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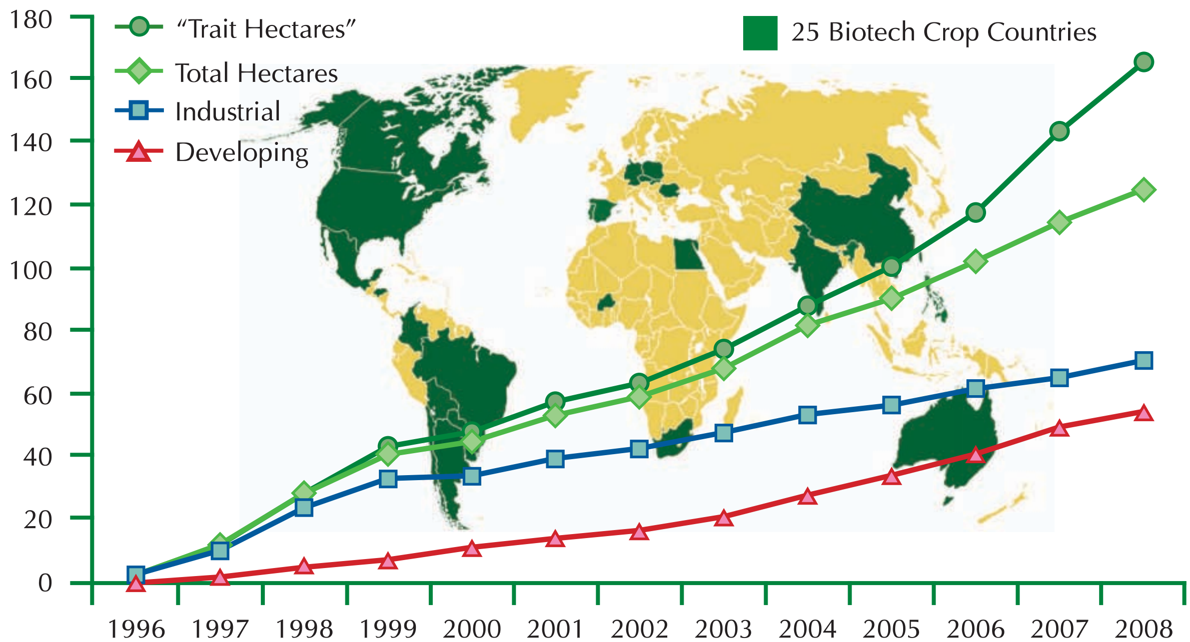
BRIEF 39

Global Status of Commercialized Biotech/GM Crops: 2008

by

Clive James
Founder and Chair, ISAAA Board of Directors

GLOBAL AREA OF BIOTECH CROPS
Million Hectares (1996-2008)



An "apparent" increase of 9.4% or 10.7 million hectares between 2007 and 2008, equivalent to a "real" increase of 15% or 22 million "trait hectares"

Source: Clive James, 2008.

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Highlights of the Global Status of Commercialized Biotech/GM Crops: 2008

by Clive James, Founder and Chair of ISAAA

This summarizes the 2008 biotech crop highlights, comprehensively reviewed in ISAAA Brief 39 (http://www.isaaa.org). As a result of consistent and substantial economic, environmental and welfare benefits, a record 13.3 million large, small and resource-poor farmers continued to plant significantly more hectares of biotech crops in 2008. Progress was also made on several other important fronts in 2008, with a notable increase in the number of countries planting biotech crops globally; substantial progress in Africa where the challenges are greatest; increased adoption of stacked traits; and the introduction of a new biotech crop. These are very important developments given that biotech crops contribute to some of the major challenges facing global society including: food, feed and fiber security; lower price of food; sustainability; alleviation of poverty and hunger; and mitigation of some of the challenges associated with climate change.

The number of countries planting biotech crops soared to 25 – a historical milestone – a new wave of adoption of biotech crops contributed to broad-based global growth.

Progress in Africa – number of countries increased from one in 2007, South Africa, to three in 2008, with Burkina Faso (cotton) and Egypt (maize) planting biotech crops, for the first time.

Bolivia (RR®soybean) became the ninth country in Latin America to adopt biotech crops.

Global hectarage of biotech crops continued its strong growth in 2008 for the thirteenth consecutive year – a 9.4%, or 10.7 million hectare increase, reaching 125 million hectares, or more precisely, 166 million "trait hectares", equivalent to a 15% growth or a 22 million "trait hectare" increase. The 74-fold hectare increase since 1996 makes biotech crops the fastest adopted crop technology.

In 2008, for the first time, the accumulated hectarage of biotech crops, for the period 1996 to 2008, exceeded 2 billion acres (800 million hectares) – it took 10 years for the 1st billionth acre in 2005, but only 3 years for the 2nd billionth acre in 2008. Notably, of the 25 countries planting biotech crops, 15 were developing countries versus only 10 industrial countries.

A new biotech crop, RR®sugar beet, was first commercialized in the USA and Canada in 2008.

Five countries, Egypt, Burkina Faso, Bolivia, Brazil and Australia introduced, for the first time, biotech crops that have been commercialized in other countries.

Stacked traits are an increasingly important feature of biotech crops. Ten countries planted approximately 27 million hectares of stacked traits in 2008 and at 23% growth, they grew faster than single traits.

The number of biotech crop farmers increased by 1.3 million in 2008, reaching 13.3 million globally in 25 countries – notably, 90%, or 12.3 million were small and resource-poor farmers in developing countries.

Biotech crops have improved the income and quality of life of small and resource-poor farmers and their families, and contributed to the alleviation of their poverty – case studies are cited in Brief 39 for India, China, South Africa, and the Philippines.

Five principal developing countries: China, India, Argentina, Brazil and South Africa, with a combined population of 2.6 billion, are exerting leadership with biotech crops, and driving global adoption – benefits from biotech crops are spurring strong political will and substantial new investments in biotech crops in several of these lead countries.

Notably, all seven EU countries planting Bt maize increased their hectarage in 2008, resulting in an overall increase of 21%, to reach over 107,000 hectares.

The impressive contribution of biotech crops to sustainability is reviewed: 1) Contributing to food, feed and fiber security including more affordable food (lower prices); 2) Conserving biodiversity; 3) Contributing to the alleviation of poverty and hunger; 4) Reducing agriculture's environmental footprint; 5) Helping mitigate climate change and reducing greenhouse gases; 6) Contributing to more cost-effective production of biofuels; and 7) Contributing to sustainable economic benefits worth US$44 billion from 1996 to 2007. In summary, collectively these seven thrusts are a significant contribution to sustainability and the potential for the future is enormous.

Of the economic gains of US$44 billion during the period 1996 to 2007, 44% were due to substantial yield gains, and 56% due to a reduction in production costs (including a 359,000 tonnes a.i. saving in pesticides); the production gains of 141 million tons, would have required 43 million additional hectares had biotech crops not been deployed – a land-saving technology.

In agricultural-based and transforming developing countries, biotech crops are an engine of rural economic growth, which in turn can contribute substantially to national economic growth.

More than half (55%) the world's population live in the 25 countries, which planted 125 million hectares of biotech crops in 2008, equivalent to 8% of the 1.5 billion hectares of all cropland in the world. In 2007, biotech crops saved 14.2 billion kg of CO_2 equivalent to 6.3 million less cars.

There is an urgent need for appropriate cost/time-effective regulatory systems for biotech crops that are responsible, but not onerous, and affordable for developing countries.

Twenty-five countries have approved planting of biotech crops and another 30 countries have approved import of biotech products for food and feed use for a total of 55 approving countries.

The global value of the biotech crop market in 2008 was US$7.5 billion with an accumulated historical milestone value of US$50 billion for the period 1996 to 2008.

Future Prospects. Outlook for the remaining seven years of the second decade of commercialization of biotech crops, 2006 to 2015 looks promising – the 2005 ISAAA prediction that the number of biotech crop countries, hectarage and beneficiary farmers would all double between 2006 and 2015, is on track. Rice as a crop, and drought tolerance as a trait, are expected to be pivotal for future growth. Brief 39 includes a special feature on drought tolerant biotech maize, expected to be commercialized in the USA in 2012, or earlier, and in Sub Saharan Africa in 2017.

Global Status of Commercialized Biotech/GM Crops: 2008
The First Thirteen Years, 1996 to 2008

Introduction

This Executive Summary focuses on the 2008 biotech crop highlights, which are discussed in more detail in Brief 39. The Brief also includes a fully referenced special feature on the status of drought tolerance in conventional and biotech maize.

As a result of the consistent and substantial economic, environmental and welfare benefits offered by biotech crops, millions of small and resource-poor farmers around the world continued to plant more hectares of biotech crops in 2008, the thirteenth year of commercialization. **Progress was made on several important fronts in 2008 with: significant increases in hectarage of biotech crops; increases in both the number of countries and farmers planting biotech crops globally; substantial progress in Africa, where the challenges are greatest; increased adoption of stacked traits and the introduction of a new biotech crop.** These are very important developments given that biotech crops can contribute to some of the major challenges facing global society, including: **food security, high price of food, sustainability, alleviation of poverty and hunger, and help mitigate some of the challenges associated with climate change.**

Number of countries planting biotech crops soars to 25 – a historical milestone – a new wave of adoption of biotech crops is contributing to a broad-based and continuing hectarage growth of biotech crops globally

It is noteworthy that in 2008, **the number of biotech countries planting biotech crops reached the historical milestone of 25 countries (Table 3 and Figure 4).** The number of countries electing to grow biotech crops has increased steadily from 6 in 1996, the first year of commercialization, to 18 in 2003 and 25 in 2008. A new wave of adoption of biotech crops is fueled by several factors, which are contributing to a broadly based global growth in biotech crops. These factors include: an increase in the number of biotech countries **(3 new biotech countries in 2008); significant progress in Africa, the continent with the greatest challenge with an increase from 1 country in 2007 to 3 countries in 2008 with South Africa being joined by Burkina Faso and Egypt; Bolivia planting biotech soybean for the first time; additional biotech crops being deployed in biotech countries already growing biotech crops (Brazil planting Bt maize, and Australia biotech canola, for the first time); a new biotech crop, biotech sugar beet deployed in the USA and Canada; and significant growth in stacked traits in cotton and maize, increasingly deployed by 10 countries worldwide.** 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. **Notably in 2008, accumulatively the second billionth acre (800 millionth hectare) of a biotech crop was planted – only 3 years after the first one-billionth**

acre of a biotech crop was planted in 2005. In 2008, developing countries out-numbered industrial countries by 15 to 10, and this trend is expected to continue in the future with 40 countries, or more, expected to adopt biotech crops by 2015, the final year of the second decade of commercialization. By coincidence, 2015 also happens to be the Millennium Development Goals 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.

Progress in Africa – two new countries, Burkina Faso and Egypt, plant biotech crops for the first time

Africa is home to over 900 million people representing 14% of the world population and is the only continent in the world where food production per capita is decreasing and where hunger and malnutrition afflicts at least one in three Africans. It is noteworthy that two of the three new countries that planted biotech crops for the first time in 2008 were from Africa, the continent with the greatest and most urgent need for crop biotechnology. For the first twelve years of commercialization of biotech crops, 1996 to 2007, South Africa has long been the only country on the African continent to benefit from commercializing biotech crops. Africa is recognized as the continent that represents by far the biggest challenge in terms of adoption and acceptance. Accordingly, the decision in 2008 by Burkina Faso to grow 8,500 hectares of Bt cotton for seed multiplication and initial commercialization and for Egypt to commercialize 700 hectares of Bt maize for the first time was of strategic importance for the African continent. **For the first time, there is a lead country commercializing biotech crops in each of the three principal regions of the continent: South Africa in southern and eastern Africa; Burkina Faso in west Africa; and Egypt in north Africa.** This broad geographical coverage in Africa is of strategic importance in that it allows the three countries to become role models in their respective regions and for **more African farmers to become practitioners of biotech crops and to be able to benefit directly from "learning by doing", which has proven to be such an important feature in the success of Bt cotton in China and India.** In December 2008, Kenya, a pivotal biotech crop country in east Africa, enacted a Biosafety Law (pending signature by the President as of end of December 2008), which will facilitate the adoption of biotech crops.

Bolivia becomes the ninth country in Latin America to adopt biotech crops

The third new biotech crop country in 2008 was Bolivia in the Andean region of Latin America. **Bolivia is the eighth largest grower of soybean in the world and is no longer disadvantaged compared with its neighbors, Brazil and Paraguay, which have benefited substantially for many years from herbicide tolerant RR®soybean.** Bolivia becomes the ninth country in Latin America to benefit from the extensive adoption of biotech crops; the nine Latin American countries, listed in order of hectarage are: Argentina, Brazil, Paraguay, Uruguay, Bolivia, Mexico, Chile, Colombia, and Honduras. Bolivia planted 600,000 hectares of RR®soybean in 2008.

Global hectarage of biotech crops continues strong growth in 2008 – reaches 125 million hectares, or more precisely, 166 million "trait hectares"

In 2008, the global hectarage of biotech crops continued to grow strongly reaching 125 million hectares, up from 114.3 million hectares in 2007. This translates to an "apparent growth" of 10.7 million hectares (the sixth largest increase in 13 years) or 9.4% measured in hectares, whereas the "actual growth", measured more precisely in "trait hectares", was 22 million hectares or 15% year-on-year growth, approximately double the "apparent growth". Measuring in "trait hectares" is similar to measuring air travel (where there is more than one passenger per plane) more accurately in "passenger miles" rather than "miles". Thus in 2008, global growth in "trait hectares" increased from 143.7 million "trait hectares" in 2007 to 166 million "trait hectares". As expected, more of the growth in the early-adopting countries is now coming from the deployment of "stacked traits" (as opposed to single traits in one variety or hybrid), as adoption rates measured in hectares reach optimal levels in the principal biotech crops of maize and cotton. For example, in 2008 an impressive 85% of the 35.3 million hectare national maize crop in the USA was biotech and remarkably, 78% of it was hybrids with either double or triple stacked traits – only 22% was occupied by hybrids with a single trait. SmartStax™ biotech maize, with 8 genes for several traits, is expected to be commercialized in the USA in 2010, only two years from now. Similarly, biotech cotton occupies more than 90% of the national area in the USA, Australia and South Africa, with double-stacked traits occupying 75% of all biotech cotton in the USA, 81% in Australia and 83% in South Africa. It is evident that stacked traits have already become a very important feature of biotech crops, and accordingly it is important to measure growth more precisely in "trait hectares" as well as hectares. Notably, the 74-fold hectare increase between 1996 and 2008 makes biotech crops the fastest adopted crop technology in agriculture.

In 2008, accumulated hectarage of biotech crops for the period 1996 to 2008 exceeded 2 billion acres (800 million hectares) for the first time – it took 10 years to reach the first billion acres but only 3 years to reach the second billion acres – of the 25 countries planting biotech crops, 15 were developing and 10 industrial

It took 10 years before the first one billionth acre of biotech crops was planted in 2005 – however it took only three years before the second billionth acre (800 millionth hectare) was planted in 2008. It is projected that 3 billion acres will be exceeded in 2011 with over 4 billion accumulated acres (1.6 billion hectares) by 2015, the Millennium Development Goals year. In 2008, the number of countries planting biotech crops increased to 25, comprising 15 developing countries and 10 industrial countries. The top eight countries each grew more than 1 million hectares; in decreasing order of hectarage they were; **USA (62.5 million hectares), Argentina (21.0), Brazil (15.8), India (7.6), Canada (7.6), China (3.8), Paraguay (2.7), and South Africa (1.8 million hectares).** Consistent with the trend for developing countries to play an increasingly important role, it is noteworthy that India with a high 23% growth rate between 2007 and 2008 narrowly displaced

Canada for the fourth ranking position globally in 2008. **The remaining 17 countries which grew biotech crops in 2008 in decreasing order of hectarage were:** Uruguay, Bolivia, Philippines, Australia, Mexico, Spain, Chile, Colombia, Honduras, Burkina Faso, Czech Republic, Romania, Portugal, Germany, Poland, Slovakia and Egypt. The strong growth in 2008 provides a very broad and stable foundation for future global growth of biotech crops. The growth rate between **1996 and 2008 was an unprecedented 74-fold increase making it the fastest adopted crop technology in recent history.** This very high adoption rate by farmers reflects the fact that biotech crops have consistently performed well and delivered significant economic, environmental, health and social benefits to both small and large farmers in developing and industrial countries. This high adoption rate **is a strong vote of confidence from millions of farmers who have made approximately 70 million individual decisions in 25 countries over a 13-year period to consistently continue to plant higher hectarages of biotech crops, year-after-year, after gaining first-hand insight and experience with biotech crops on their own or neighbor's fields.** High re-adoption rates of close to 100% reflect farmer satisfaction with the products that offer substantial benefits ranging from more convenient and flexible crop management, to lower cost of production, higher productivity and/or higher net returns per hectare, health and social benefits, and a cleaner environment through decreased use of conventional pesticides, which collectively contributed to a more sustainable agriculture. The continuing rapid adoption of biotech crops reflects the substantial and consistent benefits for both large and small farmers, consumers and society in both industrial and developing countries.

A new biotech crop, RR®sugar beet, was commercialized in two countries, the USA and Canada

In 2008, a new biotech crop, RR® herbicide tolerant sugar beet, was introduced for the first time globally in the USA plus a small hectarage in Canada. Notably, of the total US national hectarage of 437,246 hectares of sugar beet, a substantial 59% (the highest ever percent adoption for a launch) or 257,975 hectares were planted with RR® biotech sugar beet in 2008, the launch year; the percentage adoption in 2009 is expected to be close to 90%. The success of the RR®sugar beet launch has positive implications for sugarcane, (80% of global sugar production is from cane) for which several biotech traits are at an advanced stage of development in several countries.

Five countries Egypt, Burkina Faso, Bolivia, Brazil and Australia introduced, for the first time, biotech crops that have already been commercialized in other countries

Egypt, Burkina Faso, Bolivia, Brazil and Australia introduced for the first time biotech crops that have already been commercialized in other countries: Egypt introduced Bt maize, Burkina Faso Bt cotton, and Bolivia RR®soybean. Additional biotech crops were introduced by countries already planting biotech crops with Brazil, planting Bt maize and Australia, planting biotech canola for the first time. In 2008, the breadth and depth of the global deployment of the principal biotech crops was impressive and provides a solid foundation for further growth in the remaining seven years of the second decade of commercialization 2006 to 2015. In 2008, 17, or two-thirds of the 25-biotech countries planted biotech maize (same as 2007), 10 countries planted biotech soybean (up from 9), 10 countries planted biotech cotton (up from 9) and 3 countries planted biotech canola (up from 2 in 2007). In addition, two countries the USA and China grew virus resistant papaya, two countries Australia and Colombia grew biotech carnation, plus a small hectarage of Bt poplar in China, and biotech squash and alfalfa in the USA.

Adoption by crop

Biotech soybean continued to be the principal biotech crop in 2008, occupying 65.8 million hectares or 53% of global biotech area, followed by biotech maize (37.3 million hectares at 30%), biotech cotton (15.5 million hectares at 12%) and biotech canola (5.9 million hectares at 5% of the global biotech crop area).

Adoption by trait

From the genesis of commercialization in 1996 to 2008, herbicide tolerance has consistently been the dominant trait. **In 2008, herbicide tolerance deployed in soybean, maize, canola, cotton and alfalfa occupied 63% or 79 million hectares of the global biotech area of 125 million hectares.** For the second year running in 2008, the stacked double and triple traits occupied a larger area (26.9 million hectares, or 22% of global biotech crop area) than insect resistant varieties (19.1 million hectares) at 15%. **The stacked trait products were by far the fastest growing trait group between 2007 and 2008 at 23% growth, compared with 9% for herbicide tolerance and -6% for insect resistance.**

Stacked traits – an increasingly important feature of biotech crops – 10 countries planted biotech crops with stacked traits in 2008

Stacked products are a very important feature and future trend, which meets the multiple needs of farmers and consumers and these are now increasingly deployed by ten countries – USA, Canada, Philippines, Australia, Mexico, South Africa, Honduras, Chile, Colombia, and Argentina, (7 of the 10 are developing countries), with more countries expected to adopt stacked traits in the future. A total of 26.9 million hectares of stacked biotech crops were planted in 2008 compared with 21.8 million hectares in 2007. In 2008, the USA led the way with 41% of its total 62.5 million hectares of biotech crops stacked, including 75% of cotton, and 78% of maize; the fastest growing component of stacked maize in the USA was the triple stacks conferring resistance to two insect pests plus herbicide tolerance. Double stacks with pest resistance and herbicide tolerance in maize were also the fastest growing component in 2008 in the Philippines doubling from 25% of biotech maize in 2007 to 57% in 2008. Biotech maize with eight genes, named **SmartStax™,**

is expected to be released in the USA in 2010 with eight different genes coding for several pest resistant and herbicide tolerant traits. Future stacked crop products will comprise both agronomic input traits for pest resistance, tolerance to herbicides and drought plus output traits such as high omega-3 oil in soybean or enhanced pro-Vitamin A in Golden Rice.

Number of biotech crop farmers increased by 1.3 million in 2008, reaching 13.3 million globally in 25 countries – notably 90%, or 12.3 million were small and resource-poor farmers in developing countries

In 2008, the number of farmers benefiting from biotech crops globally in 25 countries reached 13.3 million, an increase of 1.3 million over 2007. Of the global total of 13.3 million beneficiary biotech farmers in 2008, (up from 12 million in 2007), remarkably over 90% or 12.3 million (up from 11 million in 2007) were small and resource-poor farmers from developing countries; the balance of 1 million were large farmers from both industrial countries such as the USA and Canada and developing countries such as Argentina and Brazil. Of the 12.3 million small and resource-poor farmers, most were Bt cotton farmers, 7.1 million in China (Bt cotton), 5.0 million in India (Bt cotton), and the balance of 200,000 in the Philippines (biotech maize), South Africa (biotech cotton, maize and soybeans often grown by subsistence women farmers) and the other eight developing countries which grew biotech crops in 2008. **The largest increase in the number of beneficiary farmers in 2008 was in India where an additional 1.2 million more small farmers planted Bt cotton which now occupies 82% of total cotton, up from 66% in 2007. The increased income from biotech crops for small and resource-poor farmers represents an initial modest contribution towards the alleviation of their poverty. During the second decade of commercialization, 2006 to 2015, biotech crops have an enormous potential for contributing to the Millennium Development Goals (MDG) of reducing poverty by 50% by 2015.**

Up to 10 million more small and resource-poor farmers may be secondary beneficiaries of Bt cotton in China

A 2008 seminal paper by Wu *et al.* (2008) reports that **the use of Bt cotton to control cotton bollworm in six northern provinces in China was associated with up to a substantial ten-fold suppression of cotton bollworm infestations in crops other than cotton, which are also hosts of cotton bollworm;** these crops include, maize, soybean, wheat, peanuts, vegetables, and other crops. In contrast to cotton, which occupies 3 million hectares farmed by 5 million farmers in the six provinces, these other crops occupy a much larger area of 22 million hectares and are farmed by 10 million farmers. **The initial findings reported by Wu *et al.* (2008) could be important for two reasons. Firstly, Bt cotton may have a broader and more significant impact than its documented direct impact on the cotton crop. Secondly, the findings may also apply to other countries, such as India, where small and resource-poor farmers practice similar**

mixed cropping systems and where there is, like China, extensive adoption of Bt cotton to control bollworm.

Biotech crops have improved the income and quality of life of small resource-poor farmers and their families and contributed to the alleviation of their poverty – case studies are cited from India, China, South Africa, and the Philippines

In India in 2008, 5 million small farmers, (up from 3.8 million farmers in 2007) benefited from planting 7.6 million hectares of Bt cotton, equivalent to a high adoption rate of 82%. Benefits will vary according to varying pest infestation levels in different years and locations. However, on average, conservative estimates for small farmers (Gandhi and Namboodori, 2006) indicate that **yield increased by 31%, insecticide application decreased by 39%, and profitability increased by 88% equivalent to US$250 per hectare.** In addition, in contrast to the families of farmers planting conventional cotton, families of Bt cotton farmers enjoyed emerging welfare benefits including more prenatal care and assistance with at-home births for women, plus a higher school enrollment of their children, a higher percentage of whom were vaccinated.

In China, based on studies conducted by the Center for Chinese Agricultural Policy (CCAP), it was concluded that, on average, small farmers adopting **Bt cotton increased yield by 9.6%, reduced insecticide use by 60%, with positive implications for both the environment and the farmers' health, and generated a substantial US$220/hectare increase in income** which made a significant contribution to their livelihood as the income of many cotton farmers can be as low as US$1 per day. In China in 2008, 7.1 million small and resource-poor farmers benefited from Bt cotton.

In South Africa, a study published in 2005 (Gouse *et al.,* 2005) involved 368 small and resource-poor farmers and 33 commercial farmers, the latter divided into irrigated and dry land maize production systems. The data indicated that under irrigated conditions, **Bt maize resulted in an 11% higher yield** (from 10.9 MT to 12.1 MT/ha), a cost savings in insecticides of US$18/ha equivalent to a 60% cost reduction, **and an increase income of US$117/hectare.** Under rainfed conditions, Bt maize resulted in an 11% higher yield (from 3.1 to 3.4 MT/ha), a cost saving on insecticides of US$7/ha equivalent to a 60% cost reduction, and **an increased income of US$35/hectare.**

In the Philippines at least 200,000 small farmers gained from biotech maize in 2008. A socio-economic impact study (Gonzales, 2005), reported that for small farmers, **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 years, 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.

Five principal developing countries China, India, Argentina, Brazil and South Africa are exerting leadership, and driving global adoption of biotech crops – benefits from biotech crops are spurring strong political will and substantial new investments in biotech crops

The five principal developing countries committed to biotech crops, span all three continents of the South; **they are India and China in Asia, Argentina and Brazil in Latin America and South Africa on the African continent – collectively they represent 2.6 billion people or 40% of the global population, with a combined population of 1.3 billion who are completely dependent on agriculture, including millions of small and resource-poor farmers and the rural landless, who represent the majority of the poor in the world.** The increasing collective impact of the five principal developing countries is an important continuing trend with implications for the future adoption and acceptance of biotech crops worldwide. The five countries are reviewed in detail in Brief 39 including extensive commentaries on the current adoption of specific biotech crops, impact and future prospects. Research and Development investments in crop biotechnology in these countries are substantial, even by multinational company standards. Notably in 2008, China committed an additional US$3.5 billion over twelve years with **Premier Wen Jiabao (Chairman of the State Council/Cabinet of China) expressing China's strong political will for the technology** when addressing the Chinese Academy of Sciences in June 2008, ***"to solve the food problem, we have to rely on big science and technology measures, rely on biotechnology, rely on GM."*** **Dr. Dafang Huang,** former Director of the Biotechnology Research Institute of the Chinese Academy of Agricultural Sciences (CAAS) concluded that ***"Using GM rice is the only way to meet the growing food demand"*** (Qiu, 2008).

President Luis Inacio Lula da Silva of Brazil has also demonstrated the same strong political will for biotech crops and committed public funds of the same order of magnitude as China with several of its own products being advanced for approval through Brazil's national agricultural research organization, EMBRAPA. Similarly, India is investing approximately US$300 million additional public funding to support its stable of approximately 15 biotech crops, the first of which, a public sector developed Bt cotton variety, was approved in 2008. Political will and support for biotech crops in India is high as evidenced by the following statement by India's Minister of Finance **Dr. P. Chidambaram**, who called for an emulation of the remarkable Indian biotech Bt cotton success story 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, 2007).** It is notable that the strategically important concept of South-South collaboration is already being realized between China and India with the first Bt cotton developed by China, already being marketed and adopted in India; this is a first indication of a very important new trend that is of great significance.

Due to their potential for producing more affordable food and for mitigating some of the challenges associated with climate change, biotech crops are, also gaining increased political support from global political organizations.

- **G8 members meeting in Hokkaido Japan in July 2008** recognized for the first time the significance of the important role that biotech crops can play in food security. The G8 leaders' statement on biotech crops (G8, 2008) reads as follows, ***"accelerate research and development and increase access to new agricultural technologies to boost agriculture production; we will promote science-based risk analysis, including on the contribution of seed varieties developed through biotechnology."***

- **The European Commission** stated that ***"GM crops can play an important role in mitigating the effects of the food crisis"*** (Adam, 2008).

- **The World Health Organization (WHO)** has emphasized the importance of biotech crops because of their potential to benefit the public health sector by providing more nutritious food, decreasing its allergenic potential and also improving the efficiency of production systems (Tan, 2008).

All seven EU countries increased their Bt maize hectarage in 2008, resulting in an overall increase of 21% to reach over 100,000 hectares

In 2008, seven of the 27 countries in the European Union, officially planted Bt maize on a commercial basis. The total hectarage for the seven countries increased from 88,673 hectares in 2007 to 107,719 hectares in 2008; this is equivalent to a 21% year-on-year increase equivalent to 19,046 hectares. **The seven EU countries listed in order of biotech hectarage of Bt maize were Spain, Czech Republic, Romania, Portugal, Germany, Poland and Slovakia.**

Contribution of biotech crops to Sustainability – the multiple contributions of biotech crops have enormous potential

The World Commission on the Environment and Development defined sustainable development as follows: **"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987).**

To-date, biotech crops have contributed to sustainable development in several significant ways, listed and summarized below:

1. Contributing to food security and more affordable food (lower prices)
2. Conserving biodiversity.
3. Contributing to the alleviation of poverty and hunger
4. Reducing agriculture's environmental footprint
5. Mitigating climate change and reducing greenhouse gases (GHG)
6. Contributing to the cost-effective production of biofuels
7. Contributing to sustainable economic benefits

1. **Contributing to food security and more affordable food (lower prices)**

   Biotech crops can play an important role by contributing to food security and more affordable food through increasing supply (by increasing productivity per hectare) and coincidentally decreasing cost of production (by a reduced need for inputs, less ploughing and fewer pesticide applications) which in turn also requires less fossil fuels for tractors, thus mitigating some of the negative aspects associated with climate change. **Of the economic gains of US$44 billion during the period 1996 to 2007, 44% were due to substantial yield gains, and 56% due to a reduction in production costs. In 2007, the total crop production gains globally for the 4 principal biotech crops (soybean, maize, cotton and canola) was 32 million metric tons, which would have required 10 million additional hectares had biotech crops not been deployed. The 32 million metric tons of increased crop production from biotech crops in 2008 comprised 15.1 million tons of maize, 14.5 million tons of soybean, 2.0 million tons of cotton lint and 0.5 million tons of canola. For the period 1996-2007 the production gains were 141 million tons, which (at 2007 average yields) would have required 43 million additional hectares had biotech crops not been deployed** (Brookes and Barfoot, 2009, forthcoming). Thus, biotechnology has already made a contribution to higher productivity and lower costs of production of current biotech crops, and has enormous potential for the future when the staples of rice and wheat, as well as pro-poor food crops such as cassava will benefit from biotechnology.

   Progress with control of abiotic stresses is expected in the near term with drought tolerance becoming available by 2012, or earlier in the USA and in Sub Saharan Africa by 2017 where maize is the staple food. Rice, the most important food crop of the poor in the world offers a unique opportunity for increasing supply and hence cheaper food (Bt rice) and also for providing more nutritious food (high pro-vitamin A Golden Rice). **Biotech rice, awaiting approval in China has enormous potential to contribute to food security, lower food prices and alleviation of poverty.**

2. **Conserving biodiversity**

   Biotech crops are a land-saving technology, capable of higher productivity on the current 1.5 billion hectares of arable land, and thereby can help preclude deforestation and protect biodiversity in forests and in other in-situ biodiversity sanctuaries. **Approximately 13 million hectares of biodiversity-rich forests are lost in developing countries annually.** During the period 1996 to 2007 biotech crops have already precluded the need for an additional area of 43 million hectares of crop land, and the potential for the future is enormous.

3. **Contributing to the alleviation of poverty and hunger**

   Fifty percent of the world's poorest people are small and resource-poor farmers, and another 20% are the rural landless completely dependent on agriculture for their livelihoods. Thus, increasing income of small and resource-poor farmers contributes directly to the poverty alleviation of a large majority (70%) of the world's poorest people. **To-date, biotech cotton in India, China and South Africa and biotech maize in the Philippines and South Africa have already made a significant contribution to the income of over 12 million poor farmers, and this can be enhanced significantly in the remaining 7 years of the second decade of commercialization, 2006 to 2015.** Of special significance is biotech rice which has the potential to benefit 250 million poor rice households in Asia, (up to 1 billion people based on 4 members per household) growing on average only half a hectare of rice with an income as low as US$1 per day – they are some of the poorest people in the world.

   It is evident that much progress has been made in the first thirteen years of commercialization of biotech crops, but progress to-date is just the "tip of the iceberg" compared with potential progress in the second decade of commercialization, 2006-2015. It is a fortunate coincidence that the last year of the second decade of commercialization of biotech crops, 2015 is also the year of the Millennium Development Goals (MDG). **This offers a unique opportunity for the global biotechnology community, from the North and the South, the public and the private sectors, to define in 2009 the contributions that biotech crops can make to the Millennium Development Goals and a more sustainable agriculture in the future** – this gives the global biotech crop community seven years to work towards implementing an action plan for biotech crops that can deliver on the MDG goals of 2015.

4. **Reducing agriculture's environmental footprint**

   Conventional agriculture has impacted significantly on the environment and biotechnology can be used to reduce the environmental footprint of agriculture. **Progress in the first decade includes a significant reduction in pesticides, saving on fossil fuels, and decreasing CO_2 emissions through no/less ploughing, and conserving soil and moisture by optimizing the practice of no till through application of herbicide tolerance. The accumulative reduction in pesticides for the period 1996 to 2007 was estimated at 359,000 metric tons of active ingredient (a.i.), a saving of 9% in pesticides,** which is equivalent to a 17.2% reduction in the associated environmental impact of pesticide use on these crops, as measured by the Environmental Impact Quotient (EIQ) – a composite measure based on the various factors contributing to the net environmental impact of an individual active ingredient. **The corresponding data for 2007 alone was a reduction of 77,000 metric tons a.i.** (equivalent to a saving of 18% in pesticides) and a reduction of 29% in EIQ (Brooks and Barfoot, 2009, forthcoming).

Increasing efficiency of water usage will have a major impact on conservation and availability of water globally. Seventy percent of fresh water is currently used by agriculture globally, and this is obviously not sustainable in the future as the population increases by almost 50% to 9.2 billion by 2050. The first biotech maize hybrids with a degree of drought tolerance are expected to be commercialized by 2012, or earlier in the USA in the more drought-prone states of Nebraska and Kansas where yield increases of 8 to 10% are projected. Notably, the first tropical drought tolerant biotech maize is expected by 2017 for Sub Saharan Africa. The advent of drought tolerance in temperate maize in the industrial countries will be a major milestone and will be of even greater significance in tropical maize in Sub Saharan Africa, Latin America and Asia. Drought tolerance has also been incorporated in several other crops including wheat, which has performed well in initial field trials in Australia, with the best lines yielding 20% more than their conventional counterparts. **Drought tolerance is expected to have a major impact on more sustainable cropping systems worldwide, particularly in developing countries where drought is more prevalent and severe than industrial countries.**

5. **Mitigating climate change and reducing greenhouse gases (GHG)**
   The important and urgent concerns about the environment have implications for biotech crops, which can contribute to a reduction of greenhouse gases and help mitigate climate change in two principal ways. First, permanent savings in carbon dioxide emissions through reduced use of fossil-based fuels, associated with fewer insecticide and herbicide sprays; in 2007, this was an estimated saving of 1.1 billion kg of carbon dioxide (CO_2), equivalent to reducing the number of cars on the roads by 0.5 million. Secondly, additional savings from conservation tillage (need for less or no ploughing facilitated by herbicide tolerant biotech crops) for biotech food, feed and fiber crops, led to an additional soil carbon sequestration equivalent in 2007 to 13.1 billion kg of CO_2, or removing 5.8 million cars off the road. **Thus in 2007, the combined permanent and additional savings through sequestration was equivalent to a saving of 14.2 billion kg of CO_2 or removing 6.3 million cars from the road** (Brookes and Barfoot, 2009, forthcoming).

   Droughts, floods, and temperature changes are predicted to become more prevalent and more severe, and hence there will be a **need for <u>faster</u> crop improvement programs to develop varieties and hybrids that are well adapted to more rapid changes in climatic conditions.** Several biotech tools, including tissue culture, diagnostics, genomics, molecular marker-assisted selection (MAS) and genetic engineering of crops can be used collectively for **'speeding the breeding'** and help mitigate the effects of climate change. Biotech crops are already contributing to reducing CO_2 emissions by precluding the need for ploughing a significant portion of cropped land, conserving soil and particularly moisture, reducing pesticide spraying as well as sequestering CO_2.

6. **Contributing to the cost-effective production of biofuels**
   Biotechnology can be used to cost-effectively optimize the productivity of biomass/hectare of first generation food/feed and fiber crops and also second-generation energy crops. This can be achieved by developing crops tolerant to abiotic stresses (drought/salinity/extreme temperatures) and biotic stresses (pests, weeds, diseases), and also to raise the ceiling of potential yield per hectare through modifying plant metabolism. There is also an opportunity to utilize biotechnology to develop more effective enzymes for the downstream processing of biofuels. In the USA, Ceres has just released biotech-based non-transgenic hybrids of switchgrass and sorghum with increased cellulose content for ethanol production and has transgenic varieties under development.

7. **Contributing sustainable economic benefits**
   The most recent survey of the global impact of biotech crops for the period 1996 to 2007 (Brookes and Barfoot 2009, forthcoming), estimates that **the global net economic benefits to biotech crop farmers in 2007 alone was US$10 billion (US$6 billion for developing countries and US$4 billion for industrial countries). The accumulated benefits during the period 1996 to 2007 was US$44 billion with US$22 billion each for developing and industrial countries.** These estimates include the very important benefits associated with the double cropping of biotech soybean in Argentina.

In summary, collectively the above seven thrusts represent a significant contribution of biotech crops to sustainability and the potential for the future is enormous.

National economic growth – potential contribution of biotech crops in agricultural-based countries and transforming developing countries

The 2008 World Bank Development Report "Agriculture for Development" (World Bank, 2008) notes that two-thirds of the world's agricultural added-value is created in developing countries, where agriculture is an important sector. The report classified countries into three categories: **a) Agricultural-based countries** where agriculture on average contributes one-third of GDP, and employs two-thirds of the labor force. **This category has over 400 million poor people, mainly in Sub Saharan Africa and over 80% of the poor are involved in agriculture. b) The transforming countries** – this category includes China, India, Indonesia and Romania. **On average, agriculture contributes 7% to GDP but over 80% of the poor are in the rural areas, with most of them involved in agriculture. This category has 2.2 billion rural people.** About 98% of the enormous rural population of South Asia, 96% of East Asia and the Pacific and 92% of the Middle East and North Africa are in transforming countries. **c) Urbanized countries** are the category where agriculture is least important, contributing 5% or less to GDP, and where poverty is mostly urban.

