JK-Gowri Bt, PCH-99 Bt, PCH-77 Bt, PRCH-712 Bt, PRCH-713 Bt, PRCH-714 Bt, PRCH-715 Bt,* **MH-5125Bt, MH-5174Bt, BN Bt (Variety)**

Table 1 Continued.

Zone	BG-I Hybrids	BG-II Hybrids	GFM/Event-I/MLS-9124/BNLA-601
South Zone (**294 Hybrids,** 6 Events, 35 Companies)	PCH-2270, PRCHB-405, RCH-2, RCH-20, RCH-111, RCH-371, RCH-368, RCHB-708, Rudra, Sigma, SP 1170 B1, SP1016 B1, SP911B1, SP-503, SP-504 (Dhanno), SP-700, SWCH-4428 Bt, SWCH-4531 Bt, SWCH-4314 Bt, Tulasi-9 Bt, Tulasi-4, Tulasi-45 Bt, Tulasi-117, Tulasi-118 Bt, VBCHB-1010 BG, VBCH-1016 Bt, VBCH-1018 Bt, VBCHB-1203, VICH-5, VICH-9, VCH-111, 118 Bt, 340 Bt, 6188 Bt	Tulasi-252 BG-II, Tulasi-4 BG-II, Tulasi-45 BG-II, Tulasi-117 BG-II, Tulasi-333 BG-II, Tulasi-7, Tulasi-9, Tulasi-118, VBCHB-1525 BG-II, VBCHB-1526 BG-II, VBCH-1511 BG-II, VBCH-1516 BG-II, VBCH-1519 BG-II, VBCH-1520 BG-II, VBCH-1521 BG-II, VBCH-1501, VBCH-1505, VBCH-1506, VICH-301 BG-II, VICH-303 BG-II, VICH-304 BG-II, VICH-311 BG-II, VICH-312 BG-II, VICH-313 BG-II, VICH-314 BG-II, VICH-5 Bt,VICH-15 Bt, 110-2, 118-2, 61888-2, 322-2, 113-2, 340-2	

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