In the absence of agricultural growth, national economic growth is not possible in the agricultural-based countries and plays a critical role in the transforming countries where there is a rural population of 2.2 billion, mainly involved in agriculture and representing over 80% of the poor. The World Bank report concluded that, ***"Using agriculture as the basis for economic growth in the agricultural based countries requires a productivity revolution in small holder farming."*** Crops are the principal source of food, feed and fiber globally producing approximately 6.5 billion metric tons annually. The annals of history confirm that technology can make a substantial contribution to crop productivity and production and spur rural economic growth. The best examples are the introduction of the new technology of hybrid maize in the USA in the 1930s, and the green revolution for rice and wheat in the developing countries, particularly Asia, in the 1960s. The semi-dwarf wheat was the new technology that provided the engine of rural and national economic growth during the green revolution of the 1960s, which saved 1 billion people from hunger and for which Norman Borlaug was awarded the Nobel Peace Prize in 1970. Today, at 94 years young Norman Borlaug is again the most credible advocate for the new technology of biotech crops and is an enthusiastic patron of ISAAA.

The biotech Bt rice already developed and field tested in China has the potential to increase net income by approximately US$100 per hectare for the 110 million poor rice households in China, equivalent to 440 million people, based on an average of 4 per household in the rural areas of China. **In summary, biotech crops have already demonstrated their capacity to increase productivity and income significantly and hence can serve as an engine of rural economic growth that can contribute to the alleviation of poverty for the world's small and resource-poor farmers during a global financial crisis.**

In 2008, more than half the world's population lived in the 25 countries, which planted 125 million hectares of biotech crops, equivalent to 8% of the 1.5 billion hectares of all the cropland in the world

More than half (55% or 3.6 billion people) of the global population of 6.6 billion live in the 25 countries where biotech crops were grown in 2008 and generated significant and multiple benefits worth over US$10 billion globally in 2007. Notably, more than half (52% or 776 million hectares) of the 1.5 billion hectares of cropland in the world is in the 25 countries where approved biotech crops were grown in 2008. **The 125 million hectares of biotech crops in 2008 represent 8% of the 1.5 billion hectares of cropland in the world.**

Need for appropriate cost/time-effective regulatory systems that are responsible, rigorous and yet not onerous, requiring only modest resources that are within the means of most developing countries

The most important constraint to the adoption of biotech crops in most developing countries, that deserves highlighting, is the lack of appropriate cost/time-effective and responsible regulation systems that incorporate all the knowledge and experience of 13 years of regulation. **Current regulatory systems in most developing countries are usually unnecessarily cumbersome and in many cases it is impossible to implement the system to approve products which can cost up to US$1 million or more to deregulate – this is beyond the means of most developing countries.** The current regulatory systems were designed more than ten years ago to meet the initial needs of industrial countries dealing with a new technology and with access to significant resources for regulation which developing countries simply do not have – **the challenge for developing countries is "how to do a lot with little.**" With the accumulated knowledge of the last thirteen years it is now possible to design appropriate regulatory systems that are responsible, rigorous and yet not onerous, requiring only modest resources that are within the means of most developing countries – this should be assigned top priority.

Today, unnecessary and unjustified stringent standards designed to meet the needs of resource-rich industrial countries are denying the developing countries timely access to products such as Golden Rice, whilst millions die unnecessarily in the interim. **This is a moral dilemma, where the demands of regulatory systems have become "the end and not the means".** Malawi in Southern Africa is one of many countries that are becoming increasingly aware of the critical need for an appropriate effective regulatory framework and a national biotechnology policy. **President Bingu Wa Mutharika, of Malawi who is also the Minister for Education, Science and Technology** chaired the cabinet meeting in July 2008 that approved the National Biotechnology Policy, which in conjunction with the Biosafety Act of 2002, provides a regulatory framework for effective implementation of biotechnology programs and activities in Malawi. In a foreword to the policy, the President said, ***"government recognized the pivotal role biotechnology can play towards economic growth and poverty reduction."*** He said, ***"biotechnology will facilitate Malawi's speedy attainment of capacity to be food secure, create wealth and achieve socio-economic development as stipulated in the Malawi Growth and Development Strategy (MGDS) and Vision 2020."*** The Policy provides an enabling framework to promote and regulate the development, acquisition and deployment of relevant biotechnology products to reposition Malawi from being a predominantly importing and consuming economy to a manufacturing and exporting one. It therefore creates a conducive environment that allows biotechnology business to flourish. With the Biosafety Act already in place the approval of the policy is designed to hasten the country's plans to advance biotech crops.

Drought tolerance in conventional and biotech maize - an emerging reality

Given the pivotal importance of drought tolerance, ISAAA invited Dr. Greg O. Edmeades, former leader of the maize drought program at CIMMYT, to contribute a timely global overview on the status of drought tolerance in maize, in both conventional and biotech approaches, in the private and public sector, and to discuss future prospects in the near, mid and long term. The contribution by G. O. Edmeades, **"Drought tolerance in maize: an emerging reality"**, supported by key references, is included in Brief 39 as a special feature to highlight the enormous global importance of the drought tolerance 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. **Drought tolerance conferred through biotech crops is viewed as the most important trait that will become available in the second decade of commercialization, 2006 to 2015, and beyond, because it is by far the single most important constraint to increased productivity for crops worldwide. Drought tolerant biotech/transgenic maize, is the most advanced of the drought tolerant crops under development, and is expected to be launched commercially in the USA in 2012, or earlier. Notably, a Private/Public sector partnership hopes to release the first biotech drought tolerant maize by 2017 in Sub Saharan Africa where the need for drought tolerance is greatest.**

Biofuel production in the USA in 2008

In the USA in 2008, biofuel production was mainly ethanol from maize, with some biodiesel from oil crops. It is estimated that production from 29% of the total maize area in the USA in 2008 was used for ethanol, up from 24% in 2007. Accordingly, it is estimated that in 2008, 8.7 million hectares of biotech maize was devoted to ethanol production, up from 7 million hectares in 2007. Corresponding estimates for biodiesel indicate that approximately 3.5 million hectares of biotech soybean (7% of total biotech soybean plantings) was used for biodiesel production in 2008 plus an estimated 5,000 hectares of canola. Estimates for biodiesel production from biotech soybean in Brazil were not available. Thus, in total 12.2 million hectares of biotech crops were used for biofuel production in the USA in 2008.

Number of products approved globally for planting and import – 25 countries have approved planting and another 30 have approved import for a total of 55 countries

While 25 countries planted commercialized biotech crops in 2008, an additional 30 countries, totaling 55, 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 670 approvals have been granted for 144 events for 24 crops. Thus, biotech crops are accepted for import for food and feed use and for release into the environment in 30 countries, including major food importing countries like Japan, which do not plant biotech crops. Of the 55 countries that have granted approvals for biotech crops, Japan tops the list followed by USA, Canada, Mexico, South Korea, Australia, the Philippines, New Zealand, the European Union and China. Maize has the most events approved (44) followed by cotton (23), canola (14), and soybean (8). The event that has received regulatory approval in most countries is the herbicide tolerant soybean event GTS-40-3-2 with 23 approvals (EU=27 counted as 1 approval only), followed by insect resistant maize (MON810) and herbicide tolerant maize (NK603) both with 21 approvals, and insect resistant cotton (MON531/757/1076) with 16 approvals worldwide. An up-to-date listing of all 670 approvals is detailed in Appendix 1 of Brief 39. It is notable that in 2008 both Japan and South Korea imported biotech maize for use as food for the first time. The stimulus for this was the unaffordability of the premium price for conventional maize versus biotech maize. The approvals by Japan and South Korea may be the forerunners of similar decisions by other countries importing biotech maize, including the EU.

The Global Value of the Biotech Crop Market – it was valued at US$7.5 billion in 2008 with an accumulated value of US$50 billion for the period 1996 to 2007

In 2008, the global market value of biotech crops, estimated by Cropnosis, was US$7.5 billion, (up from US$6.9 billion in 2007) representing 14% of the US$52.72 billion global crop protection market in 2008, and 22% of the approximately US$34 billion 2008 global commercial seed market. The 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$49.8 billion, which when rounded off to US$50 billion is a historical landmark for the global biotech crop market. The global value of the biotech crop market is projected at approximately US$8.3 billion for 2009.

Future Prospects

Outlook for the remaining seven years of the second decade of commercialization of biotech crops, 2006 to 2015

The future adoption of biotech crops in developing countries in the period 2009 to 2015 will be dependent mainly on a troika of major issues: first, establishment and effective operation of appropriate, responsible and cost/time-effective regulatory systems; second, strong political will and support for the adoption of biotech crops that can contribute to a more affordable and secure supply of food, feed and fiber – suffice to note that in 2008 broad and substantial political will was evident for biotech crops, particularly in developing countries; and third, a continuing and expanding supply of appropriate biotech crops that can meet the priority needs of more developing countries in Asia, Latin America and Africa.

The outlook for biotech crops in the remaining 7 years of the second decade of commercialization, 2006 to 2015 looks promising. In 2005, ISAAA projected that the number of biotech crop countries, hectarage and beneficiary farmers would all double by 2015 with the potential for number of farmers ranging from a minimum of 20 million to multiples thereof, depending on when biotech rice is first approved. From 2009 to 2015, 15 or more biotech crop countries are projected to plant biotech crops for the first time, taking the total number of biotech crop countries globally to 40 in 2015, in line with the 2005 ISAAA projection. These new countries may include three to four in Asia; three to four in eastern and southern Africa; three to four in West Africa; and one to two in North Africa and the Middle East. In Latin/Central America and the Caribbean nine countries are already commercializing biotech crops, leaving less room for expansion, however there is a possibility that two or three countries from this region may plant biotech crops for the first time between now and 2015. In eastern Europe, up to six new biotech countries is possible, including Russia, which has a biotech potato at an advanced stage of development, which also has potential in several countries in eastern Europe. Western Europe is more difficult to predict because the biotech crop issues in Europe are not related to science and technology considerations but are of a political nature and influenced by ideological views of activist groups.

The comparative advantage of biotech crops to produce more affordable and better quality food to ensure a safe and secure supply of food globally augurs well for a doubling of hectarage to 200 million hectares of biotech crops by 2015 for two principal reasons.

Firstly, there is considerable potential for increasing the biotech adoption rate of the four current large hectarage biotech crops (maize, soybean, cotton, and canola), which collectively represented 125 million hectares of biotech crops in 2008 out of a total potential hectarage of 315 million hectares; this leaves almost 200 million hectares for potential adoption with biotech crops. Deployment of biotech rice as a crop and drought tolerance as a trait are considered seminal for catalyzing the further adoption of biotech crops globally. In contrast to the first generation biotech crops that realized a significant increase in yield and production by protecting crops from losses caused by pests, weeds, and diseases, the second generation biotech crops will offer farmers additional new incentives for further increasing yield. RR2 soybean, to be launched in 2009, is the first of many such second-generation products. RR2 will further enhance yield by 7 to 11% as a result of genes that code for increased yield *per se*. Quality traits will also become more prevalent providing a much richer mix of traits for deployment in conjunction with a growing number of input traits.

Secondly, between now and 2015, there will be several new biotech crops that will occupy small, medium and large hectarages globally and featuring both agronomic and quality traits as single and stacked trait products. By far, the most important of the new biotech crops that are now ready for adoption is biotech rice: principally the pest/disease resistant biotech rice extensively field tested in China and awaiting approval by the Chinese regulatory authorities; and Golden Rice expected to be available in 2012. Rice is unique even amongst the three major staples (rice, wheat and maize) in that it is the most important food crop in the world and more importantly, it is the most important food crop of the poor in the world. Over 90% of the world's rice is grown and consumed in Asia by some of the poorest people in the world – the 250 million Asian households/families whose resource-poor rice farmers cultivate on average a meager half a hectare of rice. Several other medium hectarage crops are expected to be approved before 2015 including: potatoes with pest and/or disease resistance and modified quality for industrial use; sugarcane with quality and agronomic traits; and disease resistant bananas. Some biotech orphan crops are also expected to become available. For example, Bt eggplant may become available as the first biotech food crop in India within the next 12 months and has the potential to benefit up to 1.4 million small and resource-poor farmers. Vegetable crops such as biotech tomato, broccoli, cabbage and okra which require heavy applications of insecticides (which can be reduced substantially by a biotech product) are also under development. Pro-poor biotech crops such as biotech cassava, sweet potato, pulses and groundnut are also candidates. It is noteworthy that several of these products are being developed by public sector national or international institutions in the developing countries. The development of this broad portfolio of new biotech crops augurs well for the continued global growth of biotech crops, which ISAAA projected to reach 200 million hectares by 2015, grown by 20 million farmers, or more.

The second decade of commercialization, 2006-2015, is likely to feature significantly more growth in Asia and Africa compared with the first decade, which was the decade of the Americas, where there will be continued vital growth in stacked traits, particularly in North America, and strong growth in Brazil. Adherence to good farming practices with biotech crops, such as rotations and resistance management, will remain critical, as it has been during the first decade. Continued responsible stewardship must be practiced, particularly by the countries of the South, which will be the major new deployers of biotech crops in the second decade of commercialization of biotech crops, 2006 to 2015. The use of biotechnology to increase efficiency of first generation food/feed crops and second-generation energy crops for biofuels presents both opportunities and challenges. **Whereas biofuel strategies must be developed on a country-by-country basis, food security should always be assigned the first priority and should never be jeopardized by a competing need to use food and feed crops for biofuel.** Injudicious use of the food/feed crops, sugarcane, cassava and maize for biofuels in food insecure developing countries could jeopardize food security goals if the efficiency of these crops cannot be increased through biotechnology and other means, so that food, feed and fuel goals can all be adequately met. The key role of crop biotechnology in the production of biofuels is to cost-effectively optimize the yield of biomass/biofuel per hectare, which in turn will provide more affordable fuel. However, by far the most important potential role of biotech crops will be their contribution to the humanitarian Millennium Development Goals (MDG) of ensuring a secure supply of affordable food and the reduction of poverty and hunger by 50% by 2015.

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 notes 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 big challenge is to transform this problem of a 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. **It is encouraging to witness the growing "political will" for biotech crops at the G8 international level and at the national level in developing countries. This growing political will and conviction of visionaries and lead farmers for biotech crops is particularly evident in several of the lead developing countries highlighted in this Brief. Failure to provide the necessary political will and support for biotech crops at this time will risk many developing countries missing out on a one-time window of opportunity and as a result become permanently disadvantaged and non-competitive in crop productivity. This has dire implications for the hope of alleviating poverty for up to 1 billion resource-poor farmers and the rural landless whose livelihoods, and indeed survival, is largely dependent on improved yields of crops which are the principal source of food and sustenance for over 5 billion people in the developing world, a significant proportion of whom are extremely poor and desperately hungry – a situation that is morally unacceptable in a just society.**

Global Status of Commercialized Biotech/GM Crops: 2008

by

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Chair, ISAAA Board of Directors

Introduction

2008 marks the thirteenth year of the commercialization, 1996-2008, 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 twelve years of commercialization, 1996 to 2007, 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 dozen years of commercialization, 1996 to 2007, 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 2007, developing and industrial countries contributed to a 67-fold increase in the global area of biotech crops from 1.7 million hectares in 1996 to 114.3 million hectares in 2007. Adoption rates for biotech crops during the period 1996 to 2007 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 12 million farmers in 23 countries grew biotech crops in 2007 and derived multiple benefits that included significant agronomic, environmental, health, social and economic advantages. ISAAA's 2007 Global Review (James, 2007) predicted that the number of farmers planting biotech crops, as well as the global area of biotech crops, would continue to grow in 2008. 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. Today, 852 million people in the developing countries suffer from hunger and malnutrition and 1.3 billion are afflicted by poverty. Biotech crops represent promising technologies that can make a vital contribution, but not a total solution, 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 and fuel security,** with benefits for producers, consumers and society at large; **contribution to more affordable food** as a result of coincidentally increasing productivity significantly and reducing production costs substantially;

- **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;

- **mitigating climate change 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 would 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;

- **the cost-effective production of renewable resource-based biofuels,** which will reduce dependency on fossil fuels, and therefore contribute to a cleaner and safer environment with lower levels of greenhouse gases that will mitigate global warming; and

- 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 (novel traits). This integrated product must be incorporated as the 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 plant breeding offers the global population.

The author has published global reviews of biotech crops annually since 1996 as ISAAA Briefs (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 2008 and the changes that have occurred between 2007 and 2008 are highlighted. The global adoption trends during the last 13 years from 1996 to 2008 are also illustrated and the contribution of biotech crops to the world's 1.3 billion poor people, of which resource-poor farmers are a significant proportion.

Given the pivotal importance of drought tolerance, ISAAA invited Dr. Greg O. Edmeades, former leader of the maize drought program at CIMMYT, to contribute a timely global overview on the status of drought tolerance in maize, in both conventional and biotech approaches, in the private and public sector, and to discuss future prospects in the near, mid and long term. The contribution by G. O. Edmeades, **"Drought tolerance in maize: an emerging reality"**, supported by key references, is included in Brief 39 as a special feature to highlight the enormous global importance of the drought tolerance 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. In order to provide the contribution by Dr. Edmeades a broader distribution, an abridged unreferenced version, is featured as a companion publication to the Executive Summary of Brief 39, with more of a focus on biotech approaches than conventional, more on the activities of the private sector than the public sector, and on Sub Saharan Africa, where there is considerable work underway on drought because of the urgent humanitarian need to boost the yields of maize, which is the staple food for more than 300 million people, a significant proportion of whom is suffering from hunger and malnutrition.

This Brief documents the global database on the adoption and distribution of biotech crops in 2008, and in the Appendix there are 4 sections: 1) a comprehensive inventory of biotech crop products that have received regulatory approvals for import for food and 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 2007, courtesy of Cropnosis; and 4) a commentary by Mr. Robert Wager, Vancouver Island University, Nanaimo, Canada on the interim report of IAASTD (International Assessment of Agricultural Science and Technology for Development). IAASTD managed a multiyear project designed to evaluate the role of agricultural science and technology with the goal to help reduce hunger, malnutrition and poverty. The interim report and its findings have been the subject of active on-going discussion. The commentary of Mr. Robert Wager is included in Appendix 4 for the convenience of ISAAA Brief readers in the developing countries who may not be aware of the report and the follow-up discussion. The views expressed in the text in Annex 4 are attributed to Mr. Robert Wager and not to ISAAA.

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. A few of the listed references are not cited in the text – for convenience they have been included because they are references in preparatory documents for the Brief. Global figures and hectares planted commercially with biotech crops have been rounded off to the nearest 100,000 hectares and in some cases this leads to insignificant approximations, and there may be minor variances in some figures, totals, and percentage estimates. 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 2008 information for Argentina, Brazil, Australia, South Africa, and Uruguay is hectares usually planted in the last quarter of 2008 and harvested in the first quarter of 2009 with some countries like the Philippines planting more than one season per year.

Over the last 13 years, ISAAA has devoted considerable effort to consolidate all the available data on officially approved biotech crop adoption globally; 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. Data sources vary by country and include, where available, government statistics, independent surveys, and 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 in that it is global in nature, and provides continuity from the genesis of the commercialization of biotech crops in 1996, to the present. The database has gained acceptance internationally as a benchmark for the global status of biotech crops and is widely cited in the scientific literature and the international press.

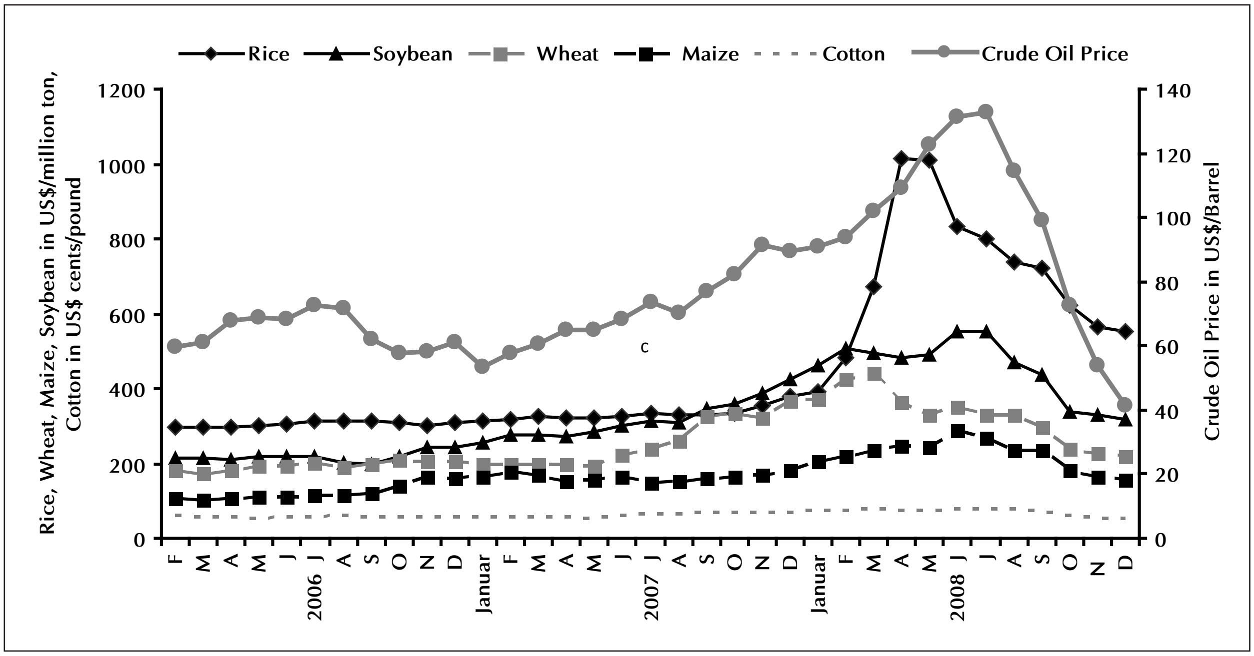
Global Area of Biotech Crops in 2008

2008 was an uncertain year for farmers globally with a weak US dollar and high prices of oil and increased demand for food and feed at the beginning of the year driving fuel and input prices for fertilizers and pesticides as well as commodity prices to unprecedented high levels, and impacting farmers planting biotech crops in the temperate northern hemisphere in the first quarter of 2008 (Figure 1). The receding prices of oil and commodities towards the end of 2008 coupled with the global financial crisis, a tightening credit supply and a stronger US Dollar leading to uncertainty which impacted on farmers in the southern hemisphere, in countries like Brazil, which are planting crops in November and December of 2008. The record prices of food and feed commodities in early 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 2008, the 13th year of commercialization, the global area of biotech crops continued to climb at a sustained growth rate of 9.4% reaching 125 million hectares or 308.8 million acres (Table 1). The accumulated hectarage during the first thirteen years, 1996 to 2008, has reached over 800 million hectares (815.9 million hectares) and notably reached over 2 billion accumulated acres for the first time (2,016,000 acres). Biotech crops have set a precedent in that the biotech area has grown impressively every single year for the past 13 years, since commercialization first began in 1996. The number of farmers growing biotech crops in 2008 also increased by 1.3 million reaching 13.3 million (up from 12.0 million in 2007) of which 90% or 12.3 million, up from 11 million in 2007, were small and resource-poor farmers from developing countries.

Thus, in 2008, 125 million hectares of biotech crops were planted by 13.3 million farmers in 25 countries, compared with 114.3 million hectares grown by 12 million farmers in 23 countries in 2007. It is notable that 10.7 million hectares more were planted in 2008 by 13.3 million farmers in the 13th year of commercialization at a high growth rate of 9.4%. Three additional countries,

Figure 1. International Prices of Crop Commodities and a Barrel of Crude Oil, 2006 to 2008



Source: International Monetary Fund, 2008.

Table 1. Global Area of Biotech Crops, the First 13 Years, 1996 to 2008

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
Total	**815.9**	**2,016.1**

Increase of 9.4%, 10.7 million hectares (26 million acres) between 2007 and 2008.
Source: Clive James, 2008.

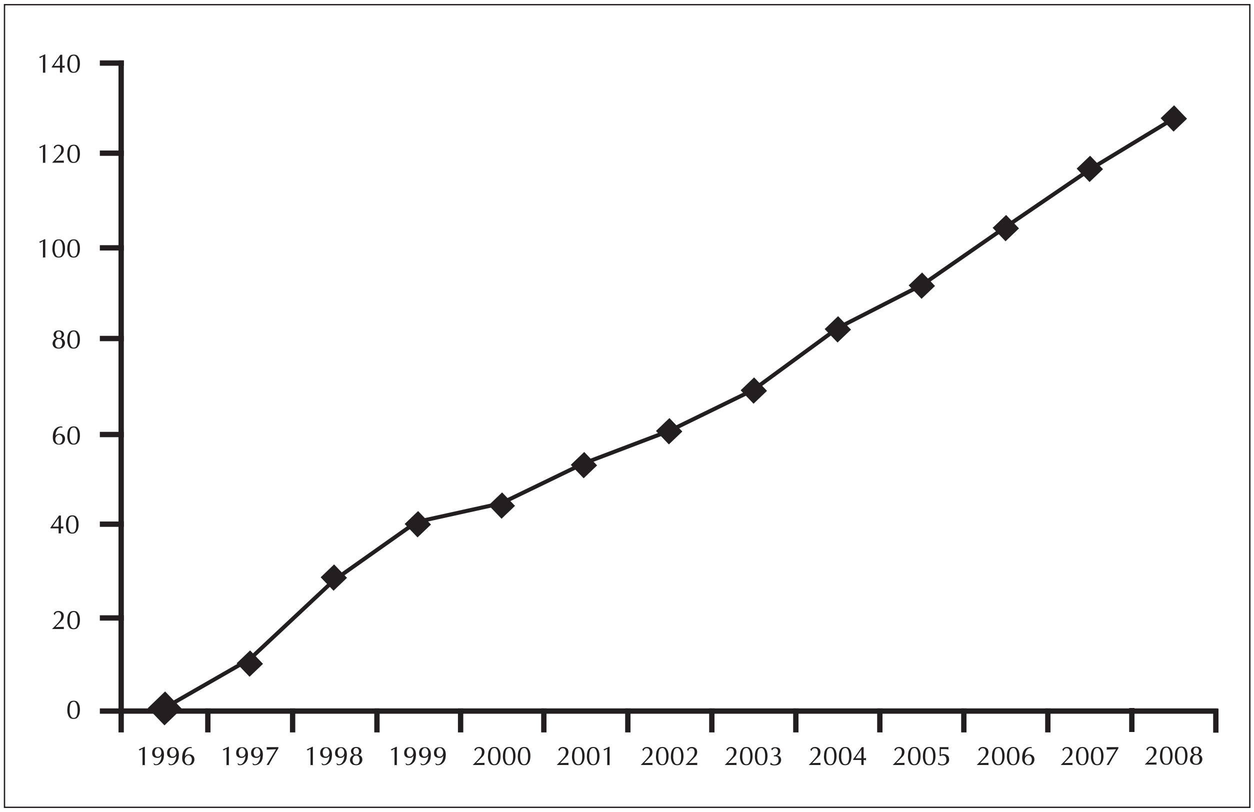
Burkina Faso, Egypt and Bolivia have been added to the global list of biotech countries in 2008, bringing the total to the historical milestone of 25 countries. The total number of EU countries now growing biotech crops is seven and includes Spain, Czech Republic, Romania, Portugal, Germany, Poland and Slovakia.

To put the 2008 global area of biotech crops into context, 125 million hectares of biotech crops is equivalent to more than 10% 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 2007 and 2008 of 9.4% is equivalent to 10.7 million hectares or 26.8 million acres.

During the thirteen years of commercialization 1996 to 2008, the global area of biotech crops increased 74-fold, from 1.7 million hectares in 1996 to 125 million hectares in 2008 (Figure 2). This rate of adoption is the highest rate of crop technology adoption for any crop technology and reflects the 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 tripled, increasing from 6 in 1996 to 12 countries in 1999, 17 in 2004, 21 countries in 2005, and 25, a historical milestone in 2008. A new wave of adoption of biotech crops is fueled by several factors which are contributing to a broadly-based global growth in biotech crops. These factors include: an increase in the number of biotech countries (3 new countries in 2008, Burkina Faso and Egypt from Africa and Bolivia in Latin America); notably, significant progress in Africa, the continent with the greatest challenge (an increase from 1 to 3 countries in 2008 which now includes South Africa, Burkina Faso and Egypt); additional biotech crops being deployed in biotech countries (Brazil planting Bt maize, and Australia biotech canola, for the first time); a new biotech crop, biotech sugar beet deployed in the USA and Canada; and significant growth in stacked traits in cotton and maize increasingly deployed by 10 countries worldwide. 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. Notably, in 2008 accumulatively the second billionth acre (800 millionth hectare) of a biotech crop was planted. In 2008, developing countries out-numbered industrial countries by 15 to 10, and 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 Goals 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.

2008 was the first time that more than 12 million small and resource-poor farmers from the developing countries benefited from biotech crops. The year 2008 also marked the first year when the number of biotech countries in Africa jumped from 1 to 3 and a new biotech crop, RR®sugar beet was commercialized for the first time in the USA and Canada.

Figure 2. Global Area of Biotech Crops, 1996 to 2008 (Million Hectares)



Source: Clive James, 2008.

The USA reported the largest absolute increase in biotech crops at 4.8 million hectares, followed by Argentina at 1.9 million hectares and India at 1.4 million hectares. The largest proportional increase in 2008 on significant biotech hectarages was in India with a 23% increase in Bt cotton area from 6.2 million hectares in 2007 to 7.6 million hectares in 2008; India with 7.6 million hectares now grows significantly more Bt cotton than China with 3.8 million hectares. Notably, large proportional increases in biotech crops in more modest hectarages of biotech crops were reported by Uruguay (40%), the Philippines (33%), Argentina (10%). In fact, no country registered a net significant decrease in biotech crops even though high prices of inputs, particularly fertilizers, pesticides and fuel represented significant constraints in several countries.

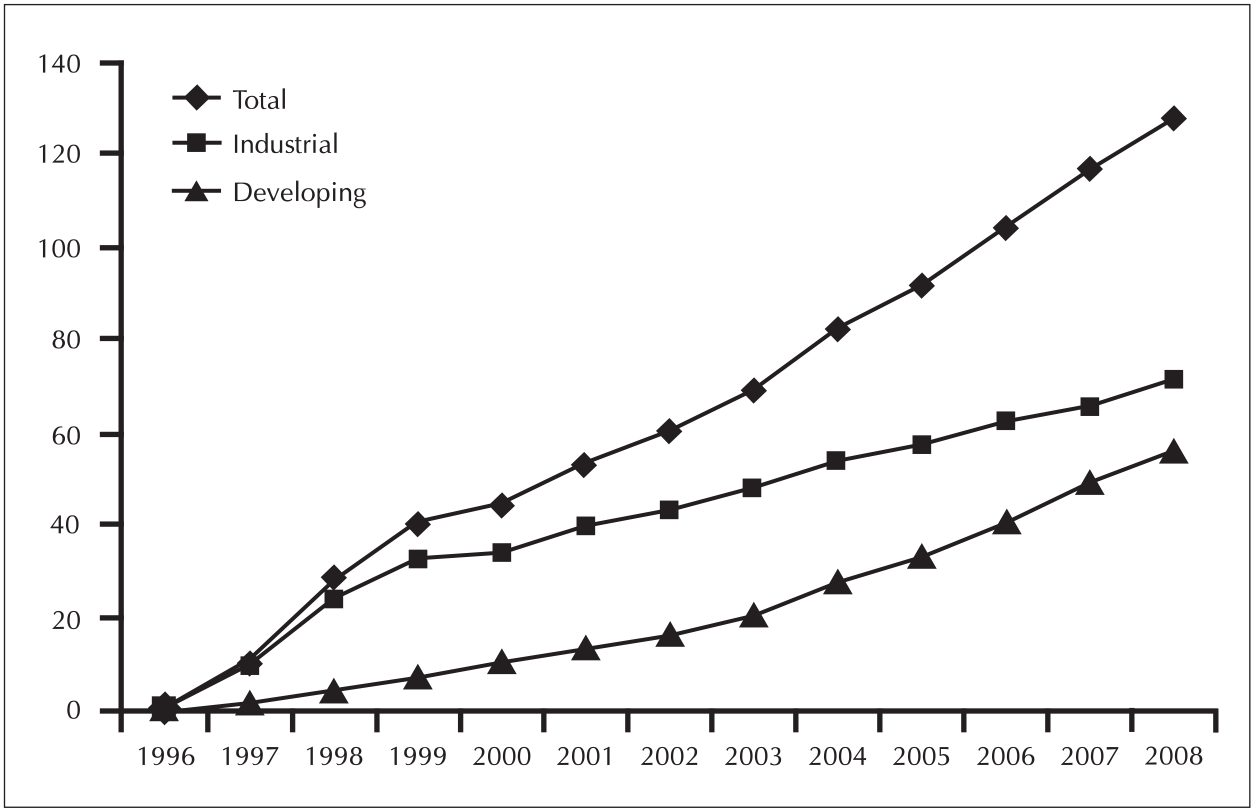
In summary, during the first thirteen years of commercialization 1996 to 2008, an accumulated total of over 800 million hectares or over 2 billion acres of biotech crops have been successfully grown as a result of approximately 70 million repeat decisions by farmers to plant biotech crops (Table 1 and 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 increasing from 6 to 25 in the same 13-year period. However, the significant hectarage of 125 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 22% of the 125 million hectares had two or three traits (planted primarily in the USA, but also increasingly in nine other countries, Canada, the Philippines, Australia, Mexico, South Africa, Honduras, Colombia, Argentina and Chile), the true global area of biotech crops in 2008 expressed as "trait hectares" was 166 million compared with 143.7 million "trait hectares" in 2007. Thus, the real growth rate measured in "trait hectares" between 2008 (166 million) and 2007 (143.7 million) was 15% or 22 million hectares compared with the apparent growth rate of 9.4% when measured conservatively in hectares between 2007 (114.3 million hectares) and 2008 (125 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 2008. It clearly illustrates that whereas the substantial but consistently declining share (56% in 2008 compared with 57% in 2007 and 60% in 2006) of biotech crops continued to be grown in industrial countries in 2008, 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, and 43% in 2007, and 44% in 2008. Thus, in 2008, more than 40% of the global biotech crop area of 125 million hectares, equivalent to 54.5 million hectares, was grown in 15 developing countries where growth continued to be strong, compared with the 10 industrial countries growing biotech crops (Table 2). Developing countries that exhibited exceptionally strong proportional growth included India and the Philippines in Asia, and Uruguay and Argentina in Latin America. Unlike the previous five years, when growth was consistently and significantly stronger in the developing than industrial countries, in 2008 growth was similar. More specifically, in 2008, year-on-year growth, measured either in absolute hectares or by percent, was similar in developing countries (5.1 million hectares and 10% growth) and industrial countries (5.6 million hectares and 9% growth). However, for the near mid and long-term growth is likely to be higher in the developing countries, as more countries from the South adopt biotech crops. For example in 2008, all three new biotech countries were from Africa and Latin America, resulting in a mix of 15 developing countries and 10 industrial countries.

Of the US$44 billion additional gain in farmer income generated by biotech crops in the first 12 years of commercialization (1996 to 2007), it is noteworthy that half, US$22 billion, was generated in developing countries and the other half, US$22 billion, in industrial countries. It is notable that in 2007, developing countries had a slightly higher share (57%), or US$5.8 billion of the US$10.2

Figure 3. Global Area of Biotech Crops, 1996 to 2008: Industrial and Developing Countries (Million Hectares)



Source: Clive James, 2008.

Table 2. Global Area of Biotech Crops, 2007 and 2008: Industrial and Developing Countries (Million Hectares)

	2007	%	2008	%	+/-	%
Industrial countries	64.9	57	70.5	56	5.6	+9
Developing countries	49.4	43	54.5	44	5.1	+10
Total	**114.3**	**100**	**125.0**	**100**	**10.7**	**+9.4**

Source: Clive James, 2008.

billion gain, with industrial countries at slightly less than half of the share (43%) with US$4.4 billion (Brookes and Barfoot, 2009, forthcoming).

Distribution of Biotech Crops, by Country

The eight principal countries that grew biotech crops on 1 million hectares or more in 2008 remained the same as 2007 with the exception that India with 7.600 million hectares had slightly more hectares than Canada at 7.582 million hectares. The eight countries are listed by hectarage in Table 3 led by the USA which grew 62.5 million hectares (50% of global total), Argentina with 21.01 million hectares (17%), Brazil 15.8 million hectares (13%), India 7.6 million hectares (6%), Canada 6.2 million hectares (6%), China 3.8 million hectares (3%), Paraguay with 2.7 million hectares (2%), and South Africa with 1.8 million hectares (1%). An additional 17 countries grew a total of 2.2 million hectares in 2008 (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, Argentina, Brazil, 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) numbered 14 in 2008. Notably, 10 of the 14 mega-countries are developing countries from Latin America, Asia and Africa. The high proportion of biotech mega-countries in 2008, 14 out of 25, equivalent to approximately 56%, 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 13 years.

It is noteworthy that in 2008, the number of biotech countries reached the historical milestone of 25 countries for the first time. Equally notable, is that all three new biotech countries were developing rather than industrial countries, and furthermore that two of the three countries were from Africa, the continent with the greatest and most urgent need for the technology.

For the first twelve years of commercialization of biotech crops, 1996 to 2007, South Africa has long been 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, is of strategic importance for the African continent. For the first time there is 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.

Table 3. Global Area of Biotech Crops in 2007 and 2008: by Country (Million Hectares)

	Country	2007	%	2008	%	+/-	% Increase
1.	USA*	57.7	50	62.5	50	+4.8	+8
2.	Argentina*	19.1	17	21.0	17	+1.9	+10
3.	Brazil*	15.0	13	15.8	13	+0.8	+5
4.	India*	6.2	5	7.6	6	+1.4	+23
5.	Canada*	7.0	6	7.6	6	+0.6	+9
6.	China*	3.8	3	3.8	3	+0.0	- -
7.	Paraguay*	2.6	2	2.7	2	+0.1	+4
8.	South Africa*	1.8	2	1.8	1	+0.0	- -
9.	Uruguay*	0.5	<1	0.7	1	+0.2	+40
10.	Bolivia*	- -	- -	0.6	<1	+0.6	- -
11	Philippines*	0.3	<1	0.4	<1	+0.1	+33
12.	Australia*	0.1	<1	0.2	<1	+0.1	+100
13.	Mexico *	0.1	<1	0.1	<1	<0.1	- -
14.	Spain *	0.1	<1	0.1	<1	<0.1	- -
15.	Chile	<0.1	<1	<0.1	<1	<0.1	- -
16.	Colombia	<0.1	<1	<0.1	<1	<0.1	- -
17.	Honduras	<0.1	<1	<0.1	<1	<0.1	- -
18.	Burkina Faso	<0.1	<1	<0.1	<1	<0.1	- -
19.	Czech Republic	<0.1	<1	<0.1	<1	<0.1	- -
20.	Romania	<0.1	<1	<0.1	<1	<0.1	
21.	Portugal	<0.1	<1	<0.1	<1	<0.1	- -
22.	Germany	<0.1	<1	<0.1	<1	<0.1	- -
23.	Poland	<0.1	<1	<0.1	<1	<0.1	- -
24.	Slovakia	<0.1	<1	<0.1	<1	<0.1	- -
25.	Egypt	- -	- -	<0.1	<1	<0.1	
TOTAL		114.3	**100**	**125.0**	**100**	**+10.7**	**+9.4**

*** Mega-biotech countries (14) growing 50,000 hectares, or more, of biotech crops.**
Source: Clive James, 2008.

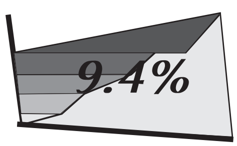
Figure 4. Global Area (Million Hectares) of Biotech Crops, 1996 to 2008, by Country, and Mega-Countries, and for the Top Eight Countries

Biotech Mega-Countries	
50,000 hectares, or more	
USA	62.5 million
*Argentina**	21.0 million
*Brazil**	15.8 million
*India**	7.6 million
Canada	7.6 million
*China**	3.8 million
*Paraguay**	2.7 million
*South Africa**	1.8 million
*Uruguay**	0.7 million
*Bolivia**	0.6 million
*Philippines**	0.4 million
Australia	0.2 million
*Mexico**	0.1 million
Spain	0.1 million

Less than 50,000 hectares	
*Chile**	Romania
*Colombia**	Portugal
*Honduras**	Germany
*Burkina Faso**	Poland
Czech Republic	Slovakia
	*Egypt**

* *Developing countries*

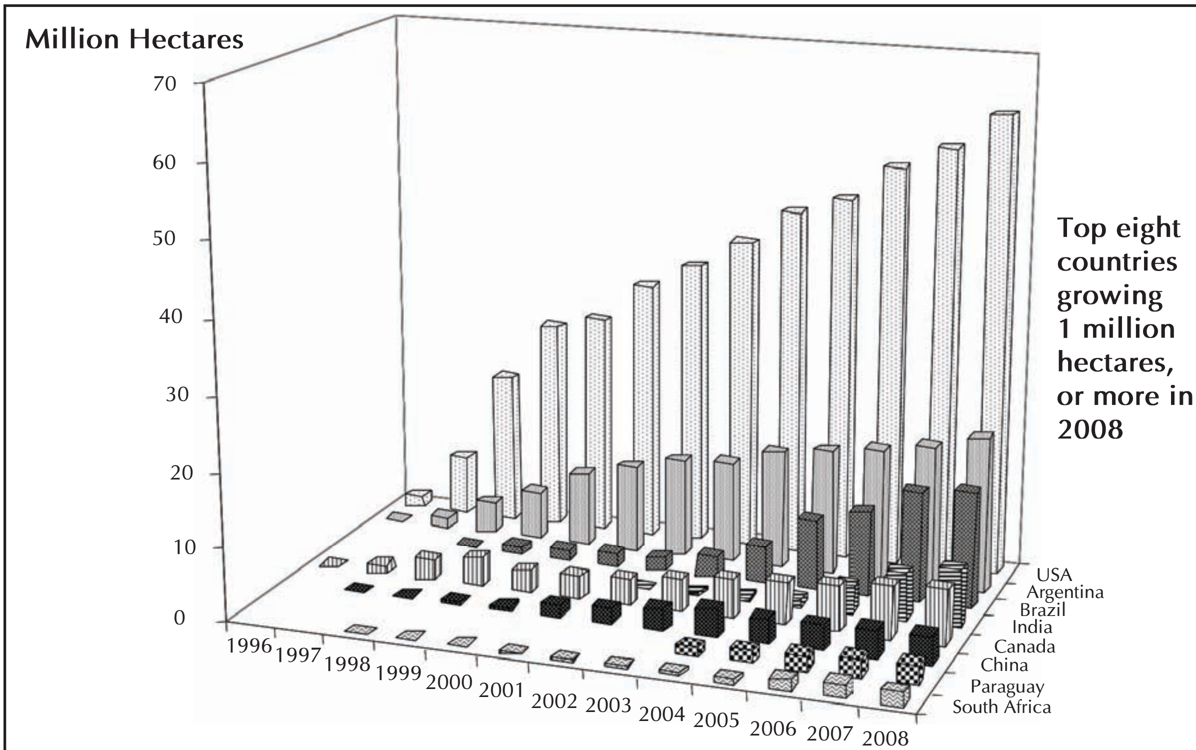
Increase over 2007



25 countries which have adopted biotech crops

In 2008, global area of biotech crops was 125.0 million hectares, representing an increase of 9.4% over 2007, equivalent to 10.7 million hectares.

Source: Clive James, 2008.



Source: Clive James, 2008.

The third new biotech crop country in 2008 was Bolivia in the Andean region of Latin America. Bolivia is the eighth largest grower of soybean in the world and like its neighbors, Brazil and Paraguay, now benefits from herbicide tolerant RR®soybean. Bolivia becomes the ninth country in Latin America to benefit from the extensive adoption of biotech crops; the nine Latin American countries, listed in order of hectarage include, Argentina, Brazil, Paraguay, Uruguay, Bolivia, Mexico, Chile, Colombia, and Honduras.

In 2008, the seven EU countries, Spain, Czech Republic, Portugal, Germany, Slovakia, Romania and Poland grew a total of 107,719 of Bt maize. Despite the fact that France suspended Bt maize plantings in 2008, the biotech crop hectarage in the EU increased in each of the seven countries for a significant collective total of 19,046 hectares equivalent to a substantial growth rate of 21% from 2007 to 2008.

The three countries with increases in absolute area of biotech crops of 1.0 million hectares or more, between 2007 and 2008 were the USA with a 4.8 million hectare increase, Argentina with a 1.9 million hectare increase, and India with a 1.4 million hectare increase. Modest growths in crop biotech areas were reported in Canada, Uruguay, Paraguay, Philippines and Australia.

Based on proportional year-to-year annual growth in biotech crop area, six countries (notably, four are mega-biotech developing countries), Australia, Uruguay, Philippines, India, Argentina and Canada had exceptionally high rates of growth, resulting in 100 to 9% annual growth in biotech crop area. Australia doubled its biotech crop hectarage from a low base in 2007 following two years of the most severe droughts in the country's history. India continued to experience high year-on-year proportional growth, with a 23% increase in Bt cotton area in 2008 over 2007. Philippines also increased its biotech crop area by 33% reporting a significant increase in maize with the stacked traits for borer resistance and herbicide tolerance.

The six principal countries that have gained the most economically from biotech crops, during the first 12 years of commercialization of biotech crops, 1996 to 2007 are, in descending order of magnitude, the USA (US$20.0 billion), Argentina (US$8.3 billion), China (US$6.7 billion), India (US$3.2 billion), Brazil (US$2.9 billion), Canada (US$2.0 billion), Paraguay (US$0.5 billion) and others (US$0.4 billion) for a total of approximately US$44 billion; US$22 billion for developing countries and US$22 billion for industrial countries (Brookes and Barfoot, 2009, forthcoming).

In 2007 alone, economic benefits globally were US$10.2 billion of which US$5.8 billion was for developing and US$4.4 billion was for industrial counties. The countries that have gained the most economically from biotech crops in 2007 are, in descending order of magnitude, the USA (US$3.8 billion), India (US$2.0 billion), Argentina (US$1.7 billion), China (US$0.9 billion), Brazil (US$0.8 billion), Canada (US$0.5 billion), Paraguay (US$0.1 billion) and others (US$0.4 billion) for a total of US$10.2 billion. In 2007, developing countries gained slightly more than industrial countries – US$5.8 billion or 57% for developing countries and US$4.4 billion or 43% for industrial countries.

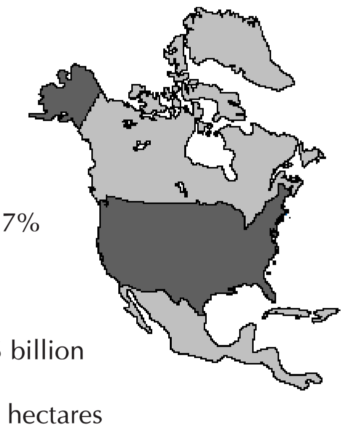
The 25 countries that grew biotech crops in 2008 are listed in descending order of their biotech crop areas in Table 3. There were 15 developing countries, and 10 industrial countries including Romania, the Czech Republic, Poland and Slovakia from Eastern Europe. In 2008, biotech crops were grown commercially 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 2008, are listed in order of crop biotech hectarage in Table 3 and include the USA, Argentina, Brazil, 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, Mexico, Spain, Chile, Colombia, Honduras, Burkina Faso, Czech Republic, Romania, Portugal, Germany, Poland, Slovakia and Egypt. The following country reports provide a more detailed analysis of the biotech crop situation in each of the 25 biotech crop countries, with more detail provided for the 14 mega-biotech countries growing 50,000 hectares, or more, of biotech crops.

USA

> **The USA is the largest producer of biotech crops in the world with a 2008 global market share of 50%. In 2008, the USA planted a record hectarage of 62.5 million hectares of biotech maize, soybean, cotton, canola, sugar beet, alfalfa, papaya and squash, up significantly from the 57.7 million hectares in 2007, and equivalent to a year-on-year growth rate of 8%. The increase in biotech crop hectarage of 4.8 million hectares between 2007 and 2008 was the largest 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 2008, the USA also pioneered the commercialization of biotech sugarcane for the first time on approximately one-quarter of a million hectares. The adoption rate for the principal biotech crops in the USA: soybean, maize, cotton and canola are close to optimal and further increases will be achieved through stacking of multiple traits in the same crop. It is estimated that 29% of the US maize crop will be used for ethanol in 2008, up from 24% in 2007.**

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 2008 with impressive continued growth, particularly in terms of biotech soybean and biotech maize in which stacked traits continued to be an important feature. The adoption rate for biotech soybean exceeded 90%. Herbicide tolerant sugar beet was commercialized for the first time in the USA in 2008. The total hectarage planted to biotech soybean, maize, cotton, canola, sugar beet, alfalfa, squash, papaya was 62.5 million hectares, up 4.8 million hectares or 8% from the 57.7 million hectares planted in 2007. This 4.8 million hectare increase in 2008 is the largest increase in absolute terms, for any country in 2008, despite the fact that percent adoption of all biotech crops in the USA are now close to optimal levels.

USA



Population: 299.4 million

GDP: US$13,195 billion

% employed in agriculture: 0.7%

Agriculture as % GDP: 1%

Agricultural GDP: US$131.95 billion

Arable Land (AL): 165 million hectares

Ratio of AL/Population*: 2.4

Major crops:
- Maize
- Soybean
- Cotton
- Sugarcane
- Sugar beet
- Alfalfa
- Wheat
- Canola

Commercialized Biotech Crops:
- HT/Bt/HT-Bt Maize
- HT Soybean
- Bt/HT/Bt-HT Cotton
- HT Canola
- VR Squash
- VR Papaya
- HT Alfalfa
- Bt/HT Potato
- HT Sugar beet

Total area under biotech crops and (% increase in 2008):
62.5 Million Hectares (+8% in 2008)

Farm income gain from biotech, 1996-2007: $20.0 billion

*Ratio: % global arable land / % global population

Total plantings of maize in the USA in 2008 were 35.3 million hectares (the third highest ever since 1944 when a record 38.7 million hectares were planted), but down 7% from the 37.9 million hectares in 2007. Biotech maize continued to be attractive in the USA in 2008 because of favorable international prices, continued demand for ethanol and strong export sales, which together provided farmers with the incentive to plant the third highest hectarage of maize in 2008. Maize planting started slowly with frequent rains and low temperatures in March and April and this delayed planting in the corn belt, Ohio Valley and the Great Plains. In April and May, conditions improved and favored planting and emergence. Despite the weather delays, producers eventually made rapid progress and planting was completed just a little later than the average year. Extensive floods in June resulted in some producers changing their harvest plans, modifying, planting decisions and implementing replanting options, but overall record productivity is expected. Total plantings of soybean at 30.2 million hectares were up 17% from 2007 when plantings were 25.8 million hectares. The principal reason for the increase in soybean in 2008 was that farmers shifted from the high input costs for maize to soybean which is judged by many farmers to be more profitable than other crop options.

Total plantings of upland cotton at 3.66 million hectares in 2008 was 14% down from the 4.2 million hectares planted in 2007, the lowest hectarage since 1989. American Pima cotton growers planted 81,178 hectares in 2008, down 31% from 2007. The major reasons for the sharp decline in area of upland cotton in 2008 were the relatively low international price of cotton compared with the higher price of maize and soybean that led growers to switch to the higher profits that could be made with maize and soybeans which also offered a more secure market.

Canola hectarage in 2008 was over 400,000 hectares. The major canola state of North Dakota planted 368,000 hectares compared with a record 425,000 hectares in 2007. Sugar beet which featured RR® herbicide tolerant varieties for the first time in 2008 was planted on 437,246 hectares, of which more than half was RR®sugar beet. Estimates of alfalfa seedings for 2008 will not be available from USDA until the first quarter of 2009, but they are not likely to be very different from 2007 seedings at 1.3 million hectares – includes alfalfa harvested as hay and alfalfa haylage and green chop. Alfalfa is seeded as a forage crop and grazed or harvested and fed to animals.

In 2008, the USA continued to grow more biotech crops (62.5 million hectares) than any other country in the world, equivalent to 50% of global biotech crop hectarage. In 2008, the gain was 4.8 million hectares of biotech crops, equivalent to an 8% growth rate. Year-over-year growth at 4.8 million hectares in 2008 was the highest for any country in the world. The increase was the highest for several reasons. Firstly, there was a substantial increase of 4.4 million hectares of soybean plantings and well over 90% of this additional hectarage was planted to RR®soybean. Secondly, although the increase in soybeans was offset by decreased maize plantings the adoption of biotech maize continued to climb with strong growth in the stacked traits, particularly in the triple stacks. The significant 14% decrease in hectarage of upland cotton contributed to a decreased area of 3.2 million hectare of biotech cotton which is already at optimal levels of adoption at approximately 90%. However, even the significant growth of 4.81 million hectares in 2008 does not come close to fully measuring 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 62.5 million hectares of biotech crops planted in the USA in 2008, approximately 32.3 million hectares, (21.1 million in 2007) equivalent to 52% compared with 37% in 2007, had either two or three stacked traits.

The stacked two-trait 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 2008 was approximately 102 million hectares (up from 87.1 million hectares in 2007) compared with only 62.5 million "hectares" of biotech crops. Thus, the apparent year-to-year growth for biotech crops in the USA, based on hectares, is 8%, on an increase from 57.7 million hectares to 62.5 million hectares. However, the “real” growth rate for biotech crops in the USA in 2008 is 18%, due to the number of “trait hectares” increasing from 87.1 million hectares in 2007, by 15.5 million hectares to 102.6 million hectares in 2008. Furthermore, for maize, within the stacked traits category there are both double and triple stacks, and in 2008, the highest growth was in the triple stacks. For example, compared with 2007, in 2008 the percent occupied by single traits as a percentage of the total biotech maize area decreased from 37% in 2007 to 22% in 2008, for double traits the decrease was from 35% to 30% whereas the triple traits increased from 28% in 2007 to 48% in 2008.

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 and in 2008 reached almost half the total hectarage of all biotech maize in the USA at over 14 million hectares. 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. In fact, Canada, the Philippines, Australia, Mexico, South Africa, Honduras, Colombia, Argentina, and Chile are the nine other countries that have deployed stacked traits at this time, albeit at much lower proportions than the USA, but this is a trend that will increasingly affect other countries. The total stacked trait hectarage in Canada, the Philippines, Australia, Mexico, South Africa, Honduras, Colombia, Argentina, and Chile was less than 1,250,000 hectares. In 2008, the global “trait hectares” was 166 million hectares compared with only approximately 144 million hectares in 2007, equivalent to a growth rate of 15%. Thus, the apparent growth rate of 9.4%, based on an increase from 114.3 million hectares in 2007 to 125 million hectares in 2008 underestimates the real growth rate of 15%, equivalent to 22 million hectares based on the growth in “trait hectares“ from 144 million “trait hectares” in 2007 to 166 million “trait hectares” in 2008. Thus, in summary on a global basis “apparent growth” in biotech crops between 2007 and 2008, measured in hectares, was 9.4% or 10.7 million hectares, whereas the real growth measure in “trait hectares” was approximately double the apparent growth rates at 22 million hectares or 15%.

The biggest increase in USA biotech crops was for soybean with a gain of 4 million hectares compared to 2007. In 2008, the area of biotech soybean, 28.6 million hectares, had the highest adoption rate of any USA biotech crops at over 90%, the highest ever. The decrease in biotech cotton of approximately 750,000 hectares from 3.9 million hectares in 2007 to 3.2 million hectares in 2008 is equivalent to almost a 20% decrease and biotech cotton now occupies 87% of upland cotton in the USA. Of the 3.2 million hectares of upland cotton in the USA in 2008, 75% was occupied by the stacked traits of Bt and herbicide tolerance, 23% were herbicide tolerance, and 2% with single Bt trait. Total canola plantings in the USA were over 400,000 hectares with over 90% planted to herbicide tolerant biotech canola.

There was no change in the RR®alfalfa hectarage of 100,000 hectares between 2007 and 2008 pending resolution of the court suspension of further planting in March 2007, until additional information about the product was submitted to regulators for consideration. 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 has been well received by farmers in the USA with all available seed sold in 2006 and demand is 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 provides 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 USA 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 recent 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 provides factual evidence for USDA to complete its environmental impact study for submission to lift the court order on planting of RR®alfalfa.

A new and important biotech crop was planted for the first time in the USA in 2008, RR® herbicide tolerant sugar beet. It is estimated that in 2008, 59% of the 437,246 hectares of sugar beet planted in the USA, equivalent to 257,975 hectares were RR®sugar beet. Farmers welcomed the commercialization of sugar beet and were very pleased with the biotech product, which provided superior weed control, was more cost-effective and easier to cultivate than conventional sugar beet. Farmers cited many advantages of RR®sugar beet 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 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 collateral damage from herbicide applications; and generally more profitable and convenient to cultivate than conventional sugar beet. As a result of the significant and multiple advantages, it is projected that up to 90% of the sugar beet in the USA in 2009 will be biotech RR®sugar beet. Growers are convinced of the value of RR®sugar beet and are 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.

The USA is one of the largest importers of sugar in the world, most of the sugar produced in the USA (97%) and by-products are consumed in the USA. However, the sugar, pulp and molasses derived from the RR®sugar beet has been approved for importation in the entire major export markets including Japan and the EU. It is important to note that the sugar from RR®sugar beet does not contain any DNA from the biotech transformation process so the product is the same as conventional sugar and accordingly does not require to be labeled in the USA and in foreign markets like Japan.

Adoption of biotech derived sugar from RR®sugar beet by processors and the public has important implications regarding acceptance of biotech sugar beet in other countries including the EU and more generally from sugarcane which is grown mainly in the developing countries of the world and used extensively in some lead countries like Brazil for ethanol production. In this connection, in November 2008, Monsanto Company announced plans (Monsanto, 2008) to acquire the sugarcane breeding company Aly Participacoes Ltda. in an effort to tap the growing demand for raw sugar and biofuels. Monsanto acquired the Brazil-based company for US$209 million, which operates CanaVialis S.A. and Alellyx S.A. CanaVialis is the world's largest private sugarcane breeding company. Alellyx, on the other hand, is an applied genomics company that focuses on developing biotech traits primarily for sugarcane. Monsanto has previously established a licensing and trait-collaboration agreement with these companies to develop and commercialize Roundup Ready and Bt insect-protected technologies for sugarcane growers in Brazil.

A spokesman for Monsanto, said "We expect the additions of CanaVialis and Alellyx will allow us to combine our breeding expertise with key large-acre crops with their breeding expertise in sugarcane. Our goal with this approach is to increase yields in sugarcane while reducing the amount of resources needed for this crop's cultivation, just as we're doing now for corn, soybeans and cotton". Brazil is the world's largest producer of sugarcane, the largest exporter of finished sugar, and the world's second-largest producer of ethanol after the United States. 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 in the USA in 2008.

In the USA in 2008, biofuel production continued mainly from maize, but also for biodiesel from oil crops. It is estimated that production from 29% of the total maize area in the USA in 2008 was used for ethanol, up from 24% in 2007. Accordingly, it is estimated that in 2008, 8.7 million hectares of biotech maize was devoted to ethanol production, up from 7 million hectares in 2007. Corresponding estimates for biodiesel indicate that in 2008, 475 to 500 million gallons of biodiesel will be produced. Approximately 3.5 million hectares of biotech soybean (7% of total biotech soybean plantings) will be used for biodiesel production; this compares with 3.43 million hectares (13% of total plantings) in 2007. It is further estimated that approximately 5,000 hectares of canola was used for biodiesel. Ceres recently released two biotech-based but non-transgenic hybrids of biotech sorghum and switch grass with enhanced levels of cellulose for ethanol production with a plan to initiate marketing in 2009; transgenic products are under development.

Benefits from Biotech Crops in the USA

In the most recent global study on the benefits from biotech crops, Brookes and Barfoot (2009, forthcoming) estimate that USA has enhanced farm income from biotech crops by US$20 billion in the first twelve years of commercialization of biotech crops 1996 to 2007, (representing 45% of global benefits for the same period) and the benefits for 2007 alone are estimated at US$3.8 billion (representing 37% of global benefits in 2007) – 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 USA 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).

ARGENTINA

Argentina is the second largest producer of biotech crops in the world with a projected 2008 global market share of 17%. In 2008, Argentina was expected to plant a record hectarage of 21.0 million hectares of biotech soybean, maize and cotton, up significantly from 19.1 million hectares in 2007 and equivalent to a year-to-year growth rate of 10%.

ARGENTINA

Population: 39.9 million

GDP: US$214.3 billion

% employed in agriculture: 1%

Agriculture as % GDP: 9.5%

Agricultural GDP: US$20.35 billion

Arable Land (AL): 28.2 million hectares

Ratio of AL/Population*: 3.1

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 2008):
21 Million Hectares (+10% in 2008)

Farm income gain from biotech, 1996-2007: US$8.3 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. Argentina remained the second largest grower of biotech crops (21.0 million hectares) in 2008 comprising 17% of global crop biotech hectarage. In 2008, the year-over-year increase, compared with 2007, was 1.9 million hectares, up from 1.1 million hectares in 2007; the annual growth rate in 2008 was 10% compared with only 6% in 2007. Of the 21.0 million hectares of biotech crops in Argentina in 2008, 18.1 million hectares were expected to be planted to biotech soybean, up 2.2 million hectares over 2007. The 18.1 million hectares of biotech soybean is equivalent to 99% of the record planting of 18.2 million hectares of the national soybean crop in Argentina in 2008. Total plantings of maize in Argentina in 2008 were expected to reach about 4 million hectares. The hectarage of biotech maize plantings in 2008 is expected to be approximately 2.5 million hectares. Of the 2.5 million hectares of biotech hybrid maize, about 2 million hectares were planted to Bt maize, 200,000 to herbicide tolerant maize, and 300,000 hectares with the stacked gene Bt /HT which was approved in 2007 but adequate seed supply was not available until 2008. Thus, the adoption rate in the 3.4 million hectares of hybrid maize was approximately 60% for Bt and less than 10% for herbicide tolerant maize and the stacked traits. Argentina reported the total area of cotton for 2008 at close to 400,000 hectares. Of the 400,000 hectares of total cotton plantings in 2007, 158,000 hectares were Bt cotton and 192,000 hectares were herbicide tolerant cotton – the stacked gene Bt/HT has been submitted for approval but, unlike stacked maize, is yet to be approved. The increase in biotech cotton during the last two 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. 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.

Details of the events approved to-date for commercialization in Argentina are provided in Table 4 including the designation of the event and the year of approval.

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 5). The study estimated benefits on the basis of production increases which could be

Table 4. Commercial Approvals for Planting, Food and Feed

Crop	Trait	Event	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 × Insect resistance	NK603 × MON810	2007
Maize	Herbicide tolerance × Insect resistance	NK603 × TC 1507	2008

Source: ArgenBio, 2008 (Personal Communication).

Table 5. 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.

identified as resulting from the adoption of the new technologies, including the impact of increased productivity in animal production related to RR®soybean.

Herbicide tolerant RR®soybean was first planted in Argentina in 1996, and after a decade they account for virtually 100% of the total soybean hectarage. In addition an estimated 65% of maize and 60% of cotton planted in Argentina were also biotech varieties. 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.

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 5).

The major findings of the study were:

Herbicide tolerant RR® biotech 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, 2009, forthcoming) estimates that Argentina has enhanced farm income from biotech crops by US$8.3 billion in the first twelve years of commercialization of biotech crops 1996 to 2007, and the benefits for 2007 alone were estimated at US$1.7 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).

BRAZIL

In 2008, Brazil retained its position as the country with the third largest hectarage of biotech crops in the world, provisionally estimated at 15.8 million hectares. Of the 15.8 million hectares of biotech crops grown in Brazil in 2008, 14.2 million hectares were planted to RR®soybean, for the sixth consecutive year, 250,000 hectares were planted with a single gene Bt cotton, grown officially for the third time in 2008, and 1.3 million hectares of Bt maize for the first time in 2008. The year-over-year growth between 2007 (15.0 million hectares) and 2008 (15.8 million hectares) was 5%.

The salient aspect of Brazil's grain production in the last 20 years or so, is the doubling of production to approximately 130 million tons of grain on the same area of land of around 30 million hectares, which has remained constant since 1900 (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 already expediting the deployment of second generation and stacked traits.

BRAZIL

Population: 186.8 million

GDP: US$1,067.4 billion

% employed in agriculture: 20%

Agriculture as % GDP: 8.4%

Agricultural GDP: US$89.66 billion

Arable Land (AL): 58.6 million hectares

Ratio of AL/Population*: 1.4

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

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

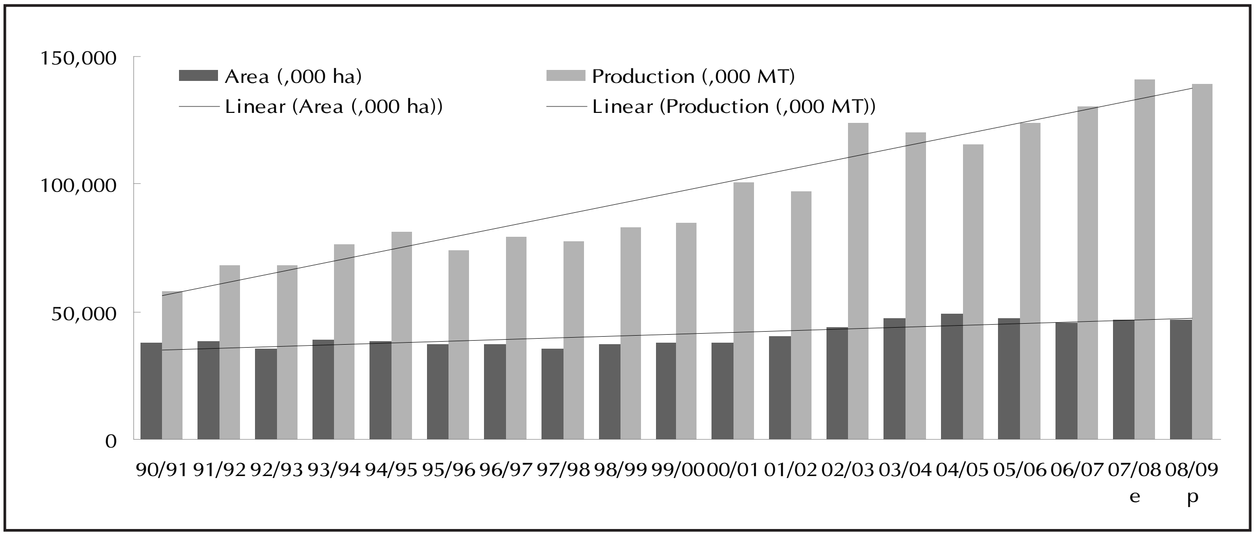
Total area under biotech crops and (% increase in 2008):
15.8 Million Hectares (+5% in 2008)

Farm income gain from biotech, 2003-2007: US$2.9 billion

*Ratio: % global arable land / % global population

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 is eroding its comparative

Figure 5. Brazilian Grain Production, 1990 to 2008



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

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 Brazil for 2007/08 has always been a challenge in Brazil involving factors that are unrelated to biotech crops *per se*. The major uncertainties are the high volatility in the price of soybean and the strength of the Brazilian Real against the US dollar as well as the higher prices of crop inputs such as fertilizers and pesticides linked to the unprecedented increase in the price of oil which almost touched US$150 per barrel in mid 2008.

The situation in the state of Matto Grosso is the most pivotal because it is the swing state in terms of soybean production that reacts strongly to both positive and negative financial developments. Whereas there is little doubt that Brazil offers more potential for biotech crops than possibly any other country in the world in the long term, short term constraints need to be addressed, including the inadequate supply of fully adapted RR®soybean germplasm with optimal yield, particularly for the Central West region, which also has to bear high cost to transport soybean to the port for exports. Another factor is the continuing short supply of expensive glyphosate in 2008, which has to compete with less expensive generic pre-and post emergence herbicides. In 2008, these constraints have instilled a sense of great uncertainty in soybean farmers in Brazil with net benefits of RR®soybean versus conventional soybeans decreasing to the point in some areas that the benefits are marginal leaving convenience as the major advantage. However, RR®soybean remains 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 Matto Grosso requiring up to 6 applications of fungicide at US$25 per application, which can make soybean production less profitable.

Many farmers expressed more uncertainty about their intent to plant more hectares of soybean which in turn impacts on hectarage of RR®soybean in 2008/09 than 2007/08. It is estimated that there are now well over 100,000 farmers growing soybean in Brazil. After Matto Grosso, the state of Parana is 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 2008, Parana is expected to plant around 61 to 69% of its 4.0 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 2006, China bought 10.8 million metric tons of soybeans from Brazil. In 2007, the figure increased to 25.0 million metric tons worth US$2.4 billion, representing 43% 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 6 confirm the importance of agricultural exports in Brazil which constituted almost US$56 billion in 2007 with a growth of over 13% between 2006 and 2007, with RR®soybean playing a major role. Similarly, the trade data indicates net agricultural trade of US$47.5 billion, growing at a vigorous 11.5% per year and agricultural trade constituting 118.5% of total trade, and again RR®soybean playing a major role. 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 India. The total soybean export market for Brazil in 2007 was worth US$11.4 billion, comprising US$6.7 billion for the soybean grain. The projected market for 2008 is US$18.4 billion for total soybean exports of which US$11.1 billion for beans the projection for the 2009 market, is a decrease of total soybean exports to US$16.8 billion capered with US$18.4 billion for 2008 (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 stable supply for China. Soybean exports now account for 25% of Brazil's total exports to China worth US$1.7 billion in 2005 and according to China, Brazilian soybean accounts for 30% of total soybean imports.

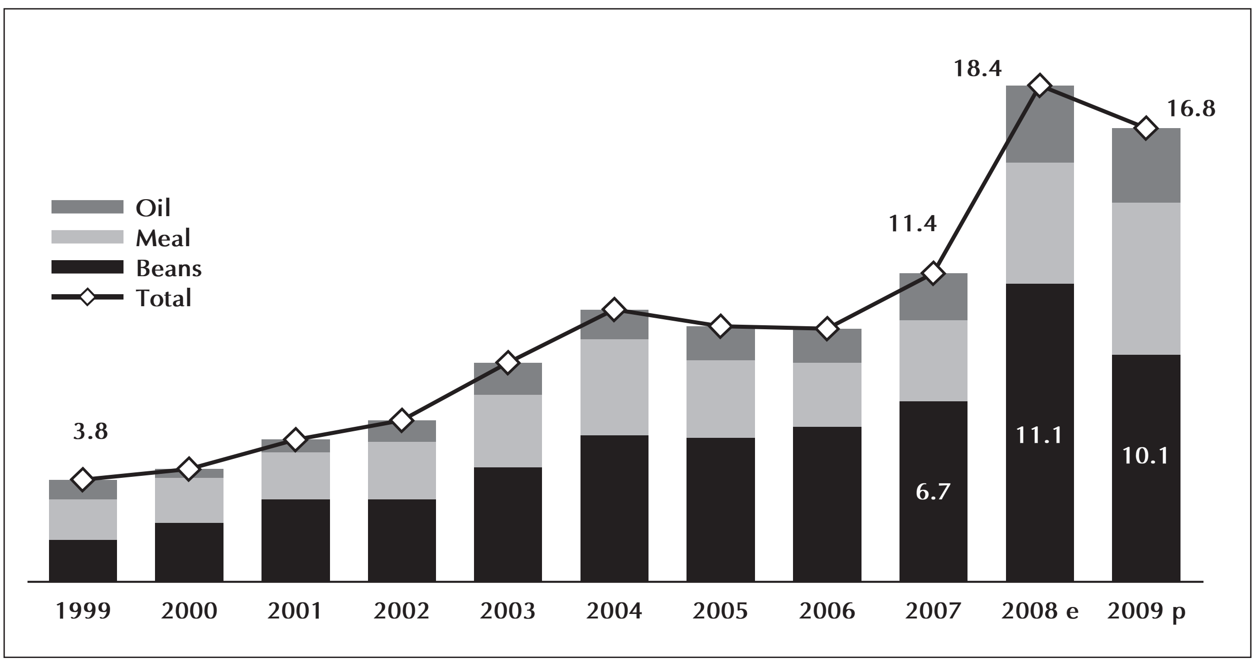
With the strengthening Real against the US dollar the cost of production and lower income from soybean exports has been offset with unprecedented increases in the price of soybean on the export markets. Thus, a stronger Real plus increasing cost of production plus the plummeting of future prices in the next few months has contributed to enormous uncertainty for 2008/09 soybean planting and in turn the 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

Table 6. Agricultural Exports and Net Agricultural Trade in Brazil, in US$ Billions, for 2005 to 2007

	2005	2006 (a)	2007 (b)	Change (a/b)	Share
Ag exports	43.6	49.4	56.0	+13.4%	34.8%
Total exports	118.3	137.5	160.7	+16.9%	
Ag imports	5.2	6.8	8.5	25.0%	7.0%
Total imports	73.6	91.4	120.6	32.0%	
Net trade					
Ag trade	38.4	42.6	47.5	11.5%	118.5%
Total trade	44.7	46.1	40.1	-13.0%	

Source: Brazilian External Trade Secretariat (SECEX), 2008. Elaboration: Céleres

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



Source: SECEX. Elaboration (e) and Projection (p): Céleres, 2008.

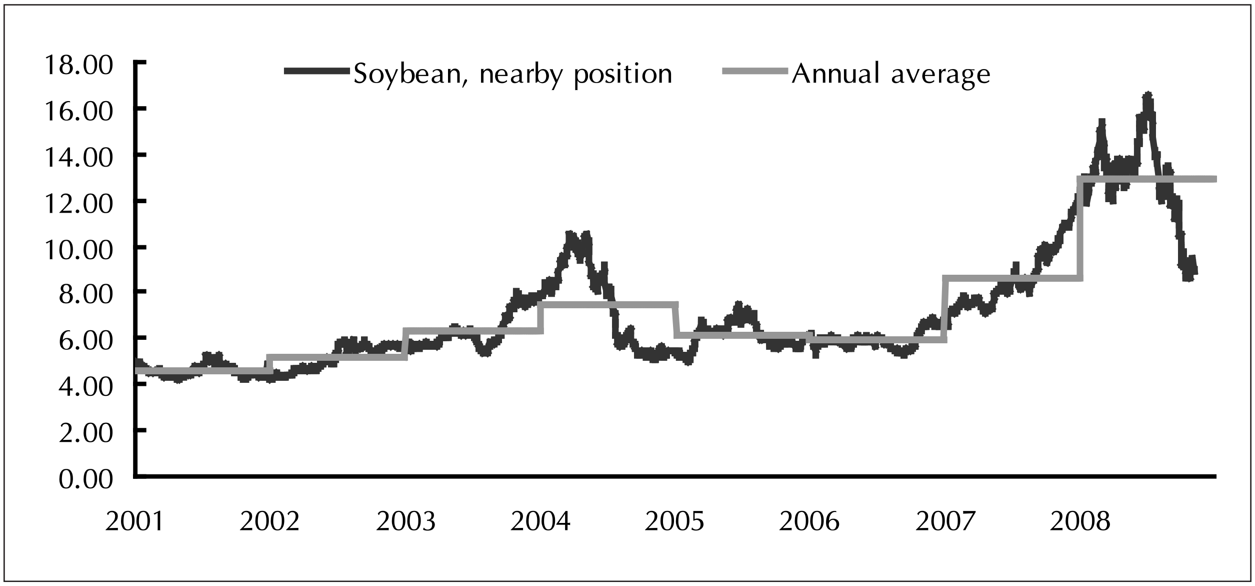
cause more uncertainty in terms of credit. Nevertheless, Brazil remains strong agriculturally being the world's largest producer of sugarcane and oranges, has the largest commercial cattle herd on the globe, and is the world leader in beef exports. It is the second biggest producer of soybean and ethanol in the world and agricultural exports reached US$56 billion in 2007, comprising a substantial 35% of total exports (Table 6 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 grain and oil seeds for feed and poultry and pork production; large productivity gaps in crops such as maize, cotton, and rice with entrepreneur farmers that 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, which could suffer significantly in the current recession. Note the 44% precipitous drop in global soybean prices between the high of July 2008 and October 2008 (Figure 7).

The significant increase in cost of production of soybean in Brazil between 2007 and 2008 is exhibited in Figure 8 with fertilizers representing half of the total production costs but seeds at only 5%. 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. In summary, in 2008 farmers are likely to switch from crops with higher production costs such as maize and cotton to crops such as soybean which have relatively lower production costs. The data presented in Figure 9 projects lower hectarages for maize, cotton and wheat with small increases in rice, and edible beans and a larger increase of approximately 600,000 hectares in soybean resulting in a net reduction in grain hectarage of approximately 100,000 hectares.

In 2007, several million 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 (3.8 million hectares), Parana (2.8), Matto Grosso (2.7), Goias (1.3), and Matto Grosso do Sul (1 million hectares). Given farmer options and profitability of alternate crops, total planting of soybean in Brazil in 2008/09 is expected to be 21.9 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 mid December 2008, approximately half to two-thirds of the soybean crop had been planted in Brazil.

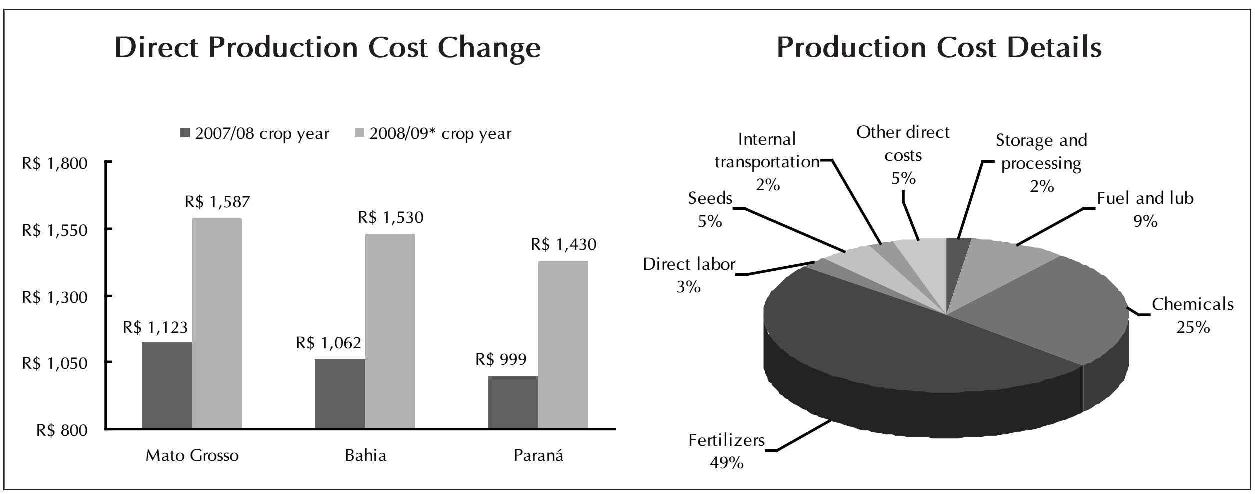
Whereas RR®soybean was approved in Brazil in 1998 (Table 7) legal issues delayed its official planting until 2003 when the first RR® varieties were registered (Figure 10). It is provisionally projected that RR® biotech soybean will occupy approximately 14.2 million hectares of the 21.9 million hectare crop in Brazil in the 2008/09 season, equivalent to an adoption rate of 65% which is similar to 2007/08 in percentage terms and within 2% of the RR®soybean hectarage of 14.5 million hectares in 2007. The unavailability of adequate quantities of RR varieties adapted to the

Figure 7. Global Soybean Prices, 2001 until 2008



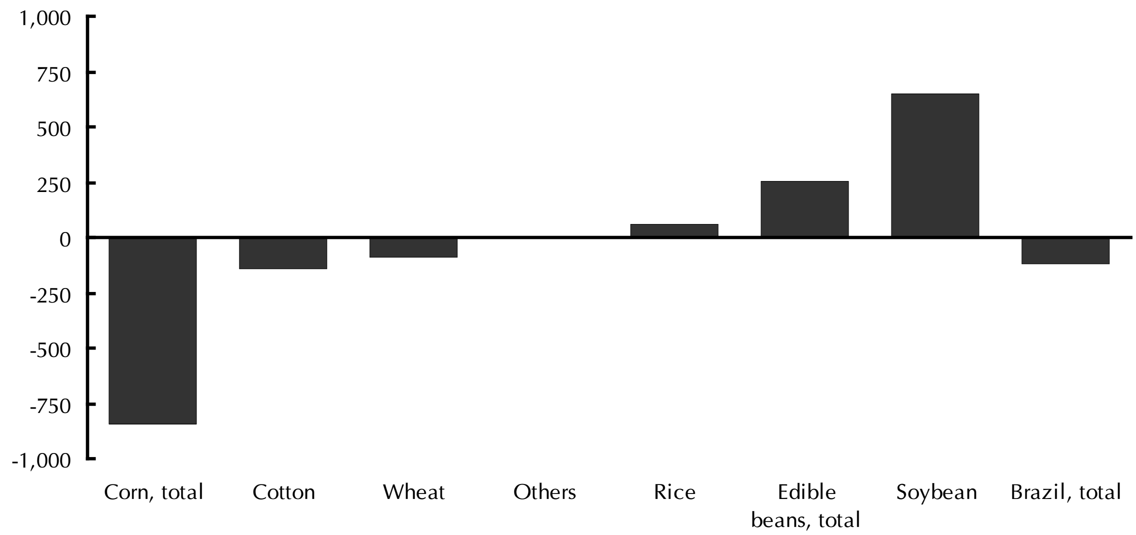
Source: Chicago Board of Trade, 2008. Values in US$/bushel

Figure 8. Soybean Production Cost in Brazil, 2007/08 and 2008/09



Source: Céleres, 2008. Values in BRL/hectare Estimated in October, 2008

Figure 9. Projected Changes in Grain Planted Area, Brazil, 2008/09 and 2007/08



Source: Céleres based on October, 2008 survey. Values in thousand hectares

Table 7. Approved and Pending Biotech Crop Products from CTNBio Brazil, as of November 2008

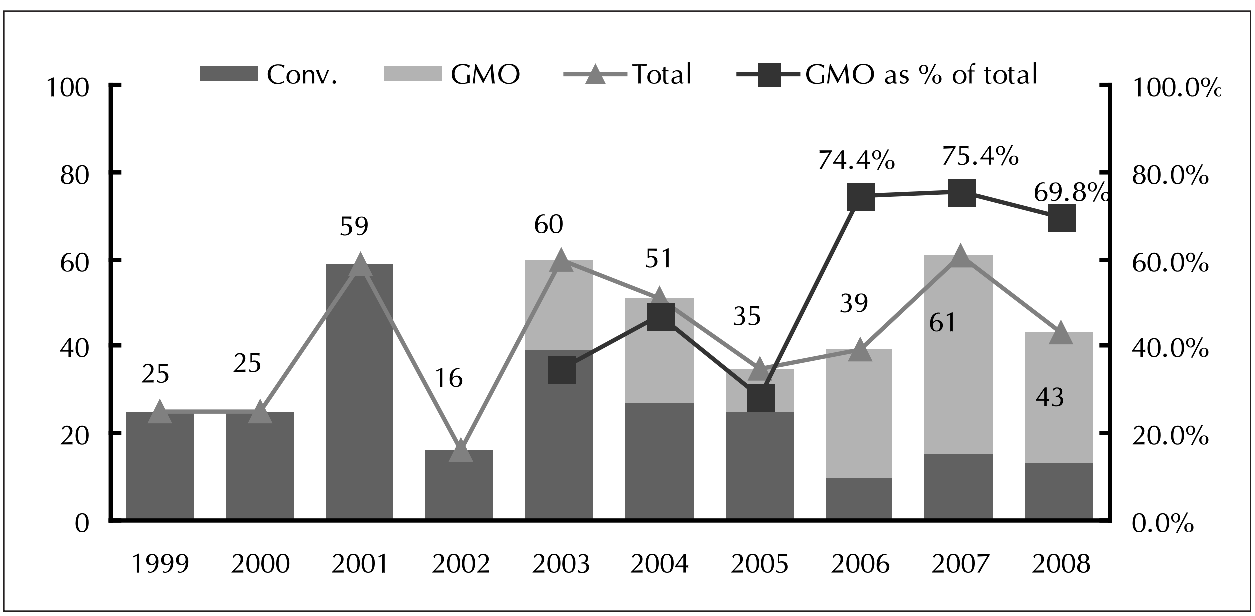
Crop	Trait	Event	Approval
Soybean	Herbicide tolerance (HT)	CP4 EPSPS (GTS 40-3-2)	1998
Cotton	Insect resistance (IR)	Cry1Ac/NPTII (MON531)	2005
Maize	Insect resistance	Cry1Ab (MON810)	2007
Maize	Herbicide tolerance	PAT (T25)	2007
Cotton	Herbicide tolerance	PAT (LLCotton25)	2008
Cotton	Herbicide tolerance	CP4 EPSPS/NPTII (MON 1445)	2008
Maize	Insect resistance	Cry1Ab/PAT (Bt11)	2008
Maize	Herbicide tolerance	CP4 EPSPS (NK603)	2008
Maize	Herbicide tolerance	mEPSPS (GA21)	2008
Maize	HT/IR	PAT/ cry1Fa2	2008
Soybean	High Oleic Acid Content	G94-1/G94-19/G168	Pending
Rice	Herbicide tolerance	LLRice62	Pending
Maize	Herbicide tolerance/Insect resistance	VIP3A/PAT	Pending

Source: CTNBio Brazil, 2008.

central area remains a constraint to increasing hectarage of RR®soybean as well as all the significant economic issues discussed earlier. A total of 43 varieties were registered for sale in 2008 of which 30, equivalent to 70% were RR®soybean with the remaining 13 varieties (30%) conventional (Figure 10). Since RR®soybean was approved in 2003 a total of 289 new varieties have been approved of which 160 or 55% were biotech and 129 or 45% were conventional. The data for the registration of both conventional and biotech soybean varieties for the period 1999 to 2008 are detailed in Figure 10 showing more RR®soybean varieties than conventional, and this trend is expected to continue. Lack of adapted approved varieties for the states outside the South, particularly the central region resulted to limited adoption in 2008/09 as it did in 2007/08; it is expected that this situation will improve but not entirely remedied in 2009/10.

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, another two varieties of herbicide tolerant cotton were approved in Brazil but was not planted in the 2008 season (Table 7). 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

Figure 10. Soybean Cultivars Registered in Brazil, 1999 to 2008



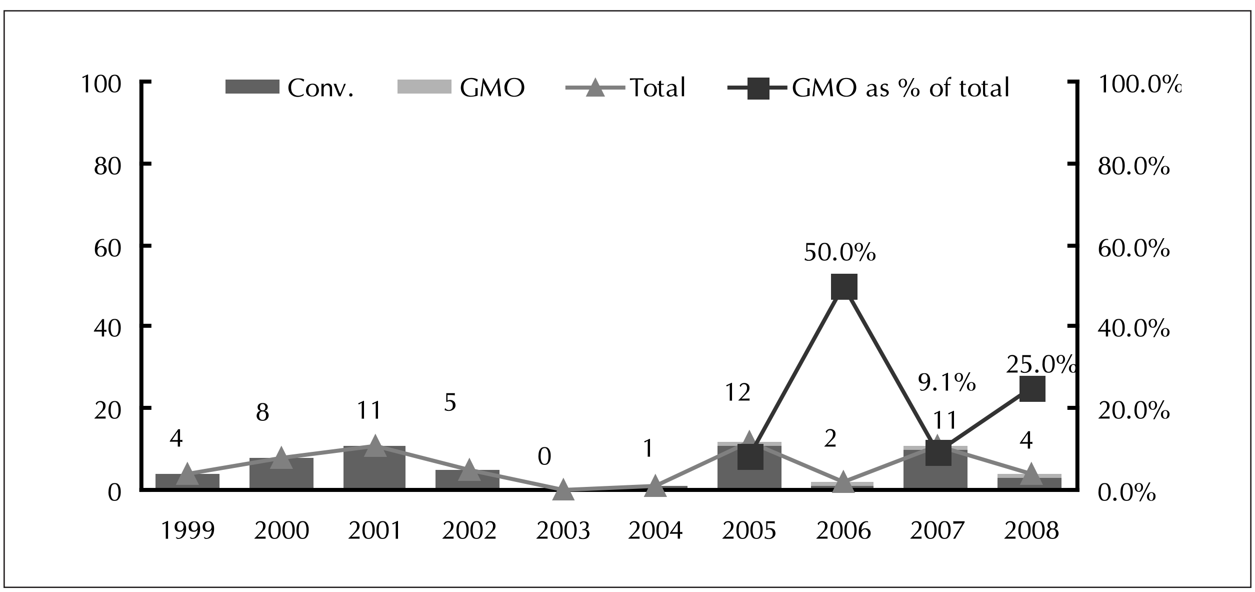
Source: Brazilian Ag Minister/SNRC, 2008. **Elaboration: Céleres**

cotton growing states of Matto Grosso and Bahia. Brazil is expected to grow approximately 960,000 hectares down from the 1.1 million hectares of cotton in 2007, making it the sixth largest grower of cotton, by area, in the world after India, USA, China, Pakistan, and Uzbekistan.

The adoption of the approved single event of biotech Bt cotton in Brazil in 2008/09 is projected at 0.250 million hectares down from 0.500 million hectares in 2007. The reason for this apparent decrease maybe due to under-reporting of the total Bt cotton plantings in Brazil. 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 2008 maybe low to a significant degree. This issue is reflected in the fact that only two varieties of Bt cotton were registered in 2008 (Figure 11) compared with 95 biotech maize hybrids (Figure 12). If the issues in relation to Bt cotton can be remedied and Bollgard®II officially approved and released, then the percentage adoption 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.

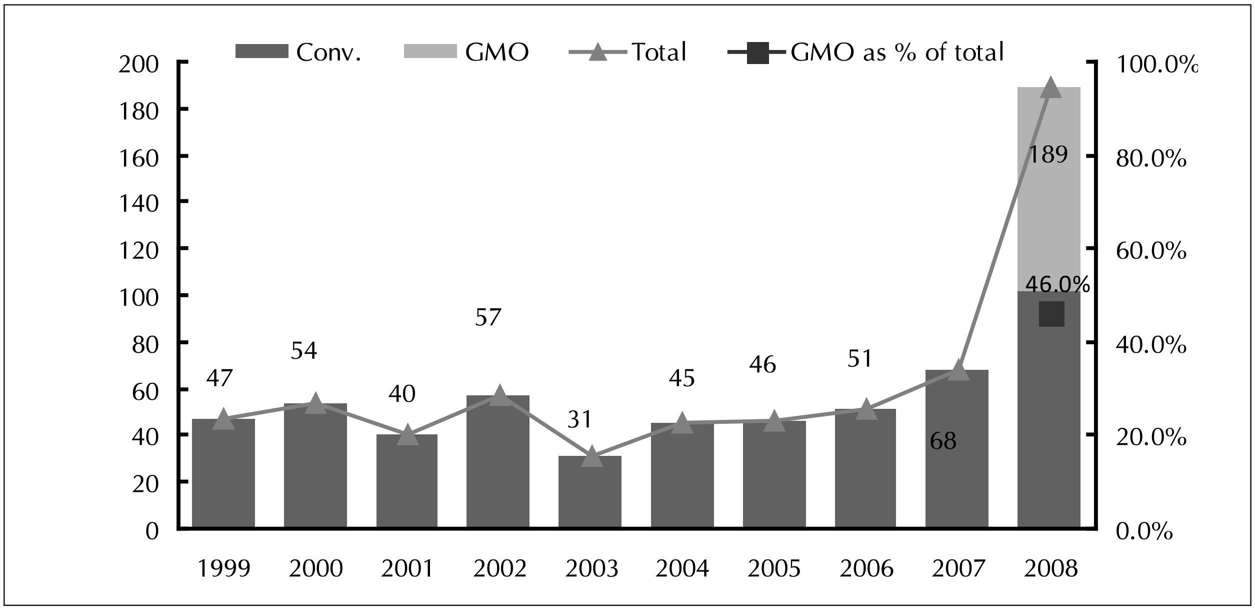
Cotton is grown by both large and small farmers, and Bt cotton offers the poor small farmers in the impoverished North East (NE) region of Brazil significant socio-economic benefits, similar to those experienced in China and India. In fact the heavy losses from insects in the North East led to the collapse 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 the

Figure 11. Cotton Varieties Registered in Brazil, 1999 to November, 2008



Source: Brazilian Ag Minister/SNRC, 2008. Elaboration: Céleres

Figure 12. Maize Hybrids and Lines Registered in Brazil, 1999 to 2008



Source: Brazilian Ag Minister/SNRC, 2008. Elaboration: Céleres

national policy 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 to the current 1 million hectares. There is the potential for reversing the decline in cotton area in Brazil with the adoption of Bt cotton and establish Brazil as an exporter of cotton to meet growing world market needs.

In 2008, one hybrid of Bt maize was approved and cultivated and two hybrids of herbicide tolerant maize were approved but not cultivated in 2008 (Table 7). 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 planting in January 2009 and beyond – given that the second planting started in December 2008, this is considered a 2008 planting for this Brief.

Of the 9.2 million hectares in the first 2008 planting harvested in September 2008, about 600,000 hectares were estimated to be Bt maize equivalent to an adoption rate of 6%. For the second planting of maize starting in December 2008 of the plantings of 4.3 million hectares, a projected 730,000 hectares is estimated to be Bt maize equivalent to an adoption rate of 17%. Consolidating the two separate maize plantings in Brazil in 2008 brings the total maize hectarage to 13.5 million hectares of which 1.3 million hectares, or 10% 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 2009 and beyond. The first stacked event (herbicide tolerance and Bt) was approved in 2008 (PAT/cry1Fa2), see Table 7.

In 2008, Brazil retained its position as the country with the third largest hectarage of biotech crops in the world, provisionally estimated at 15.8 million hectares. Of the 15.8 million hectares of biotech crops grown in Brazil in 2008, 14.2 million hectares were planted to RR®soybean, for the sixth consecutive year, 250,000 hectares planted with a single gene Bt cotton, grown officially for the third time in 2008, and 1.3 million hectares of Bt maize for the first time in 2008. The year-over-year growth between 2007 (15.0 million hectares) and 2008 (15.8 million hectares) was 5%. 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 6.2 million hectares and uses approximately half of its sugar production for generating ethanol for biofuels. In the coming five years the sugarcane hectarage in Brazil is expected to increase by more than 35% to approximately 8.5 million hectares by 2012. By 2012, Brazil will produce 643 million tons of sugarcane. The share of sugarcane hectarage devoted to bioethanol is expected to increase from the current 50 to 64% by 2012. Thus, Brazilian ethanol production should reach 29.5 billion liters of which 4.3 billion liters will be exported in 2012.

The re-instatement of authority by Comissão Técnica Nacional de Biossegurança (CTNBio) to approve RR®soybean and Bt cotton in March of 2005, was by far the most important recent development in Brazil. CTNBio's challenge now is to deal with a backlog of applications that has accumulated whilst the long debate over its authority delayed all decisions related to approval of biotech crops. In 2008, CTNBio made progress by approving five products (Table 7). Recently, CTNBio approved a stacked maize product with insect resistance and tolerance to glufosinate – the initial approval is subject to a final commercial clearance by the Ministry of Agriculture.

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 for feed, food, and to meet 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 learnt 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. An incomplete list of CTNBio approved and pending applications for products is detailed in Table 7. 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 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 8 and 9). Brazil has approximately 350 sugar mills/distilleries, another 46 under construction and yet another 46 being considered for construction. Brazil produces 19% of the 164.4 million tons of sugar produced globally, 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 2007, 85% of the biodiesel produced in Brazil was planned to be produced from soybean, which in 2007 would have required an estimated 1.2 million hectares, equivalent to 5.8% of the total hectarage of 22.5 million hectares. Thus, about 750,000 hectares of RR®soybean in Brazil were planned to be used for biodiesel production in 2007. No actual data is available for biodiesel production in Brazil in 2007, but it is understood that production targets may not have been met. There are no estimates of how much soybean were used for biodiesel production in 2008. 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 6.2 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 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.

Table 8. 2007 World Fuel Ethanol Production

Country	Millions of Gallons	Millions of Liters
USA	6,498.6	24,599.80
Brazil	5,019.2	18,999.68
European Union	570.3	2,158.81
China	486	1,839.70
Canada	211.3	799.86
Thailand	79.2	299.80
Colombia	74.9	283.53
India	52.8	199.87
Central America	39.6	149.90
Australia	26.4	99.93
Turkey	15.8	59.80
Pakistan	9.2	34.82
Peru	7.9	29.90
Argentina	5.2	19.68
Paraguay	4.7	17.79
Total	**13,101.70**	**49,592.87**

Source: F.O. Licht, in Renewable Fuels Association, 2008.
1 US gallon = 3.7854 liters

Updated information for 2007 on the global production, by country, and the top ten countries are provided in Table 8. Table 9 shows the world ethanol production for 2004 to 2006. Brazil remains the second largest producer of ethanol in the world. Based on 1 US gallon equivalent to 3.7854 liters, in 2007, Brazil produced 19 billion liters of ethanol (up by 6% from 17.0 billion liters in 2006) compared with 24.6 billion liters for the USA, up by 33.7% from 18.4 billion liters, in 2006.

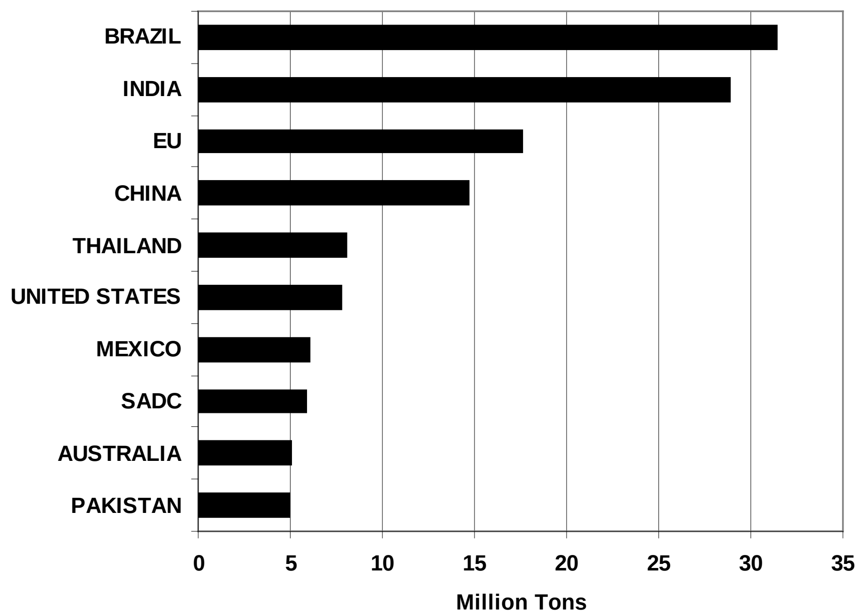
Globally, more than 100 countries produce sugar. Worldwide 80% of sugar is produced from sugarcane (the balance of 20% from sugar beet) grown principally in the tropical/sub-tropical zones of the southern hemisphere. The production and processing costs of sugarcane is lower than sugar beet. About 70% 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 2007, Brazil continued to be the top producer in the world at 31.4 million tons followed closely by India at 28.8 million tons and distally by the EU 27 at 17.6 million tons (Figure 13).

Table 9. Annual World Ethanol Production by Country, (Millions of Gallons, All Ethanol Grades)

Country	2004	2005	2006
Brazil	3,989	4,227	4,491
U.S.	3,535	4,264	4,855
China	964	1,004	1,017
India	462	449	502
France	219	240	251
Russia	198	198	171
South Africa	110	103	102
U.K.	106	92	74
Saudi Arabia	79	32	52
Spain	79	93	122
Thailand	74	79	93
Germany	71	114	202
Ukraine	66	65	71
Canada	61	61	153
Poland	53	58	66
Indonesia	44	45	45
Argentina	42	44	45
Italy	40	40	43
Australia	33	33	39
Japan	31	30	30
Pakistan	26	24	24
Sweden	26	29	30
Philippines	22	22	22
South Korea	22	17	16
Guatemala	17	17	21
Cuba	16	12	12
Ecuador	12	14	12
Mexico	9	12	13
Nicaragua	8	7	8
Mauritius	6	3	2
Zimbabwe	6	5	7
Kenya	3	4	5
Swaziland	3	3	5
Others	338	710	270
Total	**10,770**	**12,150**	**13,489**

Source: F.O. Licht, in Renewable Fuels Association, 2008.
1 US gallon = 3.7854 liters

Figure 13. Top Sugar Producers, 2007 - 2008 Estimates



Source: International Sugar Statistics (Source: ED & F Man - 2007/08, Oct/Sep basis).

Benefits from Biotech Crops in Brazil

Brazil is estimated to have enhanced farm income from biotech soybean by US$2.9 billion in the five-year period 2003 to 2007 and the benefits for 2007 alone is estimated at US$0.8 billion (Brookes and Barfoot, 2009, forthcoming).

In addition to economic benefits there are also environmental benefits associated with RR®soybean, (Carneiro, 2007) which have been determined by modeling. The study indicated that 62.7 million liters of diesel have been saved since 1997 as a result of a saving of 1.5 herbicide sprays on RR®soybean. In addition, it is estimated that 7.5 billion liters of water have been saved (through reduced herbicide sprays) plus a reduction of 160,000 tons of CO_2 emissions. For the next 10 years, 2007/08 to 2016/17, assuming a cumulative hectarage of 262 million hectares of biotech soybean in Brazil, savings of 393.3 million liters of diesel is projected in addition to savings of 47.2 billion liters of water and a reduction of 1 million tons of CO_2 emissions.

Environmental benefits can also be generated from biotech crops other than soybean. Assuming an accumulated area of 16.5 million hectares of biotech cotton in the period 2007/08 to 2016/17 it is projected that biotech cotton will save 28.2 million liters of diesel, save 4.9 billion liters of water, and reduce CO_2 emissions by 72.3 thousand tons. Similar environmental benefits will accrue from the deployment of other biotech crops such as biotech maize, expected to be deployed in 2008 and other biotech crops such as sugarcane in the near-term.

In a detailed study (Galvão Gomes, 2007) the economic benefits were calculated for RR®soybean for the period 1998 to 2006/07; RR®soybean was planted unofficially from 1998 to 2002 and officially from 2003 onwards. The data shows (Table 10) that farmers gained US$1.5 billion in the period 1998 to 2006 and technology developers gained US$0.59 billion – thus, the farmers gained 72% of the profits and technology developers 28% – 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 (2007) also estimated the 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 1998 to 2006 cost farmers US$3.10 billion and technology developers an additional US$1.41 billion for total lost benefits of US$4.51 billion. Thus, the total potential benefits for both farmers and technology developers in the period 1998 to 2006 was US$6.6 billion of which only US$2.09 billion equivalent to 31% was realized – US$4.5 billion was lost due to legal/regulatory delays which is a significant sacrifice for Brazil and the major losers were farmers (Table 11) .

Applying the implications of the 1998 to 2006 study to the next decade, Galvão Gomes, (2007) further projected that if biotech cotton suffers the same delay as RR®soybean in the 1998 to 2006 period, then the potential loss for cotton in the period 2006 to 2015 would be US$2.1 billion for biotech cotton, and US$6.9 billion for biotech maize for a total of US$9 billion (Table 11). These projections of loss are a sobering reminder of the real risks involved if the technology is not accessed in a timely and responsible manner. The recent commitments, 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 is therefore reassuring. Moreover, a significant part of the US$7 billion is to be devoted to biofuels and agriculture – this is a welcome development reflecting the political will and support of the current Government to biotechnology (Brazilian Government, 2007). 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.
- One of the key goals of this policy is to replicate in the biotechnology field, the success Brazil has achieved with biofuel production, especially ethanol from sugarcane.

Table 10. Benefits and "Lost Benefits" ($US Billions) from RR® Soybean in Brazil, 1998 to 2006

Beneficiary	Realized Benefits	Lost Benefits	Total Potential Benefits
Farmer Benefits	1.50	3.10	4.60
Tech Developer Benefits	0.59	1.41	2.00
Total	**2.09**	**4.51**	**6.60**

Source: Galvão Gomes, 2007, Personal Communication.

Table 11. Loss to Brazilian Farmers if Biotech Maize and Cotton Not Adopted in Reasonable Time Frame in Next Decade

Crop	Value of Loss (US$ Billions)
Maize	6.9
Cotton	2.1
Total	**9.0**

Source: Galvão Gomes, 2007, Personal Communication.

- The executive decree projects public and private investment of Real 10 billion (US$7 billion) over the next 10 years, from 60% public resources and 40% private resources.
- The policy aims to coordinate activities among the national agricultural, environmental, health and industry and trade Ministers.
- Being part of a national policy, the Brazilian Bank of Development (BNDS) will provide special credit lines to the biotech companies to invest in research and development.
- The Brazilian Association of Biotech Companies (ABRABI), which represents the private biotech sector in Brazil, has estimated that its current investment in biotech is between Real 5.4 billion (US$3.8 billion) and Real 9.0 billion (US$6.3 billion) and employing 28,000 workers nationwide.

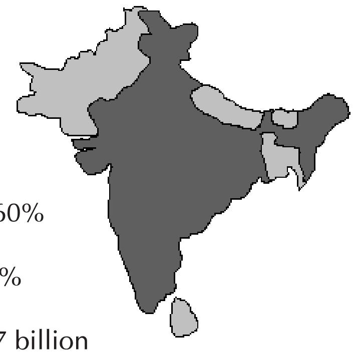
In November 2007, Brazilian President Luis Inacio Lula da Silva announced a US$23 billion investment in a four-year "Plan for Action for Science, Technology and Innovation." One of the four thrusts is to support research and innovation in strategic areas particularly biotechnology, biofuels and biodiversity. It is noteworthy that the political will for biotechnology evident in Brazil is also evident in China and India. The troika of Brazil, India and China is a formidable force in agricultural biotechnology that can deliver enormous humanitarian benefits that can be mobilized to alleviate poverty and hunger for resource-poor farmers by 2015, under the Millennium Development Goals, when it is expected that all three major staples, maize, rice and wheat, as well as several orphan crops will benefit from biotechnology.

INDIA

In 2008, 5 million small farmers in India planted and benefited from 7.6 million hectares of Bt cotton, equivalent to 82% of the 9.3 million hectare national cotton crop, the largest in the world. This is a significant increase over 2007 when 3.8 million farmers planted 6.2 million hectares equivalent to 66% of the 2007 cotton crop. The Bt cotton story in India is remarkable, with an unprecedented 150-fold increase in adoption between 2002 and 2008. In the short span of six years, 2002 to 2007, Bt cotton has generated economic benefits of US$3.2 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. A 2007 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 enhanced levels of pro-vitamin A. India has several biotech food crops in field trials, including biotech rice. However, Bt brinjal, an important vegetable that requires heavy applications of insecticide, is the most likely to be the first food crop to be commercialized in India, requiring significantly less insecticide and capable of contributing to the alleviation of poverty of 1.4 million small, resource-poor farmers who grow brinjal in India.

India, the largest democracy in the world, is highly dependent on agriculture, which generates almost one quarter of its GDP and provides two thirds of its people with their means of survival. 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 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 – 9 to 9.6 million hectares (estimated at 9.6 million hectares in 2007 and 9.3 in 2008) and cultivated by approximately 6.4 million farmers in 2007 and 6.2 million farmers in 2008. Based on the latest estimate (Table 12), the Directorate of Cotton Development, Ministry of Agriculture reports that 6.4 million farmers planted cotton on 9.6 million hectares in 2007 with an average cotton holding of 1.5 ha (Ministry of Agriculture India, 2007). In 2008, the total hectarage of cotton in India was estimated at 9.3 million hectares farmed by 6.2 million farmers, approximately 3% lower than the 9.6 million hectares farmed by 6.4 million farmers in 2007; this decrease is slightly lower than the 6% decrease in cotton hectarage globally in 2008 versus 2007. Comparing the distribution of cotton hectarage by States in India in 2007 (Table 12), Maharashtra, the largest cotton-growing State, had 2.2 million farmers growing cotton, which occupied approximately 33% of India's total cotton area; this was mostly cultivated on dry land. Gujarat had 1.4 million farmers, followed by 0.76 million in Andhra Pradesh, 0.47 million in Madhya Pradesh, 0.37 million in Rajasthan, 0.28 million in Haryana, 0.25 million farmers each in Punjab, Karnataka and Tamil Nadu and the balance in other states of India.

INDIA



Population: 1.09 billion

GDP: US$923 billion

% employed in agriculture: 60%

Agriculture as % GDP: 18.6%

Agricultural GDP: US$171.7 billion

Arable Land (AL): 145.2 million hectares

Ratio of AL/Population*: 0.60

Major crops:
- Sugarcane
- Rice, paddy
- Wheat
- Vegetables, fresh
- Potato
- Cotton

Commercialized Biotech Crop: Bt Cotton

Total area under biotech crops and (% increase in 2008):
7.6 Million Hectares (+23% in 2008)

Farm income gain from biotech, 2002-2007: US$3.2 billion

*Ratio: % global arable land / % global population

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 7 years has coincided with more than a doubling of yield, 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 zone are predominately rainfed. In 2008, of the total 9.3 million hectares, hybrids occupied 85% (7.9 million hectares) of the cotton area and only 15% (1.4 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

Table 12. Land Holdings Distribution and Production of Cotton in India, 2007 to 2008

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	0.641	2.200	583	0.243
2	Haryana	1.72	0.483	1.600	563	0.280
3	Rajasthan	0.98	0.368	0.900	416	0.375
4	Gujarat	1.80	2.516	11.200	757	1.400
5	Maharashtra	1.46	3.191	6.200	330	2.183
6	Madhya Pradesh	1.38	0.662	2.100	539	0.478
7	Andhra Pradesh	1.45	1.096	4.600	714	0.760
8	Karnataka	1.56	0.388	0.800	351	0.250
9	Tamil Nadu	0.52	0.130	0.500	654	0.250
10	Orissa	0.76	0.050	0.150	510	0.066
11	Others	0.30	0.030	1.250	283	0.103
	(Weighted Average) or Total	**(1.500)**	**9.555**	**31.500**	**(560)**	**6.388**

Source: Ministry of Agriculture, India, 2007.

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 90% of the hybrid cotton production in India and all the current Bt cotton hybrids are *G. hirsutum* (Table 13).

Hectarage of Bt Cotton Hybrid Planted in India, 2002 to 2008

Bt cotton, which confers resistance to important insect pests of cotton, was first adopted in India in hybrids in 2002. In 2002, 54,000 farmers grew approximately 50,000 hectares of officially approved Bt cotton hybrids for the first time and doubled their Bt cotton area to approximately 100,000 hectares in 2003 (Figure 14). 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 record increases in adoption 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

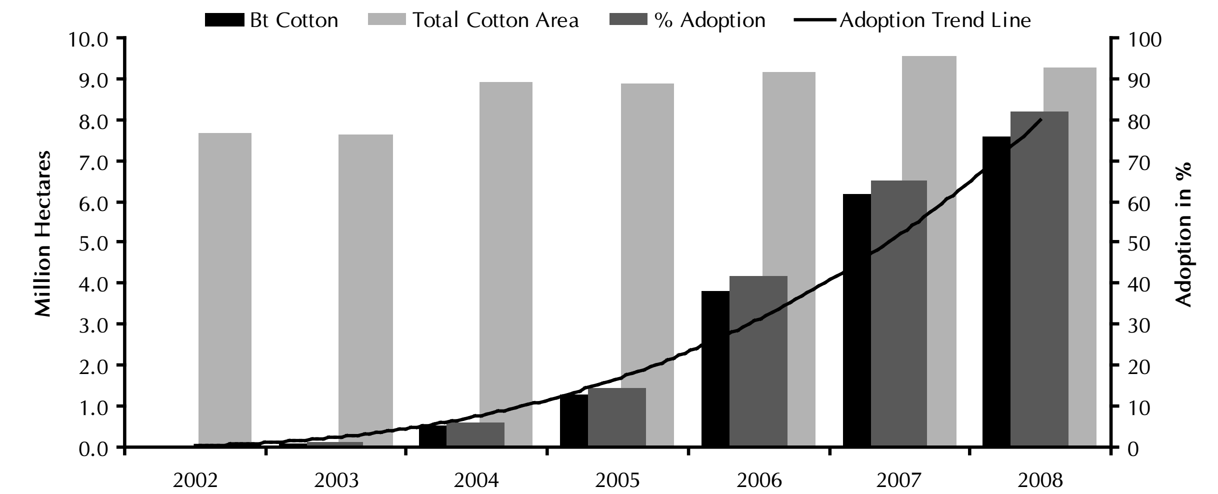
Table 13. Cotton Growing Zones in India

Zones	North Zone	Central Zone	South Zone
States	Punjab, Haryana, Rajasthan	Maharashtra, Madhya Pradesh, Gujarat, Orissa	Andhra Pradesh, Karnataka, Tamil Nadu
Area	1.492 Million hectares	6.369 Million hectares	1.614 Million hectares
Production	4.7 Million bales	19.5 Million bales	5.9 Million bales
Productivity	536 kg/ha	520 kg/ha	620 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. herbaceum*	*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, India, 2007.

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, Bt cotton area increased yet again to a record 7.6 million hectares from 6.2 million hectares in 2007. This is the fourth 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 and a 63% increase in 2007 and a 23% increase in 2008 (Figure 14). In addition, in 2006-07 India overtook the USA to become the second largest cotton producing country in the world, after China (USDA/FAS, 2007).

Figure 14. Adoption of Bt Cotton in India for the Seven Year Period, 2002 to 2008



Source: Compiled by ISAAA, 2008.

Of the estimated 9.3 million hectares of cotton in India, in 2008, 82% or 7.6 million hectares were Bt cotton hybrids – a remarkably high proportion in a fairly short period of seven years equivalent to an unprecedented 150-fold increase from 2002 to 2008. Of the 7.6 million hectares of hybrid Bt cotton grown in India in 2008, 35% was under irrigation and 65% rainfed. A total of 274 Bt cotton hybrids were approved for planting in 2008 compared with only 131 in 2007, 62 in 2006, 20 in 2005 and only 4 Bt cotton hybrids in 2004. Over the last seven 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 2008 is shown in Table 14 and Figure 15. The major states growing Bt cotton in 2008, listed in order of hectarage, were Maharashtra (3.13 million hectares) representing almost half, or 42%, of all Bt cotton in India in 2008, followed by Gujarat (1.36 million hectares or 18%), Andhra Pradesh (1.32 million hectares or 18%), Northern Zone (840,000 hectares or 11%), Madhya Pradesh (620,000 hectares or 8%), and the balance in Karnataka and Tamil Nadu and other states.

Number of Farmers Growing Bt Cotton Hybrid in India, 2002 to 2008

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 million small and resource-poor farmers, up from

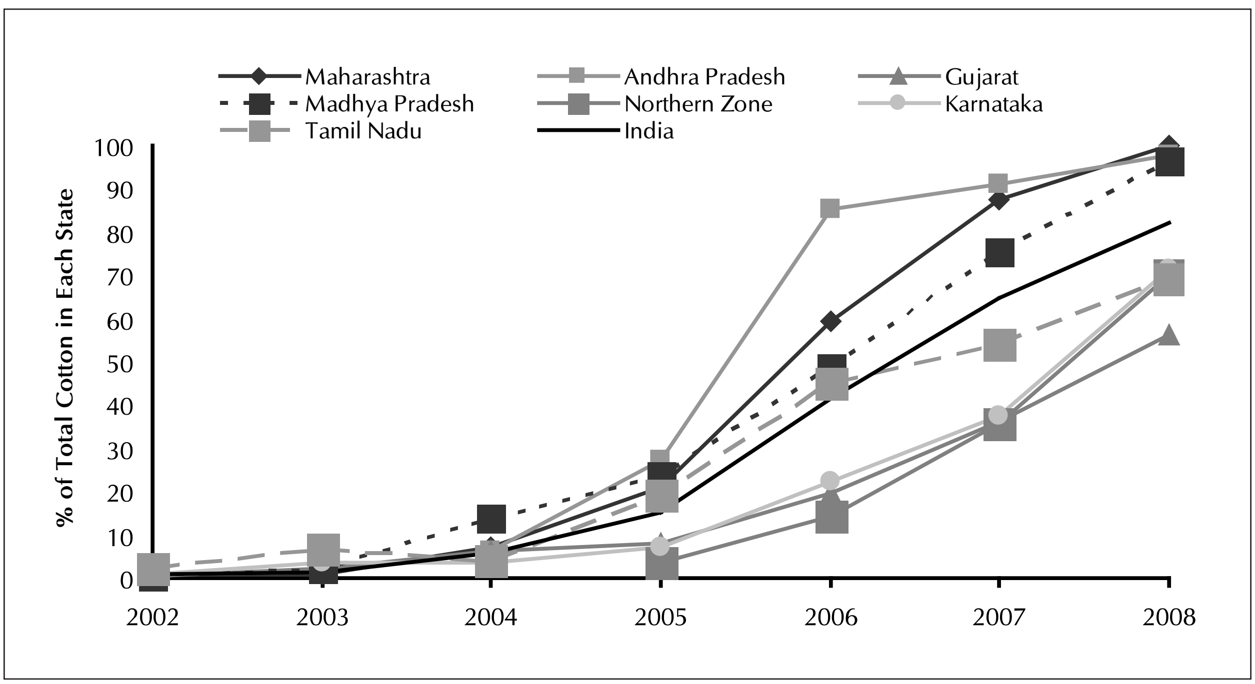
Table 14. Adoption of Bt Cotton in India, by Major States, 2002 to 2008 (Thousand Hectares)

State	2002	2003	2004	2005	2006	2007	2008
Maharashtra	25	30	200	607	1,840	2,880	3,130
Andhra Pradesh	8	10	75	280	830	1,090	1,320
Gujarat	10	36	122	150	470	908	1,360
Madhya Pradesh	2	13	80	146	310	500	620
Northern Zone*	- -	- -	- -	60	215	682	840
Karnataka	3	4	18	30	85	145	240
Tamil Nadu	2	7	5	27	45	70	90
Other	- -	- -	- -	- -	5	5	5
Total	**50**	**100**	**500**	**1,300**	**3,800**	**6,200**	**7,605**

* Punjab, Haryana, Rajasthan

Source: ISAAA, 2008.

Figure 15. Percent Adoption of Bt Cotton in India and in Different States Expressed as Percentage Adoption within States and Nationally in India, 2002 to 2008

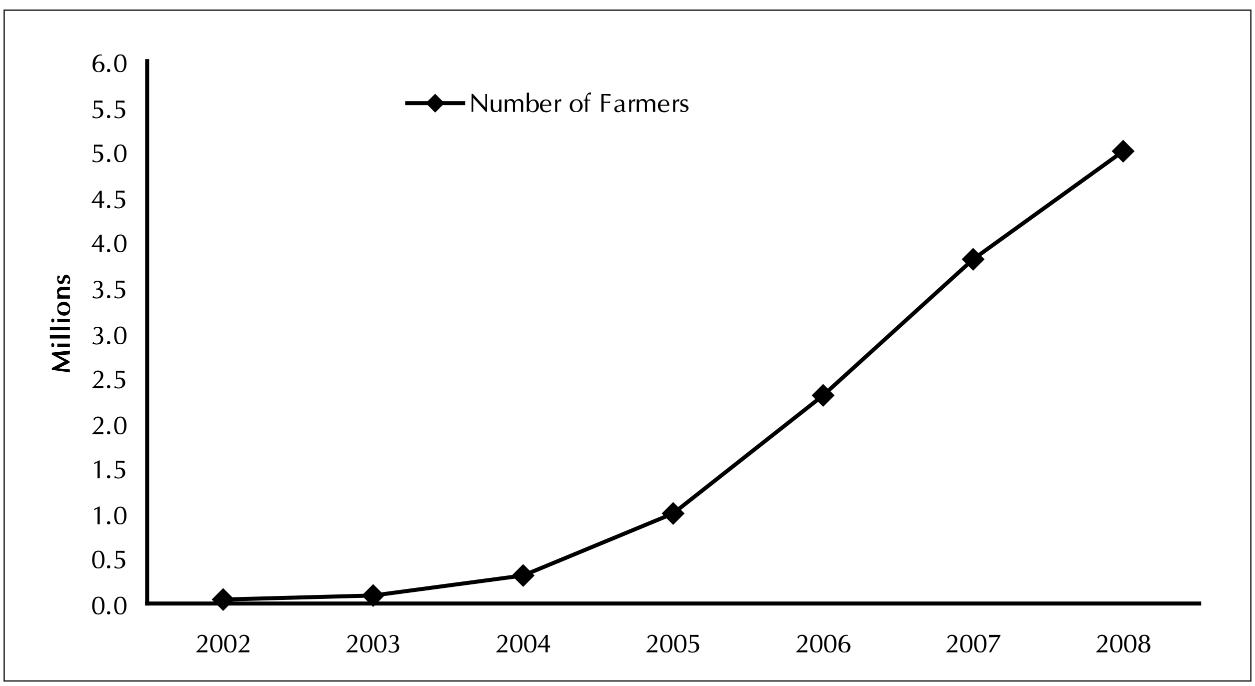


Source: Compiled by ISAAA, 2008.

3.8 million in 2007, planted Bt cotton hybrids in 2008 (Figure 16). 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, to 3.8 million farmers in 2007 and to 5 million farmers in 2008; this is the largest increase in number of farmers planting biotech crops in any country in 2008. The 5 million small and resource-poor farmers who planted and benefited significantly from Bt cotton hybrids in 2008 represented approximately 80% of the total number of 6.2 million farmers who grew cotton in India in 2008. Given that only 82% of the cotton area is planted to hybrid cotton, the percentage adoption for the 7.6 million hybrid hectares alone in 2008 was 96%; 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 Bt variety, as opposed to Bt hybrids, was approved in India in 2008 but not commercialized pending multiplication of seed for the 2009 season. Thus, the first Bt cotton variety will be planted in India in 2009 on the remaining 15% of cotton hectarage that is not occupied by hybrids.

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. A recent 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:

Figure 16. Number of Small Farmers Adopting Bt Cotton Hybrids in India, 2002 to 2008



Source: Compiled by ISAAA, 2008.

"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 15), 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, insecticides 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.

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 16). 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

Table 15. Value of the Total Pesticide Market in India, Relative to the Value of the Cotton Insecticide Market, 1998 and 2006

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

Source: Chemical Industry, 2007.

Table 16. 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 (CIBRC), Ministry of Agriculture, 2008.

rates to reach 82% of all cotton hectarage in India in 2008. The data in Table 16 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 and 2008 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 82% of all cotton in 2008. It is noteworthy that the decline in pesticide usage between 1998 and 2006 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.

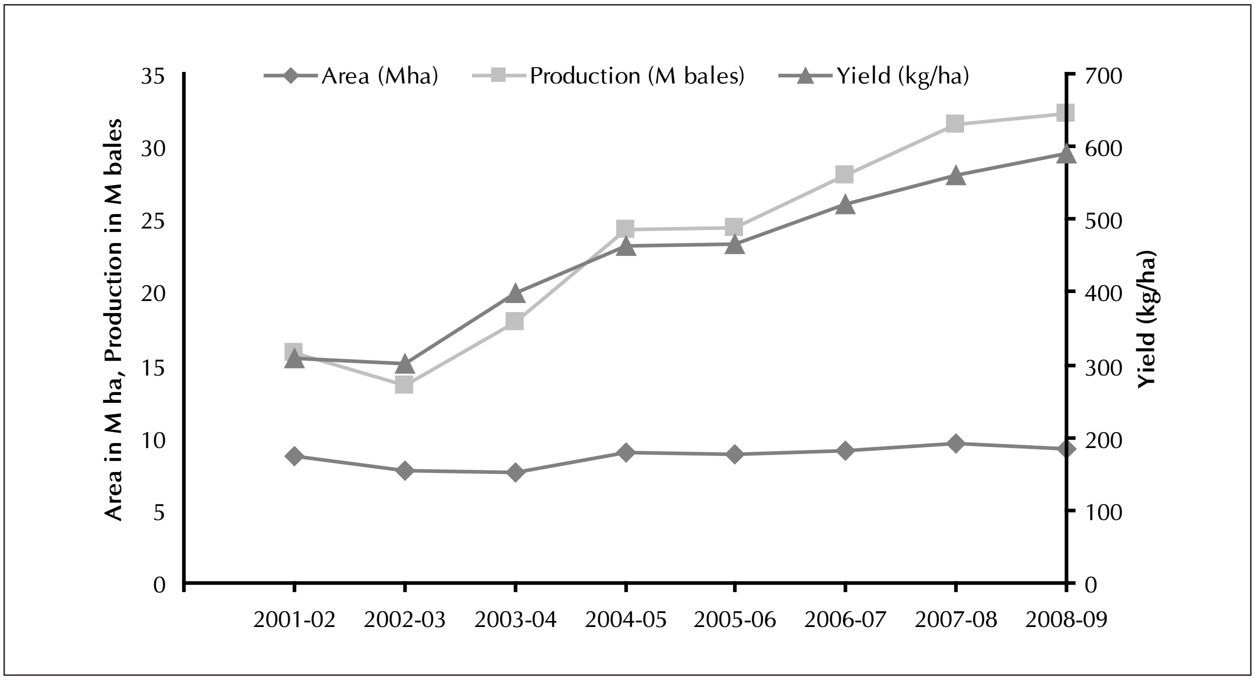
Cotton Production, Yield and Imports/Exports, Since the Introduction of Bt Cotton in 2002

Coincidental with the steep increase in adoption of Bt cotton between 2002 and 2008, the average yield of cotton in India, which had one of the lowest yields in the world, increased from 308 kg per hectare in 2001-02, to 560 kg per hectare in 2007-08 and projected to increase to 591 kg per hectare in 2008-09 season, with 50% or more of the increase in yield, attributed to Bt cotton (Figure 17). 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, to 28 million bales in 2006-07 to 31.5 million bales in 2007-08, which was a record cotton crop for India (Cotton Advisory Board, India, 2008). The Cotton Advisory Board projects 32.2 million bales of production in 2008-09 despite the fact that the total cotton hectarage in India decreased slightly by 3% from 9.6 million hectares in 2007 to 9.3 million hectares in 2008. 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 (Textile Commissioner Office, India, 2008). 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 growing 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 seven 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 5.5 million bales in 2006-07 to 8.5 million bales in 2007-08 (Figure 18). The Cotton Advisory Board of the Government of India expects a further decrease in cotton imports to 0.5 million bales.

Notably, cotton is the major raw material for the domestic textiles industry, which is predominantly in favor of cotton, compared with other fibers. With the dismantling of the Multi Fiber Agreement (MFA) under the aegis of the World Trade Organization, this will favor cotton relative to synthetic fibers. Thus, as a result of the boom in cotton, India's Ministry of Textile has projected that the value of the Indian textile industry will grow from US$47 billion in 2005-2006 to US$95 billion by 2010. In 2012, it is expected to escalate further to US$115 billion comprising the domestic market of US$60 billion and US$55 billion for exports. The cotton textiles, which constitute more than two-thirds of all textile exports of India, reached US$4.49 billion in 2005-06 recording a substantial increase of 26.8% over 2004-2005. The significant increase in cotton production during the last five or six years has increased the availability of raw cotton to the domestic textiles industry at affordable

Figure 17. Cotton Hectarage, Production and Yield in India, 2001 to 2008



1 bale = 170 kg

Source: Ministry of Textile, Government of India, 2008.

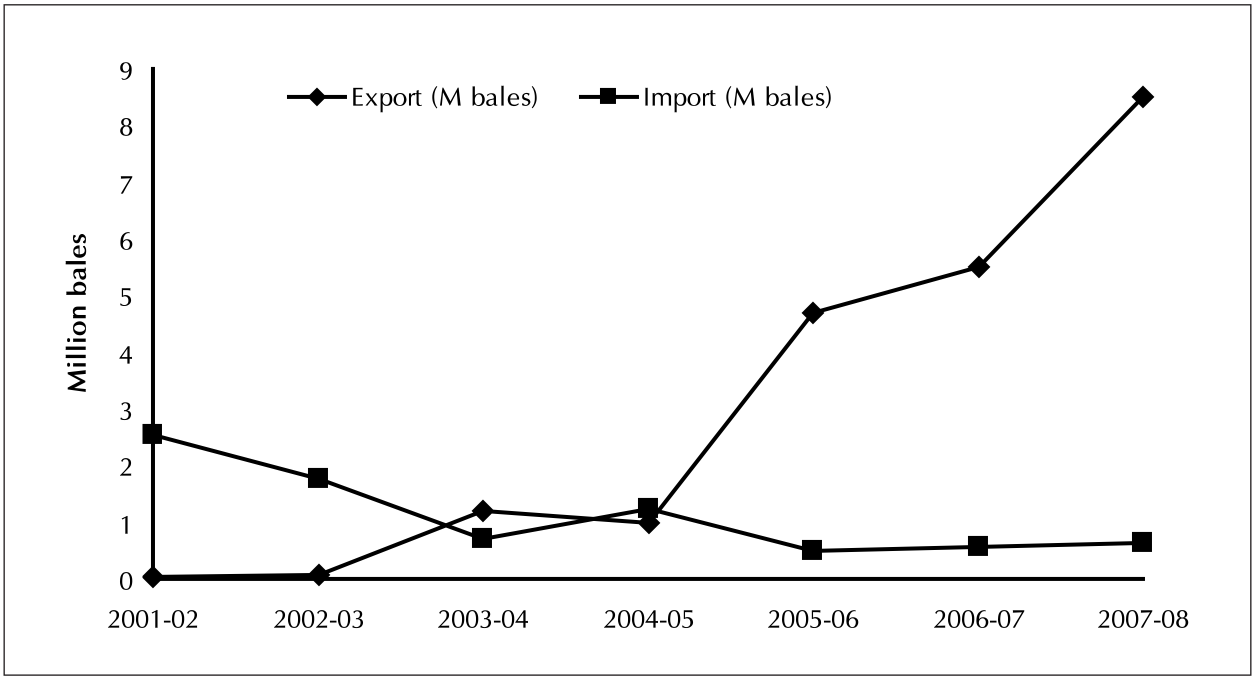
prices, and provided the textile industry with a competitive edge in the global market (Ministry of Textile, Government of India, 2007).

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 2006-07, the Indian biotech sector exceeded the US$2 billion benchmark with industry reporting nearly 31% growth over 2005-06. According to the survey conducted by BioSpectrum-ABLE (Biospectrum, India, 2008) in 2007-08, the Indian biotech industry reached US$2.5 billion in revenues, recording 30.98% growth, over the previous year's US$2.08 billion and is projected to be a US$5 billion industry by 2010. More specifically the agricultural biotech (BioAgri) sector grew 54.9% in 2006-07, 95% in 2005-06 and increased twelve-fold from US$26.8 million in 2002-2003 to US$300 million in 2007-2008.

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

Figure 18. Export and Import of Cotton in India, 2001 to 2008



1 bale = 170kg

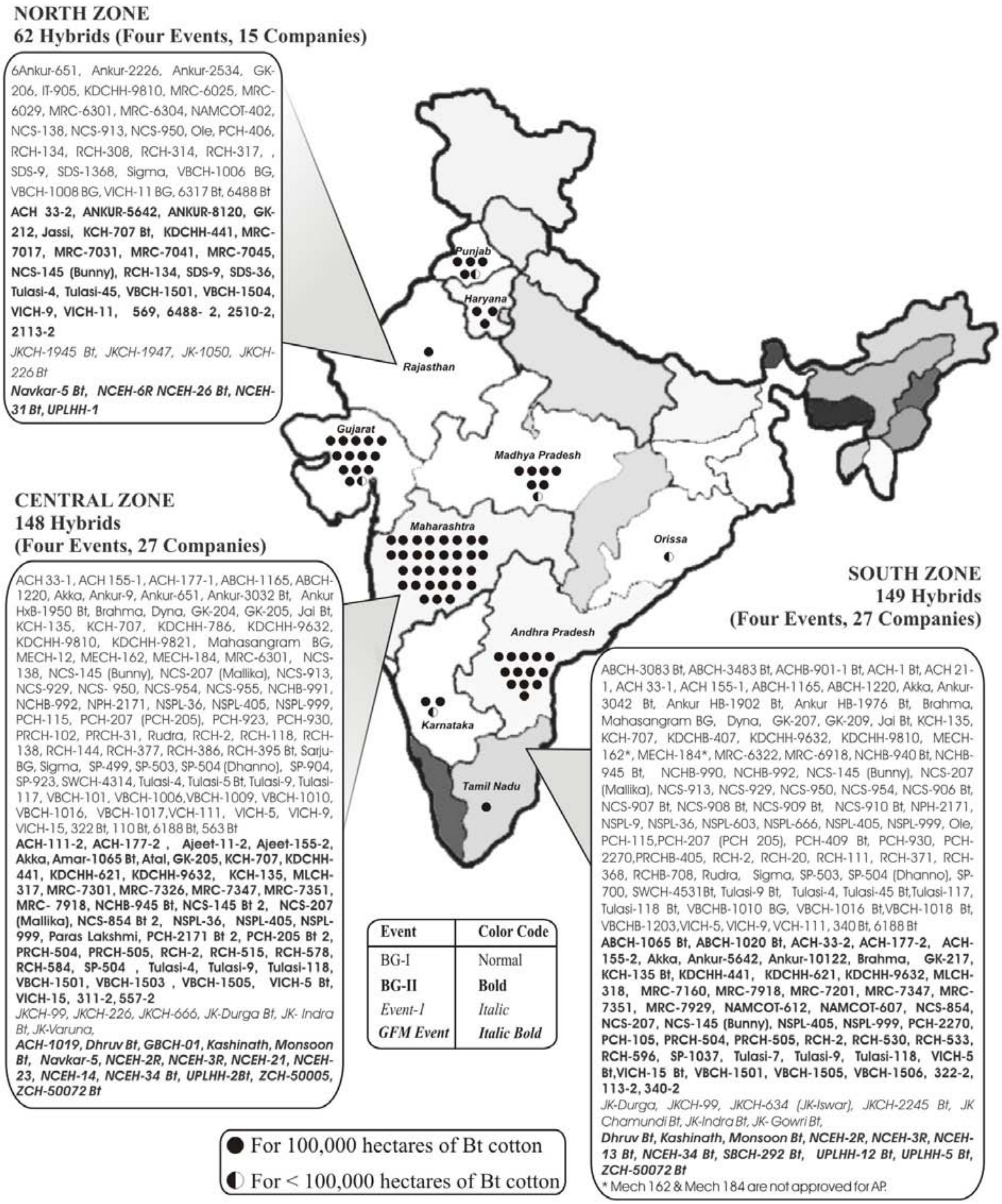
Source: Office of the Textile Commissioner and Cotton Corporation of India (CCI), Ministry of Textile and PIB Press Release, 2008.

in India. In 2008, the number of Bt cotton hybrids increased by more than two-fold to 274 from 131 hybrids in 2007; this followed a doubling of the number of hybrids from 62 in 2006 to 131 in 2007. Importantly, this increase in number of hybrids has provided much more choice in 2008 than in previous years to farmers in the North, Central and Southern regions, where specific hybrids have been approved for cultivation in specific regions (Figure 19). In 2008, a total of four events were approved for incorporation in a total of 274 hybrids with fifth event in Bt cotton variety, popularly known as Bikaneri Narma (BN) Bt which was approved for commercial cultivation in 2008 (Table 17).

The first event, MON 531, Bollgard®I (BG®I), featuring the *cry1Ac* gene was developed by Maharashtra Hybrid Seed Company Ltd. (Mahyco), sourced from Monsanto, and approved for sale in 2008, for the seventh consecutive year, in a total of 141 hybrids for use in the North, Central and South zones – this compares with 96 BG®I hybrids in 2007 and 48 BG®I hybrids in 2006.

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 regions. This event

Figure 19. Approval of Events and Bt Cotton Hybrids in India, 2008



Compiled by ISAAA, 2008.

Table 17. Commercial Release of Different Bt Cotton Events in India, 2002 to 2008

No.	Crop	Event	Developer	Status	Date of Approval
1	Cotton*	MON 531	Mahyco/Monsanto	Commercialized	2002
2	Cotton*	MON15985	Mahyco/Monsanto	Commercialized	2006
3	Cotton*	Event-1	JK Agri-Genetics	Commercialized	2006
4	Cotton*	GFM Event	Nath Seeds	Commercialized	2006
5	Cotton**	Cry1Ac Event	CICR (ICAR) & UAS, Dharwad	Commercialized	2008

***Bt cotton hybrid; ** Bt cotton variety**
Source: Compiled by ISAAA, 2008

was approved for commercial cultivation for the first time in the Northern region in 2007 and the number of hybrids for sale increased from 7 in 2006 to 21 in 2007, and further increased to 94 BG®II cotton hybrids in 2008 in the North, Central and South regions.

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 regions. Whereas this event was approved in only four hybrids in 2006, in 2008 it quadrupled to 15 hybrids.

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 2008, the number of hybrids for sale increased eight-fold from 3 to 24 in 3 regions.

In contrast to the above four events, which were all incorporated in cotton hybrids, notably the fifth event was approved in an indigenous cotton variety named Bikaneri Narma (BN) expressing the CRY1Ac protein. It was approved for commercial release in the North, Central and South cotton growing zones in India during *Kharif*, 2008. 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 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 deployment for commercialization of these four events in hybrids in India is summarized in Table 18, and their regional distribution is detailed in Table 19. The variety Bikaneri Narma was

Table 18. Deployment of Approved Bt Cotton Events/Hybrids by Region in India, 2008

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]	21	36	39	3	1	38	3	141
BG®II[2]	19	24	24	2	4	20	1	94
Event-I[3]	4	4	5	0	-	2	-	15
GFM Event[4]	5	8	4	0	-	7	-	24
Total	**49**	**72**	**72**	**5**	**5**	**67**	**4**	**274**

[1,2] Mahyco [3] JK Seeds [4] Nath Seeds
Source: Compiled by ISAAA, 2008.

Table 19. Deployment of Approved Bt Cotton Events/Hybrids by Companies in India, 2002 to 2008

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

*** Some of the 274 hybrids are being grown in multiple regions (see Figure 8)**
Source: ISAAA, 2008.

approved in 2008 and will be commercialized by CICR, Nagpur and the University of Agricultural Sciences (UAS), Dharwad in the three zones of North, Central and South India in 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 7 years since the first commercialization in 2002. In 2008, the number of Bt cotton hybrids doubled to 274 from 131 in 2007 with 30 companies marketing those hybrids in three cotton-growing zones in 2008.

By contrast in 2007, only 24 companies offered 131 hybrids, up from 15 companies offering 62 hybrids in 2006. The following 30 indigenous seed companies and one public sector institution from India, listed alphabetically, offered the 274 hybrids for sale in 2008 and one variety was approved and will be commercialized 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, Monsanto Genetics India Pvt. Ltd., Namdhari Seeds Pvt. Ltd., Nandi Seeds Pvt. Ltd., Nath Seeds Ltd., Navkar Hybrid Seeds Pvt. Ltd., Nuziveedu Seeds Ltd., Prabhat Agri Biotech Ltd., Pravardhan Seeds Ltd., Rasi Seeds Ltd., Safal Seeds and Biotech Ltd., Seed Works India Pvt. Ltd., Solar Agrotech 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 the University of Agricultural Sciences (UAS), Dharwad.

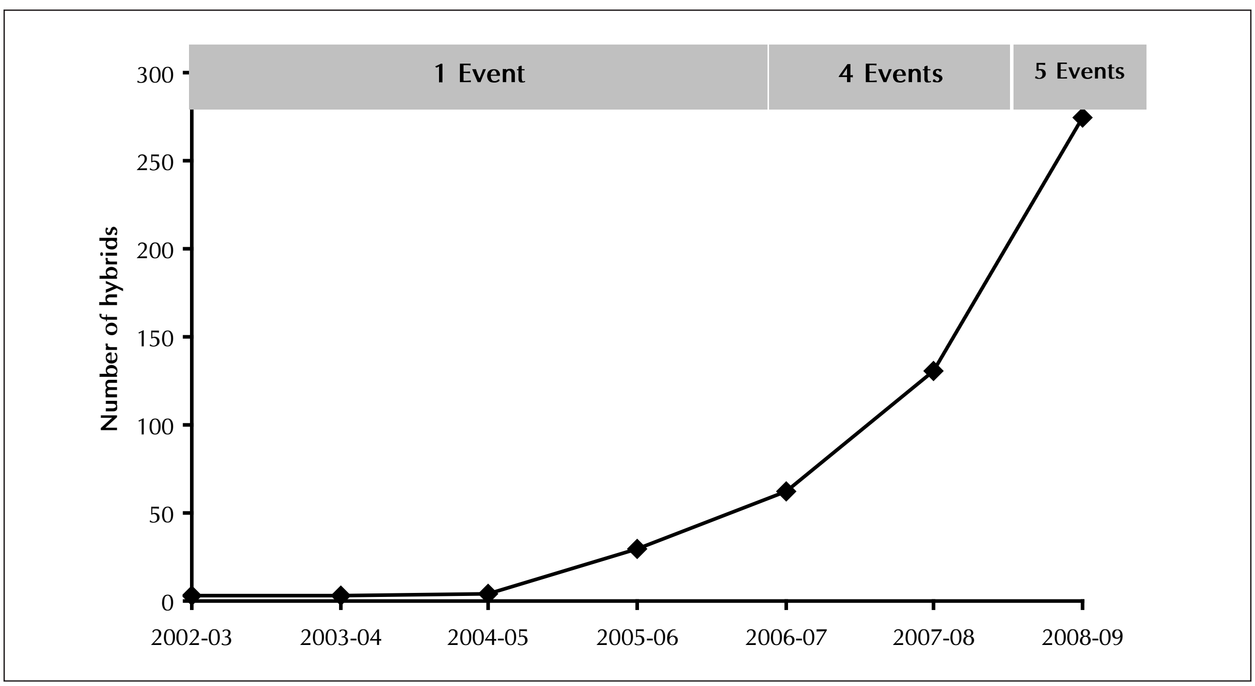
The deployment of the four events in 274 hybrids in 2008 is summarized in Table 19 and Figure 20, as well as the corresponding distribution of hybrids in 2002, 2003, 2004, 2005 and 2006. In 2008, the Genetic Engineering Approval Committee (GEAC) approved 143 new Bt cotton hybrids for commercial cultivation in the 2008 season, in addition to the 131 Bt cotton hybrids approved for sale in 2007, for a total of 274 hybrids. This provided farmers in India's three cotton-growing zones significantly more choice of hybrids for cultivation in 2008. Of the 274 Bt cotton hybrids approved for commercial cultivation, 62 hybrids featuring four events were sold by 15 companies in the Northern zone, 148 hybrids featuring four events were sold by 27 companies in the Central Zone, and 149 hybrids featuring four events were sold by 27 companies in the Southern Zone (Table 19).

There has been a substantial increase in the number of hybrids with two genes for pest resistance, the BG®II event, in 2008. The BG®II cotton hybrids quadrupled to 94 in 2008 from 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 resistant management to Indian cotton farmers.

Similarly, the distribution of the 131 hybrids approved for 2007 is summarized in Table 19 as well as the 62 hybrids approved for 2006, 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 274 Bt cotton hybrids in 2008 as well as their respective events in the three regions is summarized and illustrated in the map in Figure 19 and in Figure 20.

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 2008, India had more biotech cotton under cultivation (7.6 million hectares) than China (3.8 million hectares) whereas the number of farmers benefiting from Bt cotton was higher in China (7.1 million) than India (5.0 million) because the average cotton holding per farm in China (0.6 hectare) is smaller than in India (1.5 hectare).

Figure 20. Release of Bt Cotton Hybrids in India, 2002-2008



Source: ISAAA, 2008.

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 molecular biology in 1990 and subsequently established a new institute, the National Institute for Plant Genome Research, to focus on genomics and strengthen plant biotechnology research in the country. 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 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 the abiotic stresses of salinity and drought, and the biotic stresses associated with pests. 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 GoldenRice™, 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 publication, ISAAA Brief 38, (Choudhary and Gaur, 2009) on "The Development and Regulation of Bt brinjal in India" (Bt brinjal is discussed in more detail later in this Brief) highlights the important role that improved seeds, including biotech seed, have played in crop production in India. The following are selected modified paragraphs from Brief 38.

"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 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.

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 seven years, 2002 to 2008, 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 million small farmers in India in 2008 elected to plant 7.6 million hectares of Bt cotton which represented 82% of the total national area of cotton, 9.3 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, 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, 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 150-fold increase in Bt cotton hectarage between 2002 and 2008. 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 2006-2007 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 is Bt brinjal, (eggplant or aubergine) which is the most advanced biotech food crop, for which approval for experimental seed production was granted for 2008-2009 in anticipation of commercialization in the near-term. Thus, Bt brinjal is of special significance because it is the most probable first biotech food crop to be approved for commercialization in India.

Given that biotech crops are not a technology in which society is well informed, ISAAA Brief 38 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 the 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 and the future prospects for Bt brinjal, and implications for other biotech food crops. 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".

Several public institutions and private companies in India have projects to develop improved varieties of the drought tolerant and important perennial eggplant, known locally as brinjal; it occupies more than 0.5 million hectares, is the main source of cash, and supplies 25% of calories to many resource-poor farmers. The goal of the project is to improve resistance to fruit and shoot borer which is a very important pest that requires intensive insecticide applications, every other day in some cases, costing US$40 to US$100 per season's worth of insecticides, with environmental and health implications, since eggplant is a food crop. These eggplant projects are all geared to deliver biotech products for evaluation and approval by the government in the near-term, and Bt brinjal will probably be India's first biotech food crop. Mahyco developed an eggplant in which the *cry1Ac* gene confers resistance to the fruit and shoot borer. The product has been tested in large scale field trials with good results, and the Genetic Engineering Approval Committee (GEAC) approved experimental seed multiplication in 2008-2009 in anticipation of commercialization in the near-term. ABSP-II, the agri-biotechnology program of USAID executed by Cornell University, is supporting Mahyco's request for approval and working with public institutions in India, Bangladesh and the Philippines to incorporate the technology in varieties that would complement Mahyco's activities in hybrids; the work in the Philippines is being conducted in conjunction with ISAAA. It is noteworthy that this private-public 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. Given that the Bt eggplant will significantly reduce application of insecticides, this in turn will reduce insecticide residues in soil and groundwater. Similarly, reducing broad-spectrum insecticides, which typically kill both bad and good insects, will contribute to a greater diversity of beneficial insects. Studies on gene flow have not detected any negative effects on wild species of eggplant and this monitoring will continue.

A recent study by ISAAA (Choudhary and Gaur, 2009) estimates that the average small and resource-poor farmer in India cultivates 0.40 hectare of eggplant. ABSP II projections indicate that the potential benefits that the technology offers resource-poor farmers in India are significant and include the following: a 45% reduction in the number of insecticide sprays, applied usually by hand sometimes twice a week, 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 eggplant producers and consumers at the national level (ABSP II 2007, James, 2007). These economic benefits could make important contribution to the alleviation of poverty by increasing the income of resource-poor farmers growing eggplant 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* assessment" estimates the enormous benefits, welfare and distribution effects of Bt eggplant at the national level. The net estimated benefit of Bt eggplant 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 (Ramasamy, 2007).

The recent ISAAA study (Choudhary and Gaur, 2009) concluded that the commercialization of Bt eggplant 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 eggplant represents a quarter of the total vegetable area in these three countries and therefore the potential impact of this project is significant. Eggplant is grown all-year round and supplies 25 calories per serving, and its "meaty" texture makes eggplant a perfect staple for vegetarians.

It is evident that Bt eggplant will be a very important new biotech crop for India and will complement the Bt cotton hybrids that are already approved and other Bt cotton varieties being developed by both the public and private sectors 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 10 biotech crops in field trials in India and these are listed in Table 20. In India, an estimated 12 million farmers grow over 6 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 RR maize and Bt maize which, subject to regulatory approval could be deployed commercially within 5 years.

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 recent 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 2008 that merit inclusion in this Brief; seven events/developments are summarized in the paragraphs below:

Significant Developments in Crop Biotechnology in India in 2008

1). The Supreme Court of India Lifts Restriction on Commercial Release of GM Crops in 2008

The Supreme Court of India lifted restrictions on all field trials and commercialization of biotech crops in its judgment, dated 13 February 2008 and 8 April 2008. In 2005, a group of NGOs filed public interest litigation (PIL) against Union of India regarding the genetically modified crops which was listed as Writ Petition (Civil) No. 260 of 2005 in the Supreme Court of India. After a detailed hearing on 22 September 2006, 8 May 2007, 13 Feb 2008 and 8 April 2008, a three member bench headed by the Chief Justice of India lifted restriction on all field trials and commercialization of GM crops in India. The orders also directed GEAC of the Ministry of Environment and Forest to invite

Table 20. Biotech Crops in Field Trial in India, 2008

No.	Crop	Organization	Transgene/Event
1.	Brinjal	IARI, New Delhi	*cry1Aabc*
		Sungro Seeds Ltd., New Delhi	*cry1Ac*
		Mahyco, Jalna	*cry1Ac*
		TNAU, Coimbatore	*cry1Ac*
		UAS, Dharwad	*cry1Ac*
		Bejo Sheetal, Jalna	*cry1Fa1*
2.	Cabbage	Nunhems, Gurgaon	*cry1Ba and cry1Ca*
		Sungro Seeds Ltd., New Delhi	*cry1Ac*
3.	Castor	Directorate of Oilseeds Research (DOR), Hyderabad	*cry1Aa and cry1Ec*
4.	Cauliflower	Sungro Seeds Ltd., New Delhi	*cry1Ac*
		Nunhems, Gurgaon	*cry1Ac, cry1Ba and cry1Ca*
5.	Corn	Monsanto, Mumbai	Mon89034, NK603
6.	Groundnut	ICRISAT, Hyderabad	Rice *chit* and DREB
7.	Okra	Mahyco, Mumbai	*cry1Ac*
		Sungro Seeds Ltd., New Delhi	*cry1Ac*
		Bejo Sheetal, Jalna	*cry1Ac*
		Arya Seeds, Gurgaon	*CP-AV1*
8.	Potato	CPRI, Shimla	*RB*
		NCPGR, Delhi	*ama1*
9.	Rice	IARI, New Delhi	*cry1Aabc, DREB, GR-1 & GR-2* (Golden Rice)
		TNAU, Coimbatore	*chi11*
		MSSRF, Chennai	*MnSOD*
		DRR, Hyderabad	*cry1Ac*
		Mahyco, Mumbai	*cry1Ac, cry2Ab*
		Bayer CropScience, Hyderabad	*cry1Ac, cry1Ab, bar*
		Avesthagen, Bengaluru	*NAD9*
10.	Tomato	IARI, New Delhi	antisense replicase, osmotin, *DREB*
		Mahyco, Mumbai	*cry1Ac*
		Avesthagen, Bengaluru	*NAD9*

Source: Indian GMO Research Information System (IGMORIS), 2008 and Department of Biotechnology, 2008.

two independent experts to its meeting and take appropriate decisions after considering all aspects before the final decision is taken on GM crops.

Source: The Supreme Court of India WR (C) 260/2005 available at: http://judis.nic.in/supremecourt/chejudis.asp

2). India Drafts Plan to Establish National Biotechnology Regulatory Authority (NBRA) in 2008

India's Department of Biotechnology (DBT), (a department under the Ministry of Science and Technology) has been entrusted with the responsibility of setting up of the National Biotechnology Regulatory Authority (NBRA) and promulgation of a new legislation, namely the National Biotechnology Regulatory Act or the NBR Act. The DBT has announced a draft plan to set up the National Biotechnology Regulatory Authority (NBRA) in 2008. A draft National Biotechnology Regulatory Bill 2008 has been made available for public comment and feedback. The draft establishment plan for NBRA and draft National Biotechnology Regulatory Bill 2008 were prepared by a consultative committee of experts.

The NBRA will be set up as an independent and autonomous body to provide a single window mechanism for biosafety clearance of genetically modified products and processes. Setting up the NBRA will require the promulgation of new legislation, the "National Biotechnology Regulatory Act" or the NBR Act in the form of the National Biotechnology Regulatory Bill 2008 by the Parliament of India. It is expected that the Parliament of India will discuss and pass the bill in late 2008 or early 2009. Meanwhile, the Department has initiated a process of seeking feedback on both the documents from various stakeholders at the central and state levels.

Source: The draft National Biotechnology Regulatory Authority (NBRA) and the National Biotechnology Regulatory Bill 2008 are available at:
http://dbtindia.nic.in/Draft%20establishment%20plan%20for%20NBRA_28may2008.pdf
and http://dbtindia.nic.in/Draft%20NBR%20Act_%2028may2008.pdf

3). India Adopts a New Set of Guidelines for GE Plants and Foods

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 by the Review Committee on Genetic Modification (RCGM) and adopted by the Genetic Engineering Approval Committee (GEAC) in India. The new set of procedures 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 which will replace the existing cumbersome approval system. The new system includes:

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

Source: The decision during the 85th GEAC meeting held on 25 May 2008 regarding adoption of a new set of guidelines is available at: http://www.envfor.nic.in/divisions/csurv/geac/decision-june-85.pdf and the new set of guidelines for GE plants and foods derived from the GM plants is available at the Indian GMOs Research Information System (IGMORIS): http://www.igmoris.nic.in/

4). India's GEAC Commercially Released Publicly Bred Bt Cotton Variety

India's apex biotech regulatory body – the GEAC-approved the commercial release of indigenous cotton variety named Bikaneri Narma (BN) Bt expressing Cry1Ac protein in the North, Central and South Cotton Growing Zones in India during *Kharif*, 2008. It is important to note that the indigenously developed Bt cotton in varietal background is the first public sector GM crop in India that is 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, Dharward, Karnataka. While reviewing its earlier decision directing the CICR to conduct large scale field trials (LSTs) of Bt BN variety in North Zone, the committee decided to approve commercial cultivation of Bt BN variety as farmers can save the seeds for planting in next season.

ISAAA's Crop Biotech Update (CBU) published GEAC's earlier decision to approve the LST of publically bred Bt BN variety at http://www.isaaa.org/kc/cropbiotechupdate/online/default.asp?Date=4/25/2008#2428

Source: The decision during the 84th GEAC meeting held on 05 May 2008 available at: http://www.envfor.nic.in/divisions/csurv/geac/decision-may-84.pdf

5). Mahyco Receives Seed Production Approval for Bt Brinjal Hybrids

As a penultimate step in the regulatory procedure for commercialization of GM crops, the Government of India, through its biotechnology regulatory body GEAC-approved experimental seed production of Bt brinjal (eggplant) hybrids to Maharastra Hybrid Seed Company (Mahyco). Mahyco is a leading seed company in India which has been at the forefront in successfully introducing Bt cotton hybrids, which has substantially increased cotton yield and reduced cost of production and resulted in doubling cotton production in a short span of six years. The GEAC permitted experimental seed production of seven Bt brinjal hybrids namely MHB-4 Bt, MHB-9 Bt, MHB-10 Bt, MHB-11 Bt, MHB-80 Bt and MHBJ-99 Bt at Mahyco's fields at Jalna, Maharashtra in the coming *Kharif* season 2008.

The new Bt brinjal hybrids contains the *cry1Ac* gene (EE-1 event developed indigenously by Mahyco), which confer resistance to the important insect pest, fruit and shoot borer (FSB). The major constraint in brinjal production is FSB. The pest causes significant yield loss and reduces the number of marketable fruits. Farmers often resort to intensive use of insecticides to control FSB. The FSB resistant hybrids have been evaluated during the last couple of years for their agronomic performance, safety and efficacy in controlling FSB and their effect on beneficial insects in the experimental fields of Mahyco and the Indian Institute of Vegetable Research (IIVR), which is a premier public sector research institute of the Indian Council of Agricultural Research under the Ministry of Agriculture. The FSB resistant hybrid is expected to give higher yields with less insecticide use. Mahyco has donated this technology to public sector institutions not only in India but also to public sector institutions in Bangladesh and the Philippines. This is an excellent example of a philanthropic private/public partnership and India's emerging leadership role in the biotechnology sector and executing South-South cooperation technology transfer projects between developing countries.

Source: The decision during the 85th GEAC meeting held on 28 May 2008 available at: http://www.envfor.nic.in/divisions/csurv/geac/decision-june-85.pdf

6). India Deregulates Approved GM Cotton Events

In a major regulatory development, the Genetic Engineering Approval Committee (GEAC) decided to adopt the event-based approval system for all the four Bt cotton events, namely *cry1Ac* gene (MON 531 event), *cry1Ac* and *cry2Ab* genes (MON 15985 event), *cry1Ab-cry1A* (GFM event) and *cry1Ac* (event 1). These events were approved for commercial release in 131 cotton hybrids during the period 2002-2007 in India. The new event-based approval system for cotton crop will replace the case-by-case approval for Bt cotton hybrids based on the recommendations of a Sub-committee set up by the Ministry of Environment and Forest under the Chairmanship of the Director, Central Institute of Cotton Research (CICR), Nagpur. It is important to note that the area under Bt cotton reached 6.2 million hectare in 2007-08 which was 66% of the total cultivated area of 9.5 million hectares in 2007-08. Cotton production increased to 31 million bales in 2007-08 as compared to 15.3 million bales in 2002, when Bt cotton hybrids were first introduced. Four new events of cotton were extensively tested and are at different stages in field trials. These include:

1). Large scale field trials of Bt cotton hybrids expressing the synthetic *cry1C* gene (Event 9124) developed by M/s Metahelix Life Science Pvt. Ltd., Bangalore;

2). Multi location research trials (MLRTs) of BG®II Roundup Ready flex Cotton hybrids containing stacked *cry1Ac*, *cry2Ab* (Event 15985) and *CP4epsps* (MON 88913) genes developed by M/s Maharashtra Hybrid Seeds Company Ltd., Mumbai;

3). Multi location research trials (MLRTs) of the double gene event expressing *cry1EC* (Event 24) along with the already commercialized *cry1Ac* (Event 1) developed by M/s J.K. Agri Genetics Ltd., Hyderabad; and

4). Multi location research trials (MLRTs) of *cry1Ac* and *cry1F* gene (WideStrike = Event 3006-210-23 and Event 281-24-236) developed by M/s Dow AgroSciences, Mumbai.

The present approval system will be continued until the new event based approval system is formally notified by the Ministry of Environment and Forest (MoEF).

Source: The decision during the 83rd GEAC meeting held on 02 April 2008 is available at: http://www.envfor.nic.in/divisions/csurv/geac/decision-dec-83.pdf

7). India Joins OECD Seed Certification Schemes

In early 2008, India submitted an application to participate in the OECD seed schemes. OECD granted eligibility to India to participate in the OECD Seed Schemes program at the Annual Meeting held on 2 July 2008 at Chicago, USA. The OECD Seed Schemes, evaluated India's seed testing and certification programs in March 2008 and found that the programs for quality seed testing and certification are in place, conformed to the globally accepted OECD standards. As of now there are 57 countries eligible to issue OECD certificates. Approved countries issue official OECD certificate to accompany seed entering international trade. Most countries and seed importing companies require OECD approved seed testing and quality certificates.

The OECD Seed Schemes provide an international framework for the certification of agricultural seed moving in international trade. The Schemes were established in 1958 with a view to support fast-growing seed trade, regulatory harmonization in Europe, the development of off-season production, the seed breeding and production potential of large exporting countries in America (North and South) and Europe, and the support standardization in international seed trade.

A rapidly growing international commercial seed market which is worth US$34 billion in 2007 of which US$6.9 billion is for genetically modified seed, represents a substantial opportunity for the Indian seed sector. India aspires to be among the major seed player in the world market including USA, Netherland, France, Germany, Brazil, Chile, China, Egypt, Russia and South Africa.

Source: More information about the OECD seed schemes is available at: http://www.oecd.org/document/0/0,3343,en_2649_33905_1933504_1_1_1_1,00.html

Status of Biofuel in India

A comprehensive review of the status of biofuel in India up to 2007 was included in ISAAA Brief 37 (James, 2007). The following paragraphs provide an update of the status of biofuel in India in 2008.

Fuel security is one of the prime concerns for India, which is ranked sixth in the world in terms of fuel demand, accounting for 35% of world commercial demand in 2001. During 2004-05, the country imported 95.86 million tons of crude oil valued at US$26 billion. The Indian economy is expected to grow at a rate of over 6% per annum and the petroleum imports are expected to rise to 166 million tons by 2019 and 622 million tons by 2047 (Department of Biotechnology India, 2007). In view of the growing energy demand and to ensure fuel security for the country, the Government of India has initiated several policy actions to promote the development of a robust biofuel sector in the country.

In September 2008, India approved the much awaited National Policy of Biofuel and the road map for its implementation (Ministry of New and Renewable Energy, 2008). The policy sets an ambitious target for the blending of biofuel, both bioethanol and biodiesel, at 20% by 2017. The approval for setting up an empowered National Biofuel Coordination Committee (NBCC) headed by the Prime Minister of India and a Biofuel Steering Committee (BSC) headed by the Cabinet Secretary show political commitment at the national level to boost development of biofuel and to achieve self-sufficiency in growing energy demand. The policy will be administered by the Ministry of New and Renewable Energy (MNRE) of the Government of India, in coordination with various ministries at the Central and State levels.

Salient features of the National Policy of Biofuel India, 2008

- India will aim at a 20% blend in biofuel, both bioethanol and biodiesel, by 2017.
- Biodiesel production will be restricted to non-edible oil seeds grown on waste/degraded/marginal lands. The policy will also encourage biodiesel crop plantations on community/Government/forest wastelands; biomass for biodiesel will not be grown on fertile irrigated lands.
- The policy encourages the indigenous production of biodiesel feedstock and restricts the import of Free Fatty Acid based feedstocks such as oil, palm, and others for biofuel production in India.

- The policy seeks a Minimum Support Price (MSP) with the provision of periodic revision for biodiesel oil seeds at a fair price to the growers – the working details of the MSP mechanism will be the responsibility of the Biofuel Steering Committee.
- The policy envisages a Minimum Purchase Price (MPP) for the purchase of bioethanol by the Oil Marketing Companies (OMCs) based on the actual cost of production and import price of bioethanol. In the case of biodiesel, the MPP should be linked to the prevailing retail price for diesel.
- The National Biofuel Policy envisages that biofuels, biodiesel and bioethanol may be brought under the ambit of "Declared Goods" by the Government to ensure unrestricted movement of biofuels within and outside the States.

With regard to research and development of biofuel, the policy entrusts the responsibility to the Department of Biotechnology and Ministry of Rural Development, and envisages the setting up of a Sub-Committee under the Biofuel Steering Committee to encourage R&D and demonstration with a focus on plantations, processing and production technologies including second generation cellulosic biofuel (Press Information Bureau, Government of India Press Release, 2008). In anticipation of the increasing feedstocks demand for biodiesel and bioethanol production, the Department of Biotechnology (DBT) of the Ministry of Science and Technology launched the "Energy Biosciences Strategy for India, 2007." The strategy aims to improve feed stock options for lignocellulosic ethanol. This will be achieved by optimally exploiting bioresources for biofuel production by adopting molecular biology and biotechnology tools for tailoring the feedstocks to meet the required needs. The DBT spends approximately US$5-7 million every year on R&D of biofuel, which is likely to be increased substantially with the establishment of energy biosciences centers – the first Center of Energy Biosciences (CEB) was established at the University Institute of Chemical Technology (UICT), Mumbai. The department has already initiated a well-defined, focused feedstock development and improvement program for *Jatropha curcas* a few years ago. Nearly 1500 accessions of *Jatropha curcas* have been collected and characterized for oil content and quality, which are stored at the national gene bank. A major effort is now being made towards improvement of the *Jatropha* plant for improved yield, oil content and quality and resistance to biotic and abiotic stress. Biotechnological interventions are being used to develop an integrated breeding program for developing mapping populations for genetic improvement. Work has also been initiated to: develop molecular markers; increase the oil content of *Jatropha*; reduce free fatty acid content using transgenic approach and oil quality modification to facilitate transesterification. The development of EST's, metabolic pathway engineering, gene isolation, transformation and gene expression projects are being commissioned in close partnership with public and private sector institutions such as Avesthagen, Labland biotech, Barwale Foundation, Vittal Mallya Scientific Research Foundation, MS Swaminathan Research Foundation, Puri Foundation's Indian Institute of Advanced Research, The Energy Research Institute, the University Institute of Chemical Technology, Madurai Kamaraj University, Central Food Technology Research Institute, Tamil Nadu Agricultural University and National Botanical Research Institute. Some of DBT's projects have resulted in: an optimization and enhanced recovery process at the lab scale for conversion of lignocellulosic biomass; the development of two thermo tolerant yeast strains; the development of a recombinant yeast strain for converting starch to ethanol; and the development of recombinant bacteria for enhanced cellulase production. There are many private companies and institutions that are independently undertaking R&D, improvement and planting of *Jatropha curcas* and other potential feedstocks on a large scale; they include Reliance, BP, Shell, Dupont, Indian Oil, Bharat Petroleum, Hindustan Petroleum, Mission Biofuel, International Crop Research Institute for Semi-Arid Tropics (ICRISAT) and others. Several States have also announced biofuel policies and set up biofuel missions and boards (Department of Biotechnology India, 2007; DBT's Energy Biosciences Strategy for India, 2007).

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$3.2 billion in the period 2002 to 2007 and US$2.0 billion in 2007 alone.

A sample of seven economic studies on the impact of Bt cotton, all conducted by public sector institutes over the period 1998 to 2006 are referenced in Table 21. The studies have consistently confirmed 50 to 110% increase in profits from Bt cotton, equivalent to 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 range usually from 30 to 60% and the reduction in number of insecticide sprays average 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 in the last five years.

More specifically, the work of Bennett *et al.* (2006) confirmed that the principal gain from Bt cotton in India is 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 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 report results in the same range, acknowledging that benefits will vary from year to year due to varying levels of bollworm infestations. The study by Gandhi and Namboodiri (2006), reports 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 recently 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 66.3% increase over open-pollinated cotton varieties (OPV). Data in the study covers 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 (2005) 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.

The only published impact studies of Bt cotton in 2006/07 was conducted by IMRB International (IMRB, 2007) which focused on the agronomic and economic benefits and a parallel study conducted by Indycus Analytics (2007) on the social impact of Bt cotton.

The IMRB study sampled 6,000 farmers from 37 districts and interviewed 4,188 farmers growing Bt cotton and 1,793 farmers who grew non-Bt cotton in 9 cotton-growing states in India. The IMRB study reported that Bt cotton (versus non-Bt cotton) resulted in a 50% increase in yield, a reduction of 5 insecticide sprays and a 162% increase in profit equivalent to US$475 per hectare. This estimate for the 2006 season was higher than estimates for the previous years (2002 to 2005) and took into account the higher prices of cotton, the higher value of the Indian Rupee versus the US dollar, and the most recent cost savings associated with Bt cotton in 2006. The IMRB study estimated that the value of Bt cotton at the national level in 2006 was US$1.7 billion.

The IMRB study also reported that 90.6% of farmers who planted Bt cotton in 2005 also elected to repeat the planting of Bt cotton in 2006 because they were satisfied with the performance of Bt cotton in 2005. Thus, 9 out of 10 farmers who planted Bt cotton in 2005 also elected to plant Bt cotton in 2006 – this is a very high level of repeat adoption for any technology in agriculture by any industry standard and reflects the trust and confidence that farmers have in Bt cotton. The projected repeat figure for planting of Bt cotton from 2006 to 2007 is 93.1%, even higher than that for 2005/06, and is consistent with the remarkably high adoption rate of Bt cotton by small and resource-poor farmers in India.

Table 21. Seven Studies Conducted by Public Institutes on the Benefits of Bt Cotton in India for the Years. 1998 to 2006

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
Period studied	1998-99 & 00-01	2001	2002-2003	2002 & 2003	2004	2005	2006
Yield increase	38%	60-90%	34%	45-63%	31%	30.9%	46%
Reduction in no. of sprays	4 to 1 (75%)	5-6 to 1 spray (70%)	6.8 to 4.2 (50%)	3 to 1	39%	—	55%
Increased profit	77%	68%	69%	50% or more gross margins	88%	—	110%
Average increase in profit/hectare	$76 to $236/ Hectare	$96 to $210/ hectare	$118/hectare	—	$250/hectare	—	$223/hectare

Source: Compiled by ISAAA, 2008.

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 (2006): 48-58
4. Bennett, R. et al., 2006. "Farm-level economic performance of genetically modified cotton in Maharastra, India," Review of Agricultural Economics, 28 (2006): 59-71 (2006).
5. Gandhi, V. and Namboodiri, N.V. 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 (2006).
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. (2006).

The parallel study conducted by Indicus Analytics (2007) on Bt cotton in India in 2006 is the first study to focus 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 benefited 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 only published impact study of Bt cotton in India in 2007/08 was conducted by IMRB International (IMRB, 2008), which focused on the agronomic and economic benefits, and the social impact of Bt cotton or Samiksha (IMRB), 2008. The study surveyed a large sample of 6,600 farmers, from over 600 villages in 9 major cotton growing states in India in 2007-08. The study revealed that on average the single gene BG®I cotton farmers earned Rs. 8,669 (US$222) and cotton farmers who used BG®II with the stacked genes gained Rs. 10,009 (US$256) additional incomes per acre compared to conventional cotton farmers. The BG®II cotton hybrids offered a 126% return on investment compared with 117% from BG®I and a mere 12% from conventional cotton. At the national level, Bt cotton farmers gained US$288 million (Rs. 1,127 crores) from reduced pesticide usage and contributed US$3.23 billion (Rs. 12,608 crores) as additional income to the Indian economy in 2007. Socio-economic and welfare benefits are also considered important by Bt cotton farmers. The IMRB study reports that 41% of India's Bt cotton farmers spent less time in the field, allowing more quality time to spend with their family, 35% reported enjoying peace of mind, 24% were able to invest more in their children's education, and 23% reported that they were able to repay long-pending debts during *Kharif* 2007.

The 2007 ISAAA Report projected that the adoption rate of Bt cotton in India in 2008 would reach approximately 80% or more, whereas the actual level was 82%. 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 in India is expected to continue to increase only modestly in 2009 since the current level of adoption at 82% is close to optimal. Despite the unprecedented high adoption of Bt cotton by 5 million farmers, the majority of whom have first-hand experience of up to seven years of the significant benefits it offers, anti-biotech groups 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 Bt Cotton 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 seven 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.

Smt. Pratibha Devisingh Patil, the President of India

Speech at the Foundation Day of the Indian Council of Agricultural Research (ICAR) on July 16th, 2008 in New Delhi:
"Basic to rural prosperity, is the holistic development of agriculture and the allied sectors. Foremost is that we keep agriculture at the centre stage of our development agenda. We must enhance productivity on a constant basis and bring about a second Green Revolution which, along with agro-biotechnology, can translate into an ever-Green Revolution in India" (Patil, 2008).

"The success story of the First Green Revolution has run its course. We cannot afford to rest on our laurels. The fruits of the Green Revolution and the momentum generated by it, needs to be sustained. Efforts towards sustainable agriculture can be greatly augmented with the help of space technology and biotechnology advances" (Patil, 2007).

Dr. Manmohan Singh, Prime Minister of India
Prime Minister Manmohan Singh at the opening of the International Rice Congress in New Delhi in October 2006 directly addressed the issues related to any possible health and environmental changes related to biotech rice and stated that ***"we need to strike a balance between using the potential of biotechnology to meet the requirements of hungry people while addressing concerns about interfering with nature"*** (Singh, 2006).

Dr. P. Chidambaram, the Minister of Finance
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."***

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

Speech at the Foundation Day of Indian Council of Agricultural Research (ICAR) on July 16th, 2008 at New Delhi:

"The new tools of biotechnology and other frontier sciences offer exciting opportunities in agriculture for improving farm productivity, production and quality in order to meet the challenges of feeding a nation with a billion plus population, while sustaining the environment and ensuring higher returns for the farmer" (Pawar, 2008b)

Mr. Sharad Pawar, the Indian Minister of Agriculture, at the September 2006 ILSI conference on biotechnology referred to the need to strengthen and streamline the transgenic program and testing of transgenic crops. As part of the efforts to streamline India's regulatory framework for transgenic crops, the Genetic Engineering Approval Committee (GEAC) decided at its 69th meeting held on 30th June 2006 to adopt an ***"Event Based Approval System" for biotech crops. The new system***

has been directly applicable to Bt cotton hybrids expressing the cry1Ac gene (MON531 event) as this event has cleared the three-year post release period and GEAC has renewed their approval for commercial release. The new system is also applicable to any other new events after their performance has been monitored post release for a period of three years. This will speed up the introduction of new biotech crops to the country without compromising biosafety and environmental safety. Coincidentally, developments in biotech crops in China and other progressive countries in Asia, such as the Philippines, particularly related to biotech rice and golden rice provide a stimulus and have a significant impact in India, and indeed in all rice-growing countries throughout Asia, and the world" (Pawar, 2007a).

Mr. Sharad Pawar, Union Minister of Agriculture and Consumer Affairs, Food and Public Distribution on the occasion of 78th Annual General Meeting of the ICAR Society on 17 May 2007, stated that the ***"Indian Agriculture today is facing several challenges. Recent phenomena of climatic changes pose serious threat to production and productivity of crops. There has been a decline in the growth of productivity of some crops, which does not augur well for food security, exports, growth, and poverty alleviation. Therefore, there is an urgent need for policies and programs that can invigorate productivity, so as to ensure that the declining share of food grain crop area gets compensated. Fourteen highly innovative projects in strategic research areas have been supported covering biotechnology to mitigate biotic and abiotic stresses in cereals, pulses and oilseeds; increasing feed and energy efficiency of dairy animals; reproductive efficiency of buffalo and small ruminants; to saving seeds and agri-produce from spoilage under the National Fund for Basic and Strategic Research in agriculture"*** (Pawar, 2007b).

Farmer Experience

Experience of three Bt cotton farmers from Andhra Pradesh:

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 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" (Ramadevi, 2007).

Mr. Bolla Kumara Swamy is a seasoned cotton farmer cultivating cotton for the last 12 years. He lives in Sivaji Nagar Village, Duggondi Mandal, Warangal District of Andhra Pradesh.

"I have been cultivating cotton for the last 12 years. During non-Bt days I was spraying chemicals on cotton for 15-20 times, of that 14 -16 rounds were exclusively for controlling Spodoptera and pink bollworm costing more than Rs. 6,000 per acre. The average yields were not crossing 5-6 quintals per acre, and I was not able to meet the expenses of the input cost.

I cultivated Bt cotton seeds for the first time during 2003, and my pesticide spraying reduced considerably to 2-3 rounds for sucking pest and 2 more rounds on Spodoptera. The average yield increased to 11 quintals per acre, apart from a net savings of Rs. 4,000 on pesticide costs. During 2006 and 2007, I went for Bt cotton in three acres and got 40 quintals. With the income earned from Bt cotton cultivation over the years, I installed a pipe line for irrigating the rainfed land and constructed a small house in 2006.

In 2007, I cultivated BG®II cotton hybrids on two acres, and because of better retention of bolls, I got 2-3 quintals more yield per acre when compare to BG®I cotton hybrids. In addition, I also got an additional savings of Rs. 1,200 from reduced pesticide application cost" (Swamy, 2008).

Mr. Chinthi Reddy Vijeyandhar Reddy has been cultivating cotton on 7 acres of land for the last 15 years. He is from a small village 'Kantathmakur', Parakal Mandal, Warangal District of Andhra Pradesh.

"During non-Bt cotton days the average pesticide cost used to range between Rs. 5,000-6,000 per acre. We suffered both physically and mentally during those days. Because of pink bollworm attack we were not able to harvest quality yields.

For the first time I cultivated Bt cotton hybrids in 2003 and the number of sprays came down drastically to 2-3 sprays. There was a clear increase of 4 quintals yield with Bt cotton in addition to Rs. 4,000 savings in pesticides sprays. I have planted BG®II cotton hybrids this year. BG®II cotton gave me a savings of Rs. 1,000 more on pesticide sprays. The average yields of BG®II cotton was 14 quintals compared to 12 quintals in BG®I cotton hybrids.

With the income earned from Bt cotton, I send my children to private schools and purchased a two wheeler in 2006. This year, I purchased a fridge for house hold purpose and land for cattle shed construction. I am among a very few in my village who has fridge in the house. With Bt cotton cultivation, my financial situation is rapidly improving. We hope that in the future, we will get this kind of technology in vegetables as well as other technology to control weeds" (Reddy, 2008).

Experience of a farmer and local leader from Haryana:

Mr. Balbir Khichad is a seasoned cotton farmer and the local people representative of a small village Bansudhar located in Sirsa district of Haryana State in India. He is in his late 50's and the head of an extended family (Mukhya of Khichad) comprising 3 principals who own 52 acres of land (17 acres per person). The following is his story of cotton farming which he is proud to narrate with a smiling face.

"I started cotton farming in 1966. Over the years I grew some variety called LS-320, which used to yield a meager 4.5-5 quintal per acre. Later when I changed to LH-900 variety, I got only a marginal increase in yield. However, I had to spray near 12-15 sprays for controlling bollworm (Sundi) and some additional sprays for other insects and pests. The cotton farming was very costly.

In 1990s, my family suffered unmanageable losses as boll eating sundi invaded my cotton crop. As a result, my cotton yield reduced to just 1-2 quintal although I sprayed additional pesticides of more than Rs. 3,000 per acre. At times there was no cotton left for picking. This type of farming led to huge debts to me and my fellow farmers. We used to approach local money lenders for household needs such as marriage of children, construction of house or to do any other needs. We had to pledge our land to the money lender.

But in the last three years, Bt cotton has dramatically transformed cotton farming. I planted Bt cotton in 2005 when the government approved the same in my region. Today I am convinced

that cotton farming can be profitable because my 15 acres of Bt cotton farm on an average yielded 8-10 quintals per acre in 2005. Bollworm infestation is well controlled and I needed few sprays to control sucking pests.

Last year I have planted Bt cotton in 48 acres which yielded 11-12 quintals per acre. Today I earn a net profit of around Rs. 10,000 per acre after meeting all expenses. However, my fellow farmers who are yet to adopt the Bt cotton are still running losses. Bt cotton farming has not only improved cotton farming but also changed my life" (Khichad, 2007).

Experiences of a cotton farmer and local leader from Punjab:

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 income. 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).

Experiences of a cotton farmer from Tamil Nadu:

Mr. R. Kulandai Vel cultivates cotton farm and lives in Chinna Punal Vaasal Perievu Road, Naduvalur Post, Gengavalli Taluk, Salem District in Tamil Nadu

"I have been cultivating cotton for the last 25 years. I have started growing Bt cotton since its introduction in 2002. Bt cotton was very effective in controlling bollworm. However, in BG®I cotton I had to spray 2 rounds of chemicals to protect the crop from Spodoptera and I incurred around Rs. 1,700/ acre. This year, I cultivated BG®II cotton in 5 acres of land as well. What I have noticed that BG®II cotton protect my cotton crop from both bollworm and Spodoptera and I saved additional Rs. 1,700 per acre from Spodoptera sprays. As a farmer, I never got any considerable profit from ordinary non-Bt cotton. However, there has been a

total turn-around with Bt cotton as I now earn higher income. Bt cotton cultivation helped me to buy additional two acres of land and I also got my son married recently. I tell my other fellow cotton farmers to cultivate Bt cotton, particularly BG®II cotton and get a good prosperous life" (Vel, 2008).

Experiences of a cotton farmer from Madhya Pradesh:

Mr. Vinod Kanhaiyalal Patidar belongs to Jhapadi village in Maheshwar Tehsil of Khargone District, Madhya Pradesh.

"Since 2002, I have been planting Bt cotton hybrids on my field. With Bt cotton, I have experienced a drastic reduction in pesticide sprays, resulting in higher yield and quality cotton. I adopted BG®II cotton hybrids in 2007 that further increased cotton yields and better control of bollworm and Spodoptera. In 2008, I planted BG®II cotton hybrids in my entire 8 acres farm.

BG®II cotton is better than BG®I cotton, which gave me higher yields, pesticide savings and higher income. It has changed my standard of living. With the income earned, I have constructed a pucca house and introduced drip irrigation on my 8 acres farm to cultivate some vegetables. My children study in an English medium school and most importantly, I enjoy peace of mind. I no longer need to go to money lender for any loans. I have been requesting all my fellow farmers to adopt Bt cotton technology" (Patidar, 2008).

Experiences of two cotton farmers from Gujarat:

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 onward. 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" (Patel, 2008).

Mr. Thakurbhai Balubhai is a cotton farmer and Director of a cooperative society. He lives in Dhawat village, Karjan Taluka of Vadodara district, Gujarat.

"I have been farming for the last 20-25 years and cotton is my main crop. Before the introduction of Bt technology we used to cultivate cotton hybrid seeds. But due to severe pest pressure, pesticide expenses increased drastically and resulted in cotton farming becoming unprofitable. With the introduction of Bt cotton technology, we are very happy as we get consistent higher yields and freedom from worry of crop damage from bollworms. Bt cotton helped us to get huge pesticide savings, as pesticide sprays contribute to 70% of total pesticide expenses. I yielded more than 19 quintals per acre with BG®I cotton this year. Bt cotton really helped me to earn a lot of income, which enabled me to purchase new tractor, build a new pucca home and also raise our standard of living. This helped me to earn more respect in my village. So I can proudly say that Bt cotton has increased farmers wealth and profit in cotton farming" (Balubhai, 2008).

Experiences of two cotton farmers from Maharashtra:

Mr. Ashok Waregade has 9 acres of land of which 5 acres is irrigated and the rest is rainfed. He cultivates cotton and owns a grocery shop in his village. He lives in Elakeli village of Yavatmal district, Maharashtra.

"I used to cultivate conventional cotton seeds on my fields. At maximum, I used to get 4 quintals yield per acre and spent between Rs. 3,000-3,500 per acre on pesticide sprays. The pesticide sprays alone was almost more than half of our total cotton cultivation costs. Thus, farming cotton with conventional seeds was a complete loss.

In 2004, first time I cultivated Bt cotton on my farm. I harvested yield of 9 quintals per acre and pesticide expenditure was reduced. I saved Rs. 2,500 on pesticides in addition benefiting from higher yields. I had to incur Rs. 1,000 per acre sprays to control other pests. Bt cotton farming became profitable for me which was not the case for dry land farmers like me who had no option but cultivate cotton on my farm.

In 2006, I planted BG®II cotton seeds which controlled all kind of bollworms. I saved Rs. 4,000 in total on pesticide sprays and yields increased to 12-14 quintals per acre. With the additional income, I was able to marry-off my daughter and I also opened a general store shop for my younger brother in the village. I am also planning to open a small business for my son" (Waregade, 2008).

Mr. Krushan Rao Bhanderkar is from Wardha district of Maharashtra.

"I have been doing farming for the last 20 years and been planting cotton for the last 15 years. Before 2004, I used to cultivate conventional cotton seeds and my yield was maximum 3-4 quintals per acre. The pesticides cost was between Rs. 3,000 - 4,000 per acre. Due to a lot of farming expenses, I was getting financially weaker.

In 2004, I cultivated my farm with Bt cotton which effectively controlled bollworms and increased cotton yields. Cotton yield jumped to 9-10 quintals per acre. Due to the good quality cotton, I also got a good market price for my cotton and earned an income of Rs. 19,000-20,000. With this income, I constructed a pucca house in my farm.

In 2007, I learned that BG®II cotton controls all types of bollworms. I planted BG®II cotton hybrids in 2007 when a pest called Spodoptera created havoc in soybean crop in Vidarbha, but no damage was seen on my BG®II cotton farm. This year, I am fully confident of getting a higher yield of 13-14 quintals per acre and if good market price prevails I should earn around Rs. 30,000 this year as well.

"Bt cotton is a blessing in disguise for the farmers in Vidarbha region. This year, I have planned to install drip irrigation system in my field and also purchase one motorcycle. I will utilize some money for my children's education. I am very happy as my financial situation is improving" (Bhanderkar, 2008).

CANADA

> **In 2008, in terms of biotech crop area, Canada was narrowly displaced from its traditional fourth place in world ranking by India. Canada is now ranked in fifth position globally. Growth in biotech crop area continued in Canada in 2008 with a net gain of approximately 600,000 hectares, equivalent to a 9% year-over-year growth, with a total biotech crop area of 7.6 million hectares for the three biotech crops of canola, maize and soybean.**

Canada is another member of the six "founder biotech crop countries", having commercialized herbicide tolerant canola in 1996, the first year of commercialization of biotech crops. In 2008, in terms of biotech crop area, Canada was narrowly displaced from its traditional fourth place in world ranking by India. Growth in biotech crop area continued in Canada in 2008 with a net gain of approximately 600,000 hectares, equivalent to a 9% year-over-year growth, with a total biotech crop area of 7.6 million hectares for the three biotech crops of canola, maize and soybean. The largest biotech crop, 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 2008 was 6.4 million hectares, up almost 10% in 2007 when 5.9 million hectares were planted. In 2008, the national adoption rate for biotech canola was similar to 2007 at 86%, up from 84% in 2006 and 82% in 2005. In 2008, biotech herbicide tolerant canola was grown on approximately 5.5 million hectares, 8% more than the 5.1 million hectares of biotech canola area grown in 2007; this compares with 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 national adoption rate of almost 90%, with only 1% devoted to conventional canola; the balance of 13% canola hectarage in Canada in 2008 was planted to mutation-derived herbicide tolerant canola.

CANADA

Population: 32.6 million

GDP: US$1,1275 billion

% employed in agriculture: 2%

Agriculture as % GDP: 2.2%

Agricultural GDP: US$28.05 billion

Arable Land (AL): 41.6 million hectares

Ratio of AL/Population*: 5.6

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

Commercialized Biotech Crops:
- HT Canola
- HT/Bt/HT-Bt Maize
- HT Soybean
- HT Sugar beet

Total area under biotech crops and (% increase in 2008):
7.6 Million Hectares (+9% in 2008)

Farm income gain from biotech, 1996-2007: US$2.0 billion

*Ratio: % global arable land / % global population

In Ontario and Quebec, the major provinces for maize and soybean hectarage, the total plantings of maize in 2008 were 1.2 million hectares, down from 1.3 million hectares in 2007. The total plantings of soybean were up at 1.2 million hectares compared with 1.1 million hectares in 2007. In 2008, the area of biotech maize was approximately the same as 2007 at 1,190,000 hectares, compared with 1,170,000 hectares in 2007. Canada is one of only six countries (the others are the USA, Argentina, Chile, the Philippines, and Honduras) which grow maize with stacked traits for herbicide tolerance and Bt for insect resistance. The stacked trait maize hectarage in Canada in 2008 was approximately 380,000 hectares compared with 290,000 hectares in 2007. 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 2008, just over two-thirds or 68%, had single genes, 27% had 2 stacked genes and 5% had triple stacked genes. Whereas the total of biotech maize hectarage in Canada, measured in hectares, was 1.2 million hectares in

2008, the hectarage, measured in "trait hectares" was 35% higher at 1.6 million hectares. In 2008, the biotech soybean hectarage was 880,000 hectares 28% higher compared with 688,000 hectares in 2007. The continued growth of biotech crops in Canada in 2008 occurred with significantly higher total plantings of canola (6.4 million hectares), slightly lower plantings of maize (1.2 million hectares) and slightly higher soybean hectarage (1.2 million hectares).

According to the Canola Council of Canada (2007) revised projections suggest that approximately 2% of the Canada canola production will be used for biofuel by 2012.

A new biotech crop was planted in Canada in 2008, RR® herbicide tolerant sugar beet. It is estimated that in 2008, 50% of the 3,500 hectares of sugar beet planted in Ontario, Canada, equivalent to 1,750 hectares were RR®sugar beet and will be processed in the USA.

Canada is a major producer of wheat, and biotech varieties have been field-tested but not approved and adopted. Several of the current principal wheat varieties have been developed through mutagenesis and the development of biotech wheat varieties resistant to *Fusarium* could be an important future development for Canada. 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$2.0 billion in the period 1996 to 2007 and the benefits for 2007 alone is estimated at US$0.5 billion (Brookes and Barfoot, 2009, forthcoming).

A detailed benefit study of biotech canola, conducted by the Canola Council of Canada 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 in Canada. 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

Like 2007, in 2008, 7.1 million small and resource-poor farmers in China continued to benefit from planting 3.8 million hectares of Bt cotton, which was equivalent to 68% of the national cotton crop of 5.7 million hectares. 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. Approximately 80% of the papaya in Guangdong province is biotech and plantations of Bt poplar are maintained at approximately 400 hectares. Premier Wen Jiabao, Chair of the State Council/ Cabinet, 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 represents strong political will and support for biotech crops from China's cabinet and Premier Wen Jiabao who announced a new US$3.5 billion R&D initiative for biotech crops. Chinese observers interpret this to

mean that biotech rice will be approved in the near term, possibly after the approval to commercialize biotech phytase maize developed by the CAAS.

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 2008, 5.667 million hectares was similar to that planted in 2007, 5.6 million hectares. The area planted to Bt cotton in 2008 and 2007 was also approximately the same at 3.828 million hectares, with the percentage adoption similar at 68% for 2008 and 69% for 2007. 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 7.1 million small and resource-poor farmers grew Bt cotton in China in 2008, the same as in 2007. However, a recent important paper in Science (Wu *et al.,* 2008) suggests 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

<u>CHINA</u>

Population: 1.314 billion

GDP: US$2,765.4 billion

% employed in agriculture: 49%

Agriculture as % GDP: 12.5%

Agricultural GDP: US$345.67 billion

Arable Land (AL): 138.6 million hectares

Ratio of AL/Population*: 0.5

Major crops:

- Rice, paddy
- Sugarcane
- Sweet potato
- Maize
- Vegetables, fresh
- Cotton

Commercialized Biotech Crops:

- Bt Cotton
- Bt Poplar
- PRSV Papaya
- FC Petunia
- VR Sweet Pepper
- DR, VR Tomato

Total area under biotech crops and (%increase in 2008):
3.8 Million Hectares (0% in 2008)

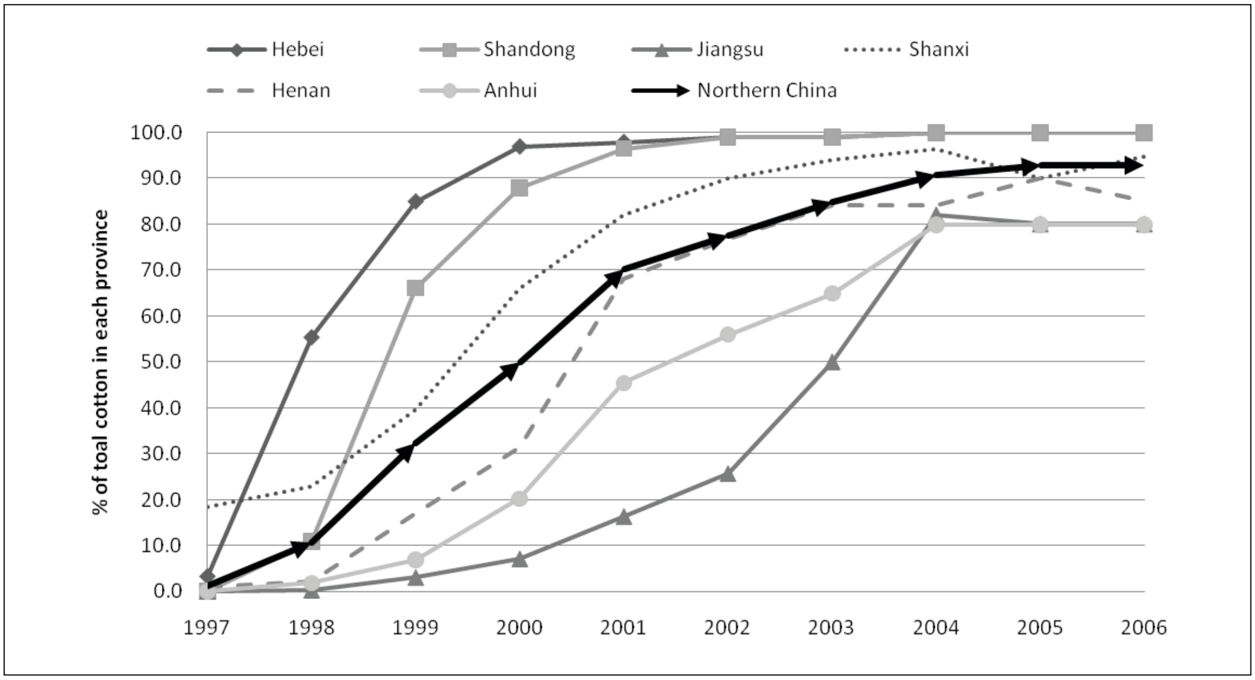
Increased farm income for 1997-2007: US$6.7 billion

*Ratio: % global arable land / % global population dropped dramatically by approximately 90% from around 3,000 in 1997 to 300 per hectare 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, mirids, 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 demonstrates 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 21). It is noteworthy that adoption of Bt cotton was fastest in the two provinces of Hebei and Shangdong reaching over 95% adoption in the short span of 5 years and 100% adoption 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 21). 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 also grew in 2007. This reflects the fact that farmers often want to compare the performance of old and improved

Figure 21. 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.

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 66 to 69%. 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 adoption rates are well above the national average. In 2007, 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 2008 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. In 2005, approval was granted to grow one of the new hybrids, Yinmian 2 on about 700 hectares in the Yellow River region. Whereas hybrids are expected to become more prevalent in the near-term, no additional information is available at this time about Yinmian 2 plantings in

2008 and its performance. It is estimated that new Bt cotton hybrids, like Yinmian 2, could boost farmer income by US$1.2 billion per year, 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 the new hybrids like Yinmian 2 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 will serve China well in the development of future biotech crops in the near-term.

In September 2006, China's National Biosafety Committee recommended for commercialization a locally developed biotech papaya resistant to papaya ringspot virus (PRSV) (Table 22). 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 is 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 2008, the total papaya hectarage in Guangdong province was 5,100 hectares (same as 2007) of which 4,500 hectares, or 88% was biotech papaya, compared with only 70% adoption, equivalent to 3,550 hectares in 2007. Thus, the percentage adoption of biotech papaya increased from 70 to 88% between 2007 and 2008.

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. In 2008, one site was replanted with cuttings and it is estimated that currently there are approximately 400 hectares of Bt poplars (240,000 trees) commercialized in China. In addition, approximately 20,000 cuttings (10,000 of Bt white hybrid and 10,000 of black poplar) were prepared in 2008 for planting in 2009 and 2010 (Zhu, 2008, Personal Communication). The Bt poplars confer resistance to leaf pests and damage has decreased from over 80% to less than 10%. Work is underway to test other biotech poplars that have modified lignin and are tolerant to stress. A poplar with the Bt886Cry3A is also undergoing testing for resistance to the pest Asian longhorn beetles which attack the trunks of poplars.

There are 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.

Table 22. Approval and Commercialization of Biotech Crops in China

Crop	Year of Commercialization
Cotton	1997
Petunia	1997
Tomato	1998
Sweet Pepper	1998
Poplar Trees	2005
Papaya	2006

Source: Compiled by Clive James, 2008.

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 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.

RR2 Soy Approval in China

The decision by China on 5 September 2008 to approve for import the new RR2 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, RR2 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%). RR2 has demonstrated a yield advantage over the first generation of RR®soybean, which was released in 1996, of 7 to 11%. The initial launch for RR2 soybean is expected in 2009 on approximately 0.5 million hectares in the USA, followed by a larger scale planting of 2 to 3 million hectares in 2010. It is projected that RR2, 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 Chinese policymakers view agricultural biotechnology as a strategic element for increasing productivity, improving national food security and ensuring competitiveness in the international market place. There is little doubt that China intends to be one of the world leaders in biotechnology since Chinese policymakers have concluded that there are unacceptable risks of being dependent on imported technologies for food security. China has over a dozen biotech crops being field-tested, including the three major staples: rice, maize, and wheat, as well as cotton, potato, tomato, soybean, cabbage, peanut, melon, papaya, sweet pepper, chili, rapeseed, and tobacco.

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 is remarkably a strong support from China's cabinet and Premier Wen Jiabao, who again 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 – ***"a signal that scientists say may speed up the commercial production of genetically modified rice or corn"*** (Shuping, 2008). As of 2006, China had approved 211 field trials for a total of 20 crops. In September, 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 will be resourced in a new novel way from local governments and indigenous agbiotech companies. A significant component in the new initiative will be 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 and Stone, 2008). Thus, biotech crops in China have been assigned the highest level of political support. Premier Wen's and the cabinet's very supportive comments on biotech crops have 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 and the principal economist. Dr. Huang commented that the ***"plan's approval is a very positive signal to the future of research and commercialization to more GMO crops."*** Dr. Huang has been involved in the development 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. All this renewed support for biotech crops in China has not surprisingly resulted in much speculation that this will catalyze and expedite commercialization of biotech maize and rice. The approval of biotech rice by China 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 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).

A Bloomberg 5 September release (Bi and Rong, 2008) reported that China, the world's biggest grain consumer plans to grow, for the first time, biotech soybean and maize in 2009. Ma Wenfeng from the Beijing Orient Agribusiness Consultant Ltd. opined that, ***"there is pressure to develop biotechnology to raise grains output because of its increased use in food, feed and even alternative energy."*** China's big challenge is to respond to the increased wealth and expectations of its people in terms of increased availability of food and feed for meat in the context of a decreasing area of arable land and dropping water tables.

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 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 approximately 2012) that could contribute to higher productivity and 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. 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 could 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 cognizant of the need for biosafety management in order to ensure protection of the environment and consumers, and this is a consideration in the pending approval of Bt rice. 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 in 2010; insect borers, which can be controlled by Bt, are prevalent on up to 75% of approximately 30 million hectares of rice in China.

Whereas ISAAA has no knowledge of biotech rice being commercialized at this time, the previous administration in Iran did officially release 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 the commercialization of rice in Iran.

Even though the global price of rice modulated to US$550 a ton in December 2008, 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 modulated rice prices.

It is estimated that China has enhanced its farm income from biotech cotton by US$5.8 billion in the period 1997 to 2006 and by US$816 million in 2006 alone. It is evident that China could enjoy significant and multiple benefits from biotech hybrid rice that has already been extensively tested in environmental and pre-production in 2001 to 2003 trials in many locations and has been subjected to regulatory evaluation, including food and biosafety. The approval of biotech rice in China will not only have major implications for China but for the rest of the world because rice is the major food crop of the world. Iran has already set a precedent in 2005 by temporarily growing a modest area of a variety of biotech rice whereas the pending Bt rice from China is a hybrid and not a variety.

With the approval of biotech rice, this would leave 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 maize in Asia will, in due course, greatly facilitate the adoption of biotech wheat, probably with improved resistance to *Fusarium* and thus lower levels of mycotoxin, followed by quality traits and in the longer term, after 2010, improved drought resistance.

The near-term food and feed needs of China, and more broadly Asia, are not limited to 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 its own portfolio of biotech crops with various traits that can be complemented with products developed by the public and private sectors for the global crop biotech market. China can derive significant benefits from biotech cotton and rice projected at US$5 billion per year by 2010, and can complement these gains by applying biotechnology to the other staples of maize and wheat, and a dozen other crops. 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 that China aims to further enhance its role as a world leader in crop biotechnology, having already approved biotech cotton, pepper and tomato in the 1990s and biotech papaya, a food fruit crop two years ago. 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 represents a very strong political will at the cabinet level for crop biotechnology in China. Chinese observers interpret this to mean that biotech rice will be approved in the near term, possibly after the approval to commercialize biotech phytase maize developed by the CAAS and licensed to Origin Seeds. The substantial economic, environmental, and social benefits from Bt cotton have provided China with its first-hand experience of biotech crops. The rich experience with Bt cotton will serve China well in its consideration of biotech rice, which is expected in the near term, following the issuance of biosafety certificates and verification of field safety data, some of which have already been generated thus expediting the final approval for commercialization.

One of the interesting aspects to observe is the growing relationship between China and Latin America, particularly Argentina and Brazil, in terms of agricultural trade in which biotech crops like soybean and maize will play an increasingly important role. It is noteworthy that all three countries are already significant players in growing and benefiting from biotech crops. China is now the world's fourth largest economy and is fast trying to regain its former number one position in GDP in the world, which it has enjoyed for most of its history. Indeed, even in the early 19th century China, the Middle Kingdom, controlled 30% of global GDP compared with 5% today, but China is expected to equal the USA GDP in 2040. To fuel China's growth, it will require commodities, including biotech soybean and maize, and Latin America is likely to be an increasingly important source of those supplies as well as other industrial commodities such as copper. With a population twice as large as the whole of Latin America, China views Latin America as an ideal trading partner and vice-versa. Indeed trade between the two partners has already ballooned to US$47 billion from only US$200 million in 1975, and is expected to reach US$100 billion by 2010 with biotech crop commodities playing an increasingly important role – this compares with trade of US$180 billion between the two neighbors of USA and Latin America. During President Hu's 2004 visit to Latin America, he pledged to invest US$100 billion in Latin America in the next 10 years. The increasing demands of China for products like soybean and other commodities from Latin America is partly responsible for both Argentina and Brazil being able to retire their respective debts to the International Monetary Fund (IMF) in 2006. The challenge will be to build a trading arrangement that fully exploits expanding trade opportunities without building a dependency that would result in over-exposure in more constrained economic times. The expanding demand and trade in commodities for the feed/food biotech-based crops of soybean, maize, and sugarcane, for both feed and biofuel/ethanol, could impact significantly on the global usage and trade in biotech crops. Given the high profile and increasing influence of the three countries involved, China, Argentina and Brazil, which collectively represent 25% of the world population, this could also have a significant impact on the general acceptance of biotech crops globally, whether they are used for food, feed, fiber or fuel.

It is noteworthy that the African Development Bank's 2007 Annual Board meeting was in Shanghai, China (Miami Herald, 2007). Jeffrey Sachs, who attended the meetings commented that the advice Chinese leaders offered their counterparts was more pragmatic than what they would typically get from the World Bank, that has instituted widespread structural adjustment loans which has led to decreased public investments, including in agriculture, which in turn has impoverished subsistence farmers who account for a majority of the world's poor. The result has been a disaster in Africa where agricultural productivity has been stagnant for decades. More pragmatically, the Chinese drew on their own practical experience of the 1970s and stressed the critical role of public investments in agriculture and infrastructure, which led the way to economic growth in China, and in turn paved the way for private sector involvement. The Chinese also stressed the need for investments in electricity and in roads to deliver agricultural inputs for farmers and for transporting farm produce to the urban areas. It is important to note that the Chinese offered to help in agricultural research where they have the largest public sector investments of any country in the world in crop biotechnology. In poor countries, an increase in farm productivity is an essential precursor for broad-based sustainable growth at the national level. Africa can gain from the practical experience of China with agricultural research, including crop biotechnology.

Benefits from Biotech Crops in China

Bt cotton – In 2008, Bt cotton was planted by 7.1 million small and resource-poor farmers on 3.828 million hectares, which is 68% of the 5.667 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 is less than US$1 per day (Huang, 2008, Personal Communication). At the national level, it is estimated that increased income from Bt cotton is approximately US$800 million per year, projected to increase to US$1 billion per year by 2010.

Biotech rice – The biotech hybrid rice is resistant to specific pests (insect borers) or diseases (bacterial blight). The product is waiting approval after extensive field tests where on average, based on CCAP's study, it increased yield by 2 to 6%, 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, 2008, Personal Communication).

The most recent study of benefits due to biotech crops globally (Brookes and Barfoot, 2009, forthcoming) estimated that China had gained US$6.7 billion from Bt cotton during the period 1996 to 2007 and US$0.9 billion in 2007 alone.

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 2008, Paraguay grew 2.66 million hectares of biotech soybean, at a 95% adoption rate.

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 2008, Paraguay is expected to increase its biotech soybean area slightly to 2.66 million hectares, up from 2.60 million hectares in 2007. The percentage adoption of RR®soybean is slightly higher than last year at 95% of the total soybean plantings of 2.8 million hectares of the national soybean crop. Paraguay is one of the 10 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, and Chile.

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 is expected to grow approximately 600,000 hectares of maize in 2008, 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. Paraguay is also expected to grow 80,000 hectares of cotton, which could benefit significantly from the biotech traits used in cotton in the neighboring countries of Argentina and Brazil.

PARAGUAY

Population: 6.5 million

GDP: US$7.281 billion

% employed in agriculture: 45%

Agriculture as % GDP: 22.4%

Agricultural GDP: US$1.63 billion

Arable Land (AL): 3.0 million hectares

Ratio of AL/Population*: 2.0

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

Commercialized Biotech Crop: HT Soybean

Total area under biotech crops and (% increase in 2008):
2.7 Million Hectares (+4% in 2008)

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$459 million in the period 2004 to 2007 and the benefits for 2007 alone is estimated at US$102 million (Brookes and Barfoot, 2009, forthcoming).

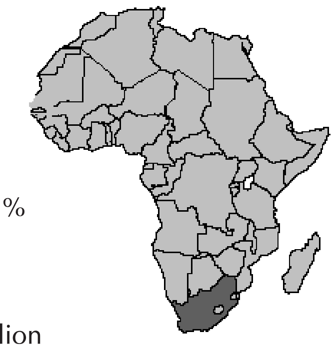
SOUTH AFRICA

In 2008, South Africa maintained its number eight position in the world ranking with a total biotech crop hectarage of 1.8 million hectares.

The South African GMO Act (Act 15/1995) was amended in 2006, passed by Parliament in 2007 and re-designated GMO Act 26 of 2006. It will enter into force when the amended regulations are approved by the Minister of Agriculture. The GMO Registrar and the Secretariat are housed in the Department of Agriculture and the GMO section moved from Genetic Resources to a new section, Biosafety, with a new Director and new Registrar. Regarding oversight for the Biodiversity Act, the Department of Environment and Tourism has delegated some functions to the new South African Biodiversity Institute (SANBI) – an amalgamation of botanical research institutions such as the Botanical Research Institute in Pretoria and the Kirstenbosch Botanical Gardens, Cape Town. One of their responsibilities is to monitor impact of GMOs on biodiversity and to this effect they established a GMO unit in 2008.

Most GM activities require a permit under the GMO Act. During the 2007 calendar year some 379 permit approvals were granted, 91% involving maize and 223 of these were for grain imports. GM maize seed import permits accounted for 70, 11 permits for commercial quantities, and 7 for commercial GM maize seed exports. More seed was exported than imported.

SOUTH AFRICA



Population: 47.4 million

GDP: US$255.4 billion

% employed in agriculture: 11%

Agriculture as % GDP: 2.5%

Agricultural GDP: US$6.4 billion

Arable Land (AL): 14.7 million hectares

Ratio of AL/Population*: 1.4

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 2008):
1.8 Million Hectares (0% in 2008)

Farm income gain from biotech, 1998-2007: US$383 million

*Ratio: % global arable land / % global population

An application for contained greenhouse facility testing by the African Bio-fortified Sorghum Project (ABS) had been turned down twice due to technical reasons. This decision by the GMO Executive Council – the official decision making body on all GMOs was challenged by the applicant, the Council for Scientific and Industrial Research (CSIR), in an appeal which ultimately led to a ruling in favor of the applicant. South African research institutions are partners in this ABS project, and work on the project will now continue in level 3 biosafety greenhouses.

Du Pont/Pioneer has obtained approval for field testing of maize with GATT® stacked tolerance to two herbicides, glyphosate and sulfonurea. Syngenta obtained approval for field trials for MIR162 insect resistance in maize, and also for the stacked Bt11 and MIR 162 in maize. An application by an external party for trials with a GM yeast to be used for wine making was refused by the Council. The GM yeast, in fact, was developed in South Africa but subsequently licensed to wine industries in Canada and California. Approval is pending for field trials of a GM table grape with tolerance to fungal disease and a GM cassava with altered starch composition.

Research is continuing on: tuber moth resistant Bt potatoes and virus resistant potatoes in field trials; high-proline, drought tolerant soybeans and groundnuts; a third run of contained greenhouse testing of maize containing genes for drought tolerance; and maize with resistance to streak virus; and the third run of virus resistant groundnuts evaluation in contained facilities. Research continues on local innovation on transgenic virus resistant selections of an ornamental bulb species, *Ornithogalum*.

In 2008, South Africa has maintained its number eight or higher position in the world ranking of biotech crop area. In 2008, South Africa has a total biotech crop hectarage of 1.813 million hectares, the same as 2007, due to a 7% reduction in maize area, partly compensated for by an increase of 60,000 hectares in soybeans and a 2,000 hectare increase in cotton. In 2008, of the estimated 2.6 million hectares of white and yellow maize, 1.617 million hectares was biotech maize, equivalent to 62% of the total maize area, up from 57% in 2007 (Table 23). Of the total hectares of biotech maize, 64%, down from 71% in 2007, equivalent to 1.035 million hectares was Bt, 17% or 280,000 hectares herbicide tolerant, up from 220,000 in 2007, and 19% or 302,000 hectares had stacked traits for Bt and herbicide tolerance, up from 3% and 80,000 hectares. The four-fold increase in stacked trait maize reflects farmer priorities for addressing the multiple constraints to increased productivity of maize. Herbicide tolerant maize, suffering from doubling of herbicide costs, is expected to continue losing market share as stacked trait benefits impact, and seed becomes more available.

White maize is expected to comprise 62% or 1.6 million hectares of the total maize area of 2.6 million hectares in 2008. Of the 1.6 million hectares of white maize, 56% was biotech made up of 579,000 hectares of Bt maize, 148,000 hectares of herbicide tolerant maize, and 164,000 hectares with stacked traits of Bt and herbicide tolerance. Yellow maize was expected to comprise 38% or 1.0 million hectares of the total maize area of 2.6 million hectares. Of the 1.0 million hectares of yellow maize, 72% was biotech maize made up of 455,000 hectares Bt maize, 131,000 hectares of herbicide tolerant maize, and 138,000 hectares of the stacked traits of Bt and herbicide tolerance.

In 2008, total plantings of soybean at 230,000 hectares will be up significantly from the 2007 plantings at 170,000 due to high soybean import cost and declining maize area. It is estimated that the area under herbicide tolerant soybean in 2008 will be 184,000 hectares, equivalent to 80% adoption, the same adoption rate as in 2007. Total cotton plantings in 2008 were estimated at 13,000 hectares, up from 10,000 hectares last year, of which 12,000 hectares or 92% were biotech cotton. This constituted 83% or 10,000 hectares of Bt/herbicide tolerant stacked traits, 9% or 1,000 hectares herbicide tolerance and 8% Bt. The stacked Bt/Bt traits, approved several years ago, are not yet used commercially as the stack is not yet available in well adapted varieties. A new type of variety with hairy leaves has been introduced with the Bt trait so as to counteract the non-target sucking insect pests that are not affected by the Bt toxin. Currently, South Africa grows biotech maize and cotton with stacked traits for herbicide tolerant and Bt for insect resistance. The approval of the stacked traits in maize and cotton was an important policy decision that will allow South Africa to retain its leadership role in biotech crops.

The progressive and steady increase in adoption of biotech crops in South Africa is captured in Table 23 which shows that the total hectarage of biotech crops increased consistently from 197,000 hectares in 2001 to 573,000 hectares in 2004 and reaching 1.8 million hectares in 2007. Of the three biotech crops, maize has always occupied the largest area with 166,000 hectares in 2001 (84% of the total biotech crop area) and 1.6 million hectares in 2007, (89% of all biotech crops). It is noteworthy that white biotech maize used for food is well accepted in South Africa occupying 6,000 hectares in 2001 (<1% of the white maize area) and increasing to 1.040 million hectares in 2007 equivalent to 62% of the total white maize area of 1.61 million hectares. The hectarage of biotech white maize decreased from 1,040,000 hectares in 2007 to 891,000 hectares in 2008, in line with 7% reduction in total white maize plantings in 2008.

South Africa plays a pivotal role in sharing its rich experience with other countries in Africa interested in exploring the potential that biotech crops offer. It is encouraging to note that South Africa already participates in technology transfer programs with other African countries and is engaged in training and human development programs with its neighboring African countries. One practical example is the collaboration with Egypt that uses a South African developed Bt maize hybrid in its first commercialization of a GM crop. Given South Africa's rich experience with biotech crops, it can also play an important role as the key partner country on the continent of Africa that can collaborate and cooperate with its counterparts in Asia, China and India, and Argentina and Brazil in Latin America. The Governments of India, Brazil and South Africa have established a platform for cooperation (IBSA) that includes research collaboration on crop biotech. South Africa has the necessary resource base and experience in biotech crops that allows it to exert leadership in international networking with both public and private sector institutions in industrial countries to develop innovative and creative new modes of cooperation and technology transfer that can be shared with other crop biotech aspiring countries in Africa. South Africa plays a critical role as an African and global hub in the sharing of knowledge and experience about biotech crops.

Benefits from Biotech Crops in South Africa

South Africa is estimated to have enhanced farm income from biotech maize, soybean and cotton by US$383 million in the period 1998 to 2007, with benefits for 2007 alone estimated at US$227 million (Brookes and Barfoot, 2009, forthcoming).

Table 23. Adoption of Biotech Crops in South Africa, 2001 to 2008 (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%)
Total	**7,082**	**6,065**	**3,273**	

Source: ISAAA, 2008.

A study conducted for and funded by the South African Maize Trust (Gouse and Van der Walt, 2008, unpublished) showed that a total of 15 million metric tons of GM maize was produced over nine years (2000-2008), 7.4 million tons white, used primarily as staple food by a large section of the population, and 7.6 million tons yellow, used mostly for animal feed and industrial processing. Calculated at an average yield increase benefit of 10.6% for Bt and Bt/HT and using average annual grain prices over the period, farmers gained an additional income of US$267 million.

A 1998-2000 extensive study on Bt cotton reported substantial benefits for small holders. A 2001-2002 study on Bt maize showed an average benefit of US$35/hectare for dry land farmers and US$117/hectare for irrigated land, based on yield increases of 10.6% and 11.0% respectively, adjusted for pesticide reductions and the extra cost of biotech seed. The estimated annual average loss due to stalk borers is 10% equivalent to a national loss of US$120 million, based on a 10 million metric tons (MT) harvest.

A study published in 2005 (Gouse *et al.,* 2005) involved 368 small and resource-poor farmers and 33 commercial farmers, the latter divided into irrigated and dry-land maize production systems. The data indicated that under irrigated conditions, Bt maize resulted in an 11% higher yield (from 10.9 to 12.1 MT /ha), a cost savings in insecticides of US$18/ha equivalent to a 60% cost reduction, and an increase income of US$117/ha. Under rainfed conditions Bt maize resulted in an 11% higher yield (from 3.1 to 3.4 MT/ha), a cost saving on insecticides of US$7/ha equivalent to a 60% cost reduction, and an increased income of US$35/ha.

For small and resource-poor farmers, the benefits were measured using a different set of comparisons using only yield per hectare data. Bt maize hybrids yielded 31% more than the corresponding conventional hybrids, and 134% more than the conventional open-pollinated varieties planted by some small farmers. Conventional non-Bt hybrids also used by some small farmers yielded only 79% more, compared with 134% more for Bt hybrids.

Selected Farmer Experiences with Biotech Crops in South Africa

Smallholder farmers that have now been assisted to enter mainstream agricultural production, known as emergent farmers as well as large scale farmers have testified on their successes with biotech crops.

Mrs. Deliwe Ntebele has been farming for 12 years near Delareyville, North West province, and now has 165 hectares under crops, mainly sunflower and maize. She was also given recognition for her successes by Grain South Africa, the grain farmers association. ***"I am happy with my GM maize and will continue to plant both Bt and stacked Bt/herbicide tolerant maize,"*** she said.

Mr. Victor Mahlinza farms with maize, soybeans and sunflower near Estcourt in KwaZulu-Nateal province. ***"I grow some 20 hectares of GM maize and 20 hectares GM herbicide tolerant soybeans and have had very good results. The Bt maize has performed well and I shall continue now with Bt/herbicide tolerant hybrids,"*** Victor said.

Mr. Morgan Gregory of Normandien said that large-scale commercial farmers have been a driving force in GM crop adoption. ***"GM maize genetics is to the benefit of humankind. It enables farmers to produce food more efficiently and it facilitates the farmer's management."***

Mr. Koos Kruger has 800 hectares under central pivot irrigation, 2,000 hectares dry-land maize and large areas under livestock. ***"GM crops have caused a total turn-around in farming. I can now control weeds with Bt/glyphosate tolerant maize that leads to attaining full yield potential, the attacks by top borers are under control at a stage when we have to devote full attention to harvesting wheat on other fields, and the technology fits in well with my change to minimum tillage systems."***

Mr. Johnnie Lourens farms 120 hectares under pivot irrigation and 800 hectares dry-land, in addition to livestock. ***"Advanced maize hybrids with Bt, herbicide tolerance and stacked traits have brought a new dimension to my farming. The ways to apply these traits are many fold. My farming operation cannot do without it."*** Koos and Johnnie also have 800 hectares under maize in a joint venture in Zambia, north of South Africa.

Chief Advocate Mdutshane, a highly respected chief of Ixopo, whose native language is Xhosa, from the Eastern Cape of South Africa says that 120 emergent poor farmers in his area increased their yields from conventional maize by up to 133% with Bt maize. Yields increased from 1.5 tons per hectare to 3.5 tons per hectare by eliminating the stalk borer which damaged up to 60% of their crops. They call the Bt maize, ***iyasihluthisa***, Xhosa for ***"It fills our stomachs."*** For the first time ever they produced enough food to feed themselves (Mdutshane, 2005).

Richard Sitole, chairperson, Hlabisa District Farmers' Union, KZN, says 250 emergent subsistence farmers of his Union planted Bt maize on their smallholdings, averaging 2.5 hectares, for the first time in 2002. His own yield increased by 25% from 80 bags for conventional maize to 100 bags, earning him an additional income of Rand (R) 2,000 (US$300) – US$1.00 is equal to R6.7 as of November 2007. Some of the farmers increased their yields up to 40%. He pointed out that taking 20 farmers, and there were many more, earning an extra income of R2,000 (US$300) totaled R40,000 (US$6,000) additional disposable income in their small community, boosting small shopkeepers, dressmakers and vegetable producers. ***"I challenge those who oppose GM crops for emergent farmers to stand up and deny my fellow farmers and me the benefit of earning this extra income and more than sufficient food for our families,"*** says Sitole (2004).

Molasi Musi, small-scale farmer from Soweto, near Johannesburg, farms on 21 hectares where for years he has been battling to make a viable living. Stalkborers took 40% of his harvest. Three years ago he planted Bt maize. With non-Bt maize his yield averaged 7.7t/hectare. With Bt maize his average over the past three years has nearly been 9t/hectare. With the surplus profit he made last year, he bought himself a secondhand tractor driven mill for his own and that of his fellow farmers' maize harvest earning himself extra income. He donated six bags of his surplus maize meal to an old-age home and a hospice in Soweto (Musi, 2007).

Philiswe Mdletshe, cotton farmer on the Makhathini Flats, KwaZulu-Natal province, increased her yield with Bt cotton from three bales per hectare to eight bales per hectare, earning her a net income of R38,400 (US$5,730). She reduced insecticide sprayings from ten times a season with non-Bt cotton to twice with Bt and saved 1,000 litres of water. She has continued planting Bt cotton for five successive years (Mdletshe, 2004).

Thousands of emergent resource-poor farmers are planting Bt cotton year after year on the Makhathini Flats. A scientific study conducted by the University of Reading in the UK and the University of Pretoria concluded that Bt cotton yields were 40% more than conventional cotton. Farmers paid 42% less in spraying costs (Morse *et al.,* 2004).

Trials done by the Agricultural Research Council on the Makhathini Flats over a five-year period noted an average increase yield gain of 349 kg per hectare with Bt cotton. At R3 per kg (US$0.45), this meant an extra profit of R1,047 (US$156) per hectare planted (Sunday Independent Business Report, 2005).

Velapi Mlambo, small-scale cotton farmer on the Makhathini Flats, South Africa has been planting Bt cotton for three years on his 5 hectare farm. His yield during one of the worst droughts in many years was 800 kg/ha compared to 600 kg with conventional cotton – an increase of 25%. He sprayed three times for insects compared to15 times with conventional cotton (Mlambo, 2007).

URUGUAY

Uruguay increased its biotech plantings of soybean and maize to 685,000 hectares in 2008.

Uruguay, which introduced biotech soybean in 2000, followed by Bt maize in 2003 increased its biotech crop area once again in 2008 to reach approximately 685,000 hectares, up by approximately 40% from 545,000 hectares in 2007, with the gain coming from both biotech soybean and maize. A modest increase was recorded in the hectarage of herbicide tolerant soybean which now occupies 100% of the 575,000 hectares (compared with 470,000 hectares in 2007) of the national soybean hectarage. The adoption of Bt maize, which Uruguay first approved in 2003, continued to grow to 110,000 hectares, up over 45% from 75,000 hectares in 2007, and occupied 73% of the total maize plantings of 150,000 hectares in Uruguay in 2008.

URUGUAY

Population: 3.4 million

GDP: US$13.24 billion

% employed in agriculture: 13%

Agriculture as % GDP: 9.3%

Agricultural GDP: US$1.23 billion

Arable Land (AL): 1.34 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 2008):
0.75 Million Hectares (+40% in 2008)

Farm income gain from biotech, 2000 to 2007: US$445 million

*Ratio: % global arable land / % global population

Benefits from Biotech Crops in Uruguay

Uruguay is estimated to have enhanced farm income from biotech soybean and maize by US$445 million in the period 2000 to 2007 and the benefits for 2007 alone is estimated at US$148 million (Brookes and Barfoot, 2009, forthcoming).

BOLIVIA

In 2008, Bolivia became the tenth country to officially grow RR®soybean. In 2008, it is estimated that 600,000 hectares of RR®soybean will be planted in Bolivia. The RR®soybean hectarage in Bolivia in 2008 is equivalent to 63% of the total national hectarage of 960,000 hectares.

BOLIVIA

Population: 9.247 million

GDP: US$39.75 billion

% employed in agriculture: 40%

Agriculture as % GDP: 14.5%

Agricultural GDP: US$5.8 billion

Arable Land (AL): 3 million hectares

Ratio of AL/Population*: .32

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

Commercialized Biotech Crop: HT Soybean

Total area under biotech crops in 2008: 0.6 Million Hectares

*Ratio: % global arable land / % global population

Bolivia is a small country in Latin America with a population of 9 million and a GDP of approximately US$9 billion. Agriculture contributes approximately 15% to GDP and employs just over 40% 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, 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 (more than 5% of total exports) in the form of beans, oil, and cake.

Bolivia ranks eighth in the world in hectarage of soybeans (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, four (USA, Argentina, Brazil and Canada) grow RR® biotech soybean.

In 2008, Bolivia became the tenth soybean country to officially grow RR®soybean. In 2008, it is estimated that 600,000 hectares of RR®soybean will be planted in Bolivia; the RR®soybean hectarage in Bolivia in 2008 is 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 14 million hectares) and Paraguay (over 2 million hectares) for many years.

__PHILIPPINES__

In 2008, the area planted to biotech maize in the Philippines is projected to significantly increase up to 350,000 hectares, up significantly by 40% from the 248,000 hectares of biotech maize in 2007. Notably, the area occupied in 2008 by the stacked traits of Bt/HT maize is 200,000 hectares, compared with only 63,000 hectares in 2007, up by a substantial 300%.

__PHILIPPINES__

Population: 89.5 million

GDP: US$117.6 billion

% employed in agriculture: 36%

Agriculture as % GDP: 14.1%

Agricultural GDP: US$16.58 billion

Arable Land (AL): 5.66 million hectares

Ratio of AL/Population*: 0.3

Major crops:

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

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

Total area under biotech crops and (% increase in 2008):
0.4 Million Hectares (+33% in 2008)

Increased farm income for 2003-2007: US$66 million

*Ratio: % global arable land / % global population

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 is projected to significantly increase in the wet and dry seasons in 2008 to reach up to 350,000 hectares, significantly up by 40% from the 248,000 hectares of biotech maize in 2007 (Figure 22). Notably, the area occupied in 2008 by the stacked traits of Bt/HT maize is 200,000 hectares, compared with only 63,000 hectares in 2007, up by a substantial 300%. Bt maize occupied 80,000 hectares in 2008, approximately the same hectarage as last year (75,000 hectares). Herbicide tolerant (HT) maize was planted on 70,000 hectares in 2008 compared with 110,000 hectares in 2007. On a percentage basis, biotech yellow maize has consistently increased by about 5% every single year from the first year of commercialization, 2003, reaching the highest ever level of 26.8% 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.

The number of small resource-poor farmers, growing on average 2 hectares of biotech maize in the Philippines in 2008, is estimated at 175,000, up significantly by 50,000 from 125,000 in 2007. A total of four events of biotech maize are approved for commercial planting in the Philippines: MON810 for insect resistance (2002), NK603 for herbicide tolerance (2005), Bt11 for insect resistance (2005) and the stacked gene product of MON810/NK603 (2005). In addition a number of stacked trait maize and cotton products have been approved in 2007 for import, including the triple stacked maize with DAS59122/TC1507/NK603. A total of 46 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, 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 April 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).

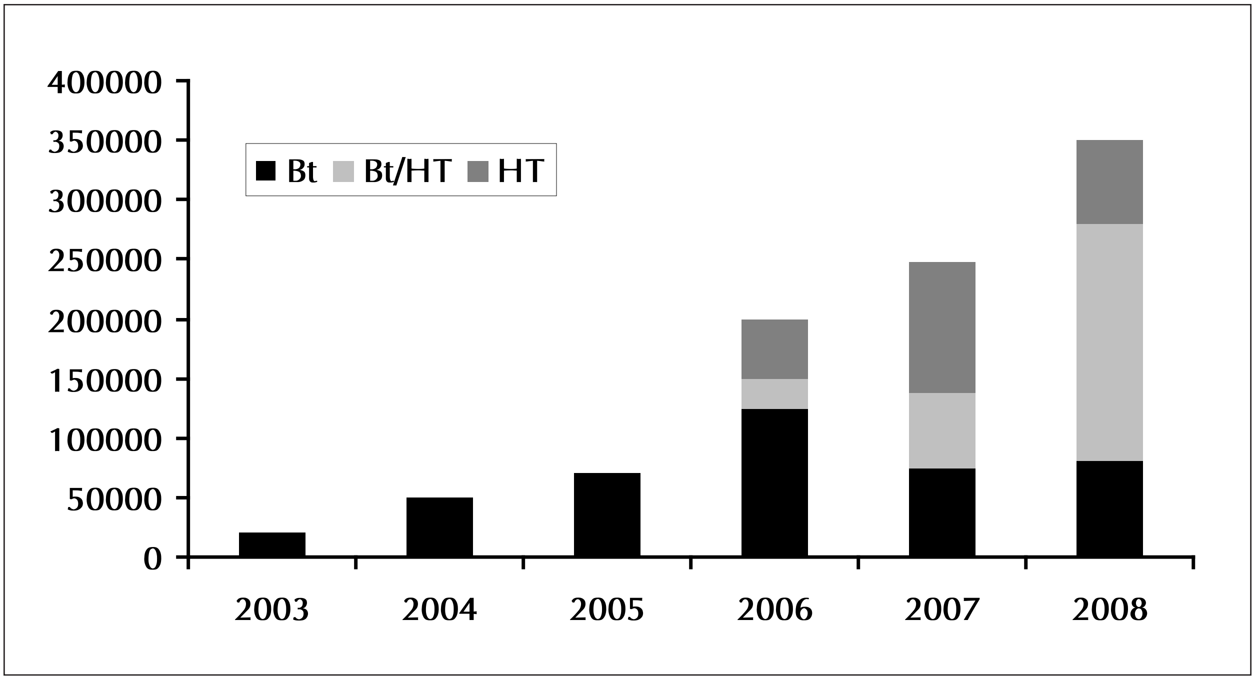
The fruit and shoot borer resistant eggplant and biotech papaya with delayed ripening and PRSV resistance being developed by the Institute of Plant Breeding at the University of the Philippines Los Baños (IPB-UPLB) have already been tested in confined field trials and ready for multi-location field trials. 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. The Philippine Department of Science and Technology has been very supportive of research and development activities on biotech crops and has 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 August 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. The Philippines, which grows approximately 2.7 million hectares of maize is the only country in Asia to 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 31% of the global 157 million hectares of maize with China itself growing 28 million hectares, plus significant production in India (7.8 million hectares), Indonesia (3.5 million hectares), Philippines (2.7 million hectares), and Vietnam, Pakistan and Thailand (each with about 1 million hectares) (FAO, 2008).

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

Figure 22. Increase in Hectarage Traits of Biotech Maize in the Philippines and Proportion of Commercialized Traits



Source: Compiled by ISAAA, 2008.

were determined to 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 2007 is estimated to have reached US$66 million, of which US$12 million was from herbicide tolerant maize and US$55 million was from insect resistant maize. For 2007 alone, the net national impact of biotech maize on farm income was estimated at US$45 million (Brookes and Barfoot, 2009, forthcoming). The 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. For the virus resistant papaya, a substantial increase in the farmer's net income was estimated after technology adoption, with expected returns up to 275% higher 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 done to help 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), was 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 almost US$30 million from biotech maize in a short span of four years, 2003 to 2006, and is advancing the adoption of the maize stacked traits, Bt/HT, faster than any other biotech maize-growing developing country. In 2008, stacked traits in maize represented almost 60% 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 5 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.

Farmer Experiences

The Biotechnology Coalition of the Philippines

The Philippines ranks number 10 in the world in area of biotech crops and is the only country in Asia to have approved and adopted a major biotech feed crop – biotech maize. The Biotechnology Coalition of the Philippines, recently prepared a brief summarizing the adoption and impact of biotech maize in the Philippines, since its introduction in 2002. The Brief documented three case studies and articulated policies that would allow the Philippines to benefit from current and future biotech crop applications. The coalition has concluded that, ***"the socio-economic benefits of biotech maize, as supported by pre- and post-commercial studies cannot be under-estimated."***

Rosalie Ellasus, dubbed as the "corn queen" in her hometown in Pangasinan province learned farming on a Farmer's Field School when she was widowed, recounts, ***"I have increased my corn yield, from 3.2 metric tons, with traditional corn variety, to 7.8 metric tons with Bt corn variety. I get almost 100 percent profit with Bt corn, that is why I was able to increase my farm from 1.3 ha to 10 ha at present and send my children to school. I have also adopted another biotech corn which is tolerant to glyphosate. The farmers in my small community enjoy the benefits from planting biotech crops. We get better yields and good buying price of our clean corn from feedmillers."*** Ms. Ellasus subsequently served as the president of the Philippine Maize Federation Incorporated (PhilMaize) and became the first recipient of the Kleckner Trade & Technology Advancement Award given by the Truth About Trade and Technology, an Iowa-based not for profit organization (Calumpang, 2008).

Delson Sonza, an agriculture graduate of the Western Visayas State University and the president of the Northern Iloilo Corn Producers Association Inc. (NICPAI), started a farmers' program in Iloilo province to allow idle lands in mountainous areas to be turned into productive lands with minimum or zero tillage. NICPAI saw the potential of biotech corn and Sonza said that, ***"with biotech corn farming, families without a carabao and other farm implements can now cultivate their grasslands which were converted into corn land."*** About 98% of the families in his hometown are now planting biotech corn and the practice is expanding to other mountain barangays in neighboring towns. ***"They can now eat three meals a day,"*** Sonza added (Fernandez, 2008).

Mary Ann Dioneda has an undergraduate degree in agriculture and is farming corn and vegetables in Pampanga province. She initially planted 9 hectares of Bt corn and subsequently increased the area to 25 hectares this year. Ms. Dioneda said that ***"Bt corn saves money and gives more profit",*** and recalled that several farmers like her ran out of biotech corn seeds last year due to very high demand. ***"Biglang lahat gusto ng Bt (corn seeds) kahit mahal ang binhi [Instantly, everybody wants Bt corn seeds, even if they are more expensive],"*** she said. Because there was no supply, she planted conventional corn but was able to harvest only an average of 2 tons per hectare, instead of the 8 tons per hectare she normally harvests when using Bt corn. Ms. Dioneda said that to avoid a similar situation this year, she bought Bt corn seeds early in the season. She notes that most local financing institutions also now recommend the use of biotech corn seeds to guarantee good harvests and income so that farmers can repay their loans easily (Dioneda, 2008).

<u>AUSTRALIA</u>

In 2008, Australia grew 160,000 hectares of biotech crops principally biotech cotton, and importantly biotech canola for the first time. This biotech hectarage is more

than a three-fold increase over the 48,000 hectares of biotech crops in 2007 during which Australia suffered a very severe drought from which the country is still recovering.

AUSTRALIA

Population: 20.3 million

GDP: US$755.3 billion

% employed in agriculture: 3.6%

Agriculture as % GDP: 3.8%

Agricultural GDP: US$28.7 billion

Arable Land (AL): 46.85 million hectares

Ratio of AL/Population*: 10.1

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

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

Total area under biotech crops and (increase in 2008):
0.2 Million Hectares (100% in 2008)

Farm income gain from biotech, 1996-2007: US$169 million

*Ratio: % global arable land / % global population

In 2008, Australia grew 160,000 hectares of biotech crops including biotech canola for the first time; this biotech hectarage is more than a three-fold increase over the 48,000 hectares of biotech crops in 2007. 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, 2008a). Western Australia (WA) which grows approximately half (320,000 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 would release up to 85% of the canola hectarage in Australia to biotech herbicide tolerant canola.

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 is expected to plant 160,000 hectares of cotton in 2008, 320% more than the 48,000 hectares in 2007, but significantly less than their normal recent plantings of 200,000 hectares or more, because of the continuing effects of the severe droughts in 2006 and 2007 – the worst that Australia has experienced. As a result, there is great uncertainty amongst cotton growers regarding irrigation supplies, and dry-land growers will be completely dependent on late rains for planting. Assuming 160,000 hectares of cotton in 2008, the overall percentage adoption of biotech cotton in 2008 is expected to be 94%, similar to the 95% in 2007. It is projected that in 2008, about 81% of all cotton in Australia will feature the stacked genes for herbicide tolerance and insect resistance (RR® or RR®Flex and Bollgard®II); 4% with the Bollgard®II dual Bt genes, compared with 12% in 2007; 9% with a single gene for herbicide tolerance including RR®, RR® Flex or Liberty Link®, and the remaining 6% in conventional cotton, compared with 5% in 2007.

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, and 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 2008, Australia, for the first time, grew herbicide tolerant RR®canola in two states, New South Wales (NSW) and Victoria. According to the Australian Oilseeds Federation, an estimated 1.235 million hectares of canola were grown in Australia in 2008 of which 440,000 hectares equivalent to 35% of the national total were grown in the two states of NSW and Victoria (Table 24). NSW and Victoria each grow a total of 222,000 hectares of canola in 2008 and each state planted an estimated 4,750 hectares of biotech RR®canola equivalent to 2% of the total canola hectarage planted in each of the two states.

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, 2008), 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. Despite

Table 24. Hectares of Canola, Conventional and RR Biotech, Planted in Australia, by State, 2008

State	Total canola (ha)	Biotech canola (ha)	Biotech canola as %
NSW	220,000	4,750	2%
Victoria	220,000	4,750	2%
South Australia	175,000	-	-
Western Australia	620,000	-	-
Total	**1,235,000**	**9,500**	

Source: Compiled by Clive James, 2008.

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 for drought tolerance would become available in biotech crops around 2010 and beyond.

In Australia, where biotech cotton has been very successfully grown for 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, had consistently increased its world exports of biotech canola and increased its yield by over 15% over 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 – 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 droughts.

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.

<u>Drought tolerant wheat</u>

The Victorian AgriBiosciences Center (VABC) in Victoria, which is part of a state government research division, field tested biotech wheat for drought tolerance in 2007-2008. The trials were planted in Northern Victoria in an area that suffered significant drought losses in 2006-2007. Two lines of biotech wheat were identified in the field trials that yielded 20% more than the controls. Regulatory approval has been obtained to extend the field trials over the next two years. The stated goal of this important research effort is to develop and commercialize the world 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 (ABC News, 2008b).

<u>Panama disease of bananas</u>

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 resistant 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 are 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, which will feature biotech varieties which are more nutritious, have a reduced non-digestible content, could reduce the amount of feed required and could also help framers survive drought (The Age, 2008).

Benefits from Biotech Crops in Australia

Australia is estimated to have enhanced farm income from biotech cotton by US$196 million in the period 1996 to 2007 and the benefits for 2007 alone is estimated at US$12 million (Brookes and Barfoot 2008, 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.

In drought stricken Australia, farmers like **Angus McLaren**, a father of three, who farms wheat and canola is excited about genetic engineering and describes it as ***"the future of Australian agriculture."*** He points out that ***"GM crops are able to adapt to the land and the environment whereas in the last 200 years we have been trying to change the environment to suit our crops."*** He is convinced that ***"there are unlimited possibilities and GM crops use a lot less chemicals.*** McLaren and his colleagues have founded a farmers group "Producers Forum" to increase the awareness of the supportive views of farmers for GM crops in Australia and the critical role that GM crops can play in ensuring that Australian crop production is competitive in world markets with important export crops like canola and wheat (McLaren, 2007).

Biotech canola in Australia

Biotech canola offers Australia the opportunity of again competing in growing world canola markets responding to increased biofuel needs, and to expand biotech canola production in Australia 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. In summary, biotech canola offers Australia a way to increase yield in a sustainable way requiring less herbicides 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.

In late November 2007, two Australian state governments, New South Wales (NSW) and Victoria, lifted state bans on the commercialization of biotech herbicide tolerant canola that has been in place for four years, subsequent to approval by the federal gene regulator in 2003. NSW and Victoria are lead states in Australia for canola and produce about half of national production. Lifting the ban will allow farmers in NSW and Victoria to plant biotech canola in April 2008. For the first time, Australia will compete on a level playing field with Canada which has been benefiting from biotech canola for the last ten years. Canada is the largest producer and exporter of canola in the world. Australia's largest farmer group, the NSW Farmers Association said the decision was a victory for the future prosperity of agriculture and that a five year trial had confirmed that biotech canola delivered superior weed control, higher yield, improved oil quality and higher profit. The following paragraphs are a useful summary of the facts about biotech canola in Australia and are reproduced with the permission of Paula Fitzgerald, Executive Director, Agrifood Awareness Australia Limited (Fitzgerald, 2007).

AUSTRALIA READY FOR GM CANOLA – LET THE EVIDENCE SPEAK

In 2003-04, a number of canola growing states in Australia introduced a moratoria preventing the commercial cultivation of approved GM canola varieties based on supposed marketing and trading uncertainties.

Between 2003 and 2007, the grains industry scoped and addressed these matters, to the extent that it is now ready to incorporate GM canola into the grain supply chain, alongside the many other grades and classifications of cereals, course grains, oilseeds and pulses, upon cessation of the moratoria.

During 2007, moratoria reviews have been conducted in Victoria, South Australia and New South Wales, in addition to Tasmania where a review is still underway. Outcomes from the reviews in Victoria, South Australia and New South Wales are due in the near future.

Considerable data was collected regarding the marketing and trading considerations for GM canola, and Australian agriculture has declared that the moratorium should be lifted while continuing to provide choice to stakeholders' right along the grain supply chain – from seed producers to consumers.

The ban was lifted in New South Wales and Victoria in 2008.

The following provides a historical summary of the evidence, capacity and commitment of the grains industry, and highlights why it was time in 2008 for Australia to catch up with the rest of the world.

Fact: GM Canola – A Global Commodity
Genetically modified canola is grown, traded, and consumed around the world. Approximately 87% of the canola crop in Canada, the world's biggest canola producer, is planted to GM varieties. This canola is marketed around the world including Japan which is often portrayed as a 'non-GM' country. Japan also buys Australian canola, and while a very small amount of Australian canola is segregated and sold as non-GM, most is co-mingled with Canada's GM canola.

Canada does not regularly market canola to Europe, however, it should be noted that (1) Europe is largely self-sufficient and has only been an occasional market, and (2) Europe's biofuel policy will see an increase in demand from Europe for canola which Canada will capitalize on.

GM crops are now being grown in EU countries – for example, GM corn in Spain.

Fact: Australia – GM Crop Experience
Australia has grown GM cotton since 1996 with more than 90% of Australia's cotton crop now consisting of GM varieties. Since the commercial introduction of GM cotton, Australia has experienced no negative market or trade implications in relation to the fiber, cottonseed oil or cottonseed meal produced from GM cotton.

Australia has imported GM soybean meal and oil for many years to meet human and animal feed requirements. Due to the ongoing drought, Australian food producers and processors imported more than 50,000 tons of GM canola from Canada to overcome local domestic shortages. These imports have been managed through the domestic supply chain and delivered to meet customer specifications.

Fact: Australian Food Producers – Innovation Drivers
Australia's farmers are rapid adopters of new technology, and through their investment in research and development, drive innovation. Since 1996, farm representative bodies, namely national and state farm associations and commodity councils have debated the GM topic and now have a common policy position, agreeing that GM canola should proceed to commercialization and that the moratoria should be lifted (http://www.afaa.com.au/n_industry_policies_landing.asp).

If the moratoria are not lifted, Australian farmers will be left behind by their counterparts in the USA, Canada, South Africa and South America, China and India – countries where the adoption of GM varieties is both rapid and extensive. In a recent study, ABARE found that "a continuation of the current moratoriums and extension to other GM crops is expected to result in a loss of gross national product of US$3 billion, over the next ten years."

Fact: Clear Benefits from Long Term Study
Canadian canola growers have reported considerable benefits from growing GM canola. A study

conducted by the Canola Council of Canada reported that growers chose to grow GM varieties for easier and better weed control, better yields, higher returns and more profit, to reduce costs and to clean up fields.

In Australia, recently published work by Charles Sturt University researchers showed that a GM canola variety consistently delivered superior weed control, higher yields and oil quality and better profits when compared to current varieties in a traditional five year crop rotation system (http://news.csu.edu.au/director/latestnews.cfm?itemID=363C755F0F03ED5034B67FEC742E1469&printtemplate=release).

A recently released review conducted by the University of Melbourne stated that if half the current canola types grown were replaced with GM canola the impact in Australia would be:

- Around 640 tons less triazine herbicide would be used each year;
- An extra 225,000 hectares of canola would be grown each year by direct drilling or minimum tilling;
- Average national canola yields would increase by eight percent – from 1.2 tons to 1.3 tons per hectare;
- An additional 200,000 tons of canola would be grown in low rainfall regions; and
- Wheat production, in rotation, would increase by 80,000 tons on the additional canola areas (http://www.jcci.unimelb.edu.au/Canola2007.pdf).

Fact: Choice – Meeting Customer Demands

In August 2007, the Australian grain industry launched a statement entitled "Delivering Market Choice with GM canola." This statement, endorsed by 29 key grain supply chain organizations, recognized:

- the integrity, capacity, and demonstrated ability of the Australian grain supply chain;
- that choice for all supply chain participants is key; and
- that there is a commitment to deliver choice along the supply chain.

This document was underpinned by a 102-page document entitled "Principles for process management of grain within the Australian supply chain" which detailed the principles and processes being utilized or able to be implemented within the Australian grain industry if the moratoria are lifted.

Over recent weeks, two food processors have emerged in the media stating their desire for non-GM canola and in doing so, have asked their respective state governments to maintain the moratoria on GM canola. While the moratoria may meet the current commercial interests of these food suppliers, it denies the many other supply chain participants the opportunity to explore the benefits of GM canola. Choice must remain the underlying principle in this decision-making process to ensure that all supply chain participants have equal opportunity to access the products which provide benefits to their business.

Fact: Let the Evidence Speak
Choice, supported by excellent science is the key.

The GM canola types in question were approved by Australia's Federal Regulator in 2003 as safe for human health and the environment. In approving the varieties, the Regulator noted that their safety was comparable to the conventional varieties which Australia produces. These varieties have been grown, traded, and consumed for over a decade around the world without concern.

To date, Australian farmers have been denied access to GM canola due to market or trade uncertainties, however, this matter has now been fully explored and addressed by the grain supply chain.

The evidence is clear – the Australian grains industry has recognized that choice is key and is committed to continue delivering it. Australian agriculture has further endorsed the positive potential of gene technology and agreed that Australian agriculture should have access to the approved GM canola varieties with the lifting of the moratoria.

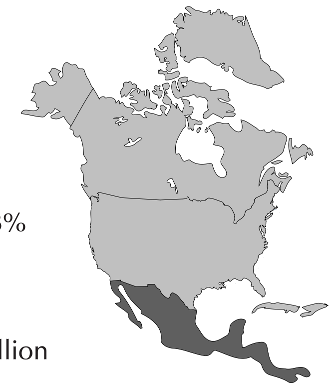
<u>MEXICO</u>

In 2008, Mexico planted 85,000 hectares of biotech cotton, and 10,000 hectares of biotech RR®soybean for a country total of 95,000 hectares.

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 2008, the total cotton plantings in Mexico were approximately 120,000 hectares. Approximately 70% or 85,000 hectares were biotech products, compared with 55% or 62,000 hectares in 2007. In addition to the biotech cotton, 10,000 hectares of RR®soybean was planted in 2008 compared with only 4,000 hectares in 2007. Thus, the total hectarage of biotech crops in Mexico in 2008 was 95,000 hectares up from the 66,000 hectares in 2007 and comprising 85,000 hectares of biotech cotton and 10,000 hectares of biotech soybean.

In 2008, the following was the hectarage of biotech cotton traits: of a total of 85,000 hectares of biotech cotton, 70,000 hectares, or 82% was the stacked trait product for insect resistance and herbicide tolerance, compared with only 40,000 hectares in 2007; 15,000 hectares of herbicide tolerance, compared with 6,000 hectares in 2007. The biotech cotton hectarage in 2008 at 85,000 hectares is one-third higher than the 62,000 hectares planted in 2007.

MEXICO



Population: 109.955 million

GDP: US$1,353 billion

% employed in agriculture: 18%

Agriculture as % GDP: 4%

Agricultural GDP: US$54.2 billion

Arable Land (AL): 24.35 million hectares

Ratio of AL/Population*: 0.22

Major crops:

- Maize
- Soybean
- Cotton
- Wheat
- Rice
- Coffee

Commercialized Biotech Crops:

- Bt Cotton
- HT Soybean

Total area under biotech crops in 2008: 0.1 Million Hectares

Farm income gain from biotech, 1996-2007: US$88 million

*Ratio: % global arable land / % global population

After a large increase in 2005 to 120,000 hectares, biotech cotton hectarage in 2006 decreased to approximately 55,000 hectares because of regulatory delays that precluded the importation of biotech cotton seed for the early plantings in Mexico. Subsequent to solving the regulatory problem, seed was imported for later plantings, but as a consequence the total biotech cotton area in 2006 was reduced significantly. Mexico is one of five countries to deploy the Bt/HT stacked cotton, the other countries are the USA, Australia, Colombia, and South Africa. In 2008, a modest area of RR®soybean in Mexico occupied 1,000 hectares for a total of 95,000 hectares of biotech cotton and soybean.

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.

Following years of debate, the Mexican Congress 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. Technology developers were eagerly waiting for the approval of the By-laws to enable application for permits to conduct biotech maize field trials in 2008. However, the authorities now advise that a transitory article in the By-laws also requires that a special regime for maize protection must be defined within 60 days after the issue of the By-laws (March 18, 2008). Although a draft of the regime was made available for public comment and many inputs received now, with a delay of more than 6 months after 18 March, the Ministry of Agriculture is still studying the "optimum" process for issuing a document defining the regime. Developers of biotech crops with applications for biotech maize field trials in Mexico are frustrated with this further delay because the window for planting in 2008 was missed.

In summary, bureaucratic legal delays are precluding 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 Mexico – until these biotech experiments are completed the stalemate will continue. Earlier applications to field test biotech maize were for locations in Northern Mexico, where the precursor of maize, Teosinte, is not found; applications were not granted because the regime for maize protection has not been defined.

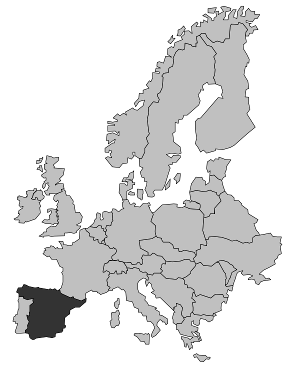
Benefits from Biotech Crops in Mexico

Mexico is estimated to have enhanced farm income from biotech cotton and soybean by US$88 million in the period 1996 to 2007 and the benefits for 2007 alone is estimated at US$18 million (Brookes and Barfoot, 2009, forthcoming).

SPAIN

Spain is the lead biotech crop country in Europe, having successfully grown Bt maize for eleven years. Spain grew approximately 80,000 hectares of Bt maize in 2008, equivalent to a 32% adoption rate, the highest ever.

SPAIN



Population: 40.491 million

GDP: US$1,361 billion

% employed in agriculture: 5.3%

Agriculture as % GDP: 3.6%

Agricultural GDP: US$49 billion

Arable Land (AL): 13.6 million hectares

Ratio of AL/Population*: 0.33

Major crops:
- Grape
- Maize
- Wheat
- Sugar beet
- Potato

Commercialized Biotech Crops: Bt maize

Total area under biotech crops in 2008: 0.1 Million Hectares

Farm income gain from biotech, 1996-2007: US$60 million

*Ratio: % global arable land / % global population

Spain is the only country in the European Union to grow a substantial area of a biotech crop. Spain has grown Bt maize for eleven 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 13 biotech mega-countries globally growing 50,000 hectares or more of biotech crops. In 2008, the Bt maize area in Spain reached an all time peak of 79,269 hectares, which represents a 5.5% increase over 2007 and a 22% adoption of the total maize plantings of 358,500 hectares in 2008. The 2008 hectarage and percentage adoption is the highest on record and compares with 53,667 hectares at 15% adoption in 2006 and 53,226 hectares and a 13% adoption in 2005. The principal areas of Bt maize in Spain are in the provinces of Aragon (31,857 hectares) where the adoption rate for Bt maize is 54%, followed by Cataluña (25,298 hectares) with the highest adoption rate of 88%, with significantly less area of Bt maize in Extremadura (10,416 hectares), with an adoption rate of 17%, with the balance of Bt maize grown in eight other provinces in Spain in 2008 (Tables 25 and 26).

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.

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.

Table 25. Hectares of Biotech Bt Maize in the Autonomous Communities of Spain, 1998 to 2008

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

Source: Ministry of Agriculture, Spain, 2008.

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.

Benefits from Biotech Crops in Spain

Spain is estimated to have enhanced farm income from biotech Bt maize by US$60 million in the period 1998 to 2007 and the benefits for 2007 alone is estimated at US$21 million (Brookes and Barfoot, 2009, 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. Recent data from the Institute of Agro-Food Research and Technology (IRTA, 2008) 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.

Table 26. Hectares of Maize in Spain by Province, 2008

Province	Hectares
Castilla Y León	112,370
Extremadura	61,100
Aragón	58,641
Castilla-Mancha	32,562
Cataluña	28,762
Andalucía	25,071
Galicia	17,120
Navarra	13,946
Madrid	5,445
La Rioja	1,000
C. Valenciana	600
Camarias	550
Pais Vasco	468
P. De Asturias	300
R. De Murcia	297
Baleares	150
Cantabria	130
Spain Total	**358,512**

Source: Ministry of Agriculture, Spain, 2008.

CHILE

> **Chile grew a total of 36,000 hectares of biotech maize, soybean and canola, for seed exports in 2008.**

In 2008-09, Chile is projected to plant over 30,000 hectares of biotech maize, 4,200 hectares biotech soybean and 1,800 hectares of biotech canola for a total of 36,000 hectares for seed export; this is an increase of approximately 30% from the 28,000 hectares planted in 2007-08. There is legislation in Parliament to allow consumption of domestically grown biotech crops in Chile.

Chile has a population of approximately 16 million and a GDP of close to US$100 billion, 6% 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. Chile has been producing biotech seed for export since commercialization began in 1996 and this activity is fully covered by current law. Chile has clearly demonstrated over the last eleven 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 second 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 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 five years, almost doubling from 10,725 hectares in 2002/03 to 18,675 hectares in a 2006/07 (Table 27). Multiplication of biotech seed for export is now a significant business activity worth approximately US$500 million in 2008. Maize has always been the most important biotech seed crop grown in Chile and in 2008/09, it reached 30,000 hectares for the first time. The area of biotech canola for seed export in 2008/09 is estimated to increase to an all time high of 4,200 hectares and biotech soybean to 1,800 hectares. Thus, the total biotech crop area for export seed production in Chile in 2008/09 is over 35,000 hectares, the highest ever. The number of biotech seed crops

Table 27. Hectares of Major Biotech Seed Crops Grown for Export in Chile, 2002/03 to 2008/09

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

Source: Government of Chile statistics, SAG, 2008. *industry estimates

multiplied in Chile is now approximately 10 crops. The country has broad and diversified experience in successfully managing all aspects related to the growing of biotech crops for over 10 years.

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 28,000 hectares of biotech cotton in 2008, plus 4 hectares of biotech carnation.

In 2008, Colombia grew approximately 28,000 hectares of cotton, up 27% from the 22,000 hectares in 2007. Of the 28,000 hectares, notably 85% equivalent to 24,000 hectares were the stacked traits Bt and herbicide tolerance, up significantly from only 2,000 hectares in 2007. In 2008, 4,000 hectares were Bt and less than 1,000 hectares were herbicide tolerant. The cotton is planted in two seasons, 8,000 hectares were planted in the first season of 2008, and 20,000 hectares in the second season.

Colombia introduced Bt cotton in 2002 on approximately 2,000 hectares and in the interim this has increased consistently every single year to reach approximately 28,000 hectares in 2008, the highest adoption level since commercialization in 2002, with 85% of the biotech cotton deployed with the stacked genes for Bt and herbicide tolerance.

Biotech maize is not approved for commercialization in Colombia. However in 2008, Colombia, for the second 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 and TC5107 were planted in 2008 on a total of 15,000 hectares, up from 6,000 hectares in 2007. Approximately 7,000 hectares were planted in the first season and the balance of 8,000 hectares in the second season. The biotech maize hectarage grown in Colombia is not included in the global biotech data for 2008 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 2008 with 4 hectares planted in greenhouses near Bogota.

Benefits from Biotech Crops in Colombia

Colombia is estimated to have enhanced farm income from biotech cotton by US$11 million in the period 2002 to 2007 and the benefits for 2007 alone is estimated at US$3 million (Brookes and Barfoot, 2009, forthcoming).

HONDURAS

Honduras grew 9,000 hectares of biotech maize in 2008.

Honduras introduced herbicide tolerant maize in 2002 with a pre-commercial introductory area of approximately 500 hectares. In the interim, the biotech maize has increased to 9,000 hectares, up approximately 30% from 7,000 hectares in 2007. In 2008, the 9,000 comprises 7,000 hectares of the stacked Bt/HT maize and 2,000 hectares of herbicide tolerant maize. The national maize crop of Honduras is approximately 350,000 hectares. Honduras is the first country in Central America and the Caribbean to grow a biotech crop.

BURKINA FASO

In 2008, for the first time, approximately 8,500 hectares of Bt cotton were planted for seed production and initial commercialization in Burkina Faso. It is estimated that Bt cotton can generate an economic benefit of US$106 million per year for

Burkina Faso, based on yield increases of approximately 20% and a decreased need for insecticides.

Burkina Faso is a landlocked country of 27 million hectares located in West Africa. It has a French speaking population of 15 million and a GDP of approximately US$7 billion, of which almost 40% is contributed by agriculture. Burkina Faso is one of the poorest countries in the world, with a GDP per capita of US$1,300 per year. Burkina Faso is located in the Sahel which is the agricultural region between the Sahara Desert and the costal rain forests. The terrain is a savannah plateau at an altitude of 300 to 400 meters. Annual average rainfall is 100 centimeters in the South to 25 centimeters in the North. Agriculture provides up to 80% of national employment, and thus is the most important sector. The major crops are cotton planted to 600,000 to 700,000 hectares in 2006 and 2007 as a cash crop, and the food crops include millet, rice, peanuts, shea nuts and maize. The major export is cotton which accounts for more than 50% of total exports. Exports of cotton have ranged from 775,000 bales per year to 1.4 million bales. Drought, poor soil, insect pests and lack of infrastructure and financial resources pose significant challenges to development, which revolves around agriculture.

Cotton is the principal cash crop in Burkina Faso which is why it is often referred to as ‘white gold’ (Vognan *et al.,* 2002). Cotton generates annual revenues in the order of US$300 million or more, and represents over 60% of the country’s export earnings (ICAC, 2006). Cotton is “king” in Burkina Faso and touches the lives of 2.2 million people who earn all or part of their income from cotton (CARITAS, 2004; Elbehri and MacDonald, 2004). The rural economies in the cotton zones are founded on cotton (Bingen, 1998) with public services including schools, infrastructure, roads, public health and agricultural extension services supported by cotton revenues.

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 (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 where pest infestations are so high in non-traditional cotton growing areas where currently growing of conventional cotton with insecticides is unprofitable.

Burkina Faso planted approximately 475,000 hectares of cotton in 2008. Insect pests and drought are the two significant constraints to increased productivity. All the cotton is produced by small resource-poor subsistence farmers, similar to the situation in countries like China and India. Burkina Faso’s cotton production in 2006/07 was 1.3 million bales but this decreased to 0.68 million bales in 2007/08. Yield of cotton is low at approximately 367 kg per hectare, compared with 985 kg per hectare in the USA (Korves, 2008). The National Agricultural Research Institute (INERA) has been field testing Bt cotton since 2003 with excellent results. The Bt cotton varieties tested are well adapted to the environment, and have the following advantages: firstly the Bt cotton requires only two 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, this saving 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 is 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.

The Burkina Faso Government has approved two varieties of Bt cotton for seed production and commercialization in 2008. The Bt gene (Bollgard®II) from Monsanto was incorporated by INERA scientists and the evaluation for approval by Government was conducted by the National Bio-Security Agency of Burkina Faso. Royalties from the sale of Bt cotton seed will be shared with 72% given to Burkina Faso farmers and 28% to Monsanto. In 2008, for the first time approximately 8,500 hectares of Bt cotton were planted for seed production and initial commercialization in Burkina Faso. It is projected that in 2009 approximately 160,000 hectares of Bt cotton will be planted, which is equivalent to one-third of total cotton in Burkina Faso. This is a significant launch by any standard, and compares favorably with the earlier impressive Bt cotton launches in the USA, Australia, China, and India. The Bt cotton program initiated and expedited by the Government of Burkina Faso can serve as a model for many other developing countries growing cotton and is 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 so that their small resource-poor cotton farmers can also enjoy the benefits of their counterparts in Burkina Faso. It is noteworthy that the National Assembly of Mali passed a National Biosafety Law on November 13, 2008, (ISAAA, 2008) and that the vote tally was very supportive of the law with 108 in favor and 20 against.

Burkina Faso becomes the tenth country globally to benefit from Bt cotton. The other nine countries that have collectively and successfully commercialized over 81 million hectares of biotech cotton (Bt, HT and Bt/HT) in the twelve year period 1996 to 2007 are listed in decreasing order of cumulative biotech cotton hectares: USA (44 million hectares), China (22 million hectares), India (12 million hectares) and Australia (1-2 million hectares), with the balance of five countries Argentina, Brazil, Mexico, South Africa and Colombia each growing less than 1 million hectares.

Two recent papers report positively on the potential benefits of Bt cotton in Burkina Faso (Vitale *et al.,* 2008), and West Africa (Falck-Zepeda *et al.,* 2008). The first paper by Vitale *et al.* (2008) documents the economic impacts of second generation Bollgard®II Bt cotton in West Africa, based on empirical evidence from Burkina Faso; it estimates 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. The second paper by Falck-Zepeda *et al.* (2008) studied potential payoffs and economic risks of adopting transgenic cotton in five countries in west Africa, Benin, Burkina Faso, Mali, Senegal and Togo. The paper concluded that “Bt technology needs to be adopted, if only 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 are worse off economically by not adopting Bt cotton.”

A paper from the World Bank (WPS3197) (Anderson *et al.,* 2006), concluded that unlike the situation with the Cotton Initiative in the WTO’s Doha Round of discussions, 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. Developing countries which have elected to continue growing conventional cotton, as opposed to Bt cotton, have the option and authority to approve and adopt Bt cotton and benefit from the significant benefits it offers, which the study claims are greater than the potential benefits from the removal of all subsidies and tariffs that is sought under the Doha Round. Furthermore, the study concludes that the gains from the Doha Round would be greater if cotton-growing developing countries adopted Bt cotton. Thus, the onus is on Governments of potentially beneficiary cotton-growing developing countries to exercise their authority and responsibility to appraise, approve and adopt Bt cotton at the earliest opportunity; fortunately this can be greatly facilitated and accelerated today by learning from the wealth of knowledge and experience of the nine countries, six of them developing, which have tested, and benefited significantly from this proven technology over the last decade. Bt cotton is no longer the “new” technology with a potential risk that it was ten years ago – now the greater risk for cotton-growing developing countries, particularly countries that are principally dependent on cotton as their major or only source of income and foreign exchange, is to consciously elect not to use the technology.

CZECH REPUBLIC (CZECHIA)

In 2008, the Czech Republic grew 8,380 hectares of biotech maize.

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. Czechia grew 288,000 hectares of maize in 2008 of which 180,000 hectares were for silage and 108,000 hectares for grain, so the potential for biotech maize 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 estimates that up to 90,000 hectares are infested with European corn borer (ECB), and that up to 30,000 hectares are being sprayed with insecticide for control of 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.

ROMANIA

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. 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.

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. If, 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 and 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. 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 when it is eventually approved for planting in the EU, thus it is appropriate to report on Romania and RR®soybean. Romania is the third largest producer of soybean in Europe, after Italy and Serbia Montenegro, and ranks equal third with France 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 range 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 has been taken by the Romanian Government, prompted by the European Union, to discontinue cultivation of biotech soybean as of January 2007 to facilitate membership in the EU, where RR®soybean has not been approved for planting. Many observers and Romanian farmers believe there are 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. Given that use of RR®soybean also results in better weed control in the crops following it in the rotation, elimination of RR®soybean will lead to higher cost of weed control and more use of herbicides for all other crops following it in the rotation, with negative implications for the environment because of more applications of alternative herbicides, which will also erode profitability. Preclusion of RR®soybean legal plantings in Romania will reduce national production by up to one third which can only be compensated with imports that will likely be RR®soybean and imports 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 is 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 and 2008. Romania is by far 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 in 2007.

Benefits from Biotech Crops 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 by US$93 million in the period 2001 to 2006 and the benefits for 2006 alone is estimated at US$29 million (Brookes and Barfoot, 2008, forthcoming). Romania had to stop growing RR®soybean when it became an EU member country in January 2007.

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" (Buzdugan, 2006).

PORTUGAL

In 2008, Portugal planted 4,851 hectares of Bt maize, a 14% increase over 2007.

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 2008, Portugal planted 4,851 hectares of Bt maize, a 14% increase over 2007 when 4,263 hectares were planted. The increase in 2008 followed a two and a half fold increase to 4,263 hectares in 2007 from the 1,250 hectares planted in 2006. 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.

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 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 in 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"*** (Rasquilla, 2006).

GERMANY

The area of officially approved commercial Bt maize in Germany in 2008 was 3,173 hectares, up 18% from the 2,685 hectares planted in 2007.

Germany has officially grown a small hectarage, from 300 to 500 hectares of Bt maize commercially for the last eight years, starting in 2000; Bt176 was used until 2003 when MON810 was introduced. The area of officially approved commercial Bt maize in Germany in 2008 was 3,173 hectares, up 18% from the 2,685 hectares planted in 2007. The regulation governing the planting of this token area of biotech maize is as follows. Given that Germany does not allow the sale of biotech seeds for unlimited planting, seed companies can apply for special permits annually to supply a limited amount of biotech seed. For maize, the limit is 0.1% of any registered variety. To preclude any liability related to the cultivation of this small area of Bt maize in Germany, the milling company Maerka Kraftfutter has voluntarily agreed to purchase, at market prices, all the maize grain from any field within 500 meters of a biotech maize field. In 2004, detailed monitoring of biotech maize fields in Germany confirmed that maize samples taken more than 20 meters from biotech maize had less than the 0.9% threshold for biotech content. In early 2005, Germany introduced the first elements of a Genetech Law, which covers coexistence and liability; the Law has been heavily criticized because it is so restrictive leaving no incentive, but significant disincentive for farmers to adopt Bt maize in Germany.

Benefits from Biotech Crop in Germany

The areas infested by European corn borer (ECB) in Germany are in the North Rhine, Westphalia, Saxony and Brandenburg regions. It is estimated that the infested area in these regions would benefit significantly from Bt maize, whereas most of the Northern states do not suffer from ECB. An estimated 18% of the 300,000 hectare maize crop could benefit from Bt maize. Given that measured yield gains due to Bt maize were of the order of 12 to 14% the average gain per hectare from Bt maize is US$150 per hectare, the gain on 55,000 hectares at the national level for Germany would be in the order of increase of US$8.25 million per year.

POLAND

The hectarage planted to Bt maize in Poland in 2008 increased more than 8-fold to 3,000 hectares.

Poland has a population of approximately 38.5 million and a GDP (nominal) of US$413 billion, 3% of which is generated from agriculture equivalent to US$12 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 a total of 670,000 hectares of maize grown in Poland in 2008 – 350,000 hectares or 52% was used for grain and 48% or 320,000 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, can cost US$35 per hectare.

Some pre-commercial Bt maize was planted in Poland in 2006 on approximately 100 hectares. 2007 was the first time for Poland to commercialize Bt maize 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. 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. One Bt yellow maize is being used in Poland for animal feed and/or for ethanol production.

Benefits from Bt Maize in Poland

In the 2007 report entitled "The benefits of adopting genetically modified maize in the European Union; first results form 1998 to 2006 plantings," Graham Brookes (Personal Communication, 2008) reported that benefits from Bt maize based on trials conducted in 2006 were on average approximately 25%, equivalent to an increase of 2.15 tons/ha gross margin of using Bt over conventional maize. 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 44 to 103 ppm in conventional maize to 0 to 8 ppm in Bt maize.

SLOVAKIA

In 2008, Slovakia increased its Bt maize area by over 100% to 1,900 hectares.

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 has again increased by over 111% to 1,900 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 Crop in Slovakia

It is estimated that from a third to a half of the 240,000 hectares of maize in Slovakia is infested with ECB 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.

EGYPT

In 2008, Egypt became the first country in the Arab world to commercialize biotech crops, by planting 700 hectares of a hybrid Bt yellow maize.

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 levels 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 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 rate of population growth 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 the biotic stresses caused by viruses, insect, fungal pests and nematodes, and tolerance to the abiotic stresses of 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 institutions internationally. 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 deregulating the biotech 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.

THE EUROPEAN UNION (EU 27)

In 2008, the total hectarage for the seven EU countries growing Bt maize increased from 88,673 hectares in 2007 to 107,719 hectares in 2008; this is equivalent to a year-on-year increase of 19,046 hectares equivalent to a significant 21% between 2007 and 2008. The seven EU countries growing Bt maize in 2008 are listed in descending order of Bt maize hectarage – Spain, Czech Republic, Romania, Portugal, Germany, Poland and Slovakia. It is noteworthy that each of the seven countries increased their hectarage in 2008 over 2007 with increases in individual countries from 5% in Spain to a 1,942% increase in Romania.

The European Union comprises 27 states, a population of almost 500 million (7% of global) with a GDP in 2007 of US$16.8 trillion, equivalent to 30% 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).

In 2008, of the 27 countries in the European Union, seven officially planted Bt maize on a commercial basis. It is noteworthy that the total hectarage for the seven countries increased from 88,673 hectares in 2007 to 107,719 hectares in 2008; this is equivalent to a year-on-year increase of 19,046 hectares

Table 28. Hectares of Bt Maize Planted in the Seven EU Countries, 2006 to 2008

Country	2006	2007	2008	Increase 2007/2008	%
1. Spain	53,667	75,148	79,269	4,121	5%
2. Czechia	1,290	5,000	8,380	3,380	68%
3. Romania*	--	350	7,146	6,796	1,942%
4. Portugal	1,250	4,263	4,851	588	14%
5. Germany	950	2,685	3,173	488	18%
6. Poland	100	327	3,000	2,673	817%
7. Slovakia	30	900	1,900	1,000	111%
Total	**57,287**	**88,673**	**107,719**	**19,046**	**21%**

*Romania grew 145,000 hectares of RR®soybean in 2006 but had to cease growing it after becoming an EU member in January 2007.
France suspended Bt maize in 2008 after growing it from 1998 to 2000 and 2005 to 2007
Source: Clive James, 2008.

equivalent to a significant 21% between 2007 and 2008. Table 28 summarizes the planting of Bt maize in the seven countries of the European Union in 2006, 2007 and 2008. The seven countries listed in order of biotech hectarage of Bt maize are Spain, Czech Republic, Romania, Portugal, Germany, Poland and Slovakia. It is noteworthy that each of the seven countries increased their hectarage in 2008 over 2007 with increases in individual countries from 5% in Spain to a 1,942% increase in Romania (Table 28). All seven countries grow Bt maize commercially which provides significant benefits to farmers, to the environment and a more affordable feed source for animals, which in turn benefits consumers who eat meat. The group of seven countries is led by Spain, which was the first country to commercialize Bt maize in 1998 when 22,137 hectares were planted.

Thus, 2008 marks the second year for over 100,000 hectares to be planted in the EU, despite the fact that France suspended Bt maize in 2008 and that Romania, which grew over 145,000 hectares of RR®soybean in 2006 but had to discontinue growing RR®soybean on becoming an EU member in January 2007 because unlike Bt maize, RR®soybean has not yet been approved for planting in the EU. In October 2007, France suspended the commercial planting of Bt maize pending completion of a government review, which resulted in no Bt maize planted in France in 2008, much to the dismay of French farmers who had used and benefited from the technology in 2007. The EU commissioner for agriculture has commented that a full ban on biotech crops would be in contravention of the law and that France would lose in court if it implemented such a ban. In November 2008, Reuters reported that "the European Food Safety Authority (EFSA) said on October 31 that France's ban on the genetically modified (GM) maize variety MON 810 is unjustified" (Reuters, 1 Nov. 2008).

EFSA states, 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." Diplomats say that the European Commission will now consider the EFSA's opinion and will very likely order France to lift its ban, the article reports. France is the EU's biggest agricultural producer. Polls show that the vast majority of French people are opposed to GM crops, according to the article (EFSA, 2008).

In 2001, the European Commission published a report (EU, 2001) on the safety of biotech crops and food. The report reviewed research conducted over a 15 year period, involving 81 projects and over 400 scientists and concluded that: "GM plants have not shown any new risks to human health or the environment, beyond the usual uncertainties of conventional plant breeding. Indeed, the use of more precise technology and greater regulatory scrutiny probably make them safer than conventional plants and food."

A later 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."***

In October 2007, the EU Commission approved three biotech maize varieties (TC1507xNK603) with insect resistance and herbicide tolerance; NK603 x MON810 with herbicide tolerance and insect resistance; and 59122 Herculex RW with resistance to the root worm pest of maize for import for feed and food use, and processing. A biotech sugar beet (H7-1) was also an approved import for food/feed use. All four of the products had been previously cleared with positive safety assessments by EFSA and endorsed by the EU approval process. The products are approved for the usual 10 year period. As in the past the EU Member States failed to register a qualified majority against or in favor in the Standing Committee, and in Council, resulting in the files being sent back to the Commission for a decision.

It is noteworthy that in September 2008, LibertyLink®A2704 herbicide tolerant soybean received final clearance for import into the EU for use as food and feed. A commercial launch is planned for 2009. The product has already been fully approved for use as food, feed, and cultivation in the USA and Canada. Import approvals have also been granted in Australia, China, Japan, Mexico, New Zealand, Russia, South Africa and Taiwan. LibertyLink®soybean is tolerant to the herbicide Ignite. The American Seed Association noted that farmers will now have an additional weed control option to RR®soybean and hence provides an effective management tool to minimize the selection for herbicide resistant weeds which will contribute to a more sustainable soybean production.

Table 29. GMO Crop Approvals for Import by the European Union, 2007-2008.

Crop	Trait	Event	Company	Import Approval for	Date Approved
Rapeseed	Male Ster/ HT	MS8 × RF3	Bayer CropScience	Processing	March 26, 2007
Maize	IR/HT	DAS 59122-7	Dow AgroSciences/ Pioneer Hi-bred	Food/Feed and Processing	Oct. 24, 2007
Maize	IR/HT	DAS1507 × Mon 810	Pioneer Hi-bred/ Mycogen Seeds	Food/Feed and Processing	Oct. 24, 2007
Maize	IR/HT	NK603 ×Mon 810	Monsanto Co.	Food/Feed	Oct. 24, 2007
Maize	HT	GA21	Monsanto Co.	Food/Feed and Processing	March 28, 2008
Soybean	HT	A2704-12	Bayer Crop Science	Food/Feed and Processing	Sept. 8, 2008
Cotton	HT	LL 25	Bayer Crop Science	Food/ Feed and Processing	Sept. 29, 2008
Sugarbeet	HT	H7-1	KWS SAAT AG/ Monsanto	Food/Feed	Oct. 24, 2008
Soybean	HT	RR2 MON 89788	Monsanto Co	Food/Feed and Processing	Dec. 4, 2008

Source: GMO Compass Database, 2008.

The events approved in the EU for imports (not planting) in 2007 and 2008 are summarized in Table 29.

Sir David King, the UK Government's Chief Scientific Adviser, who finished his term in December 2007 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 recent 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 sugar beet alone could generate annual gains in the order of US$1 billion per year for the EU.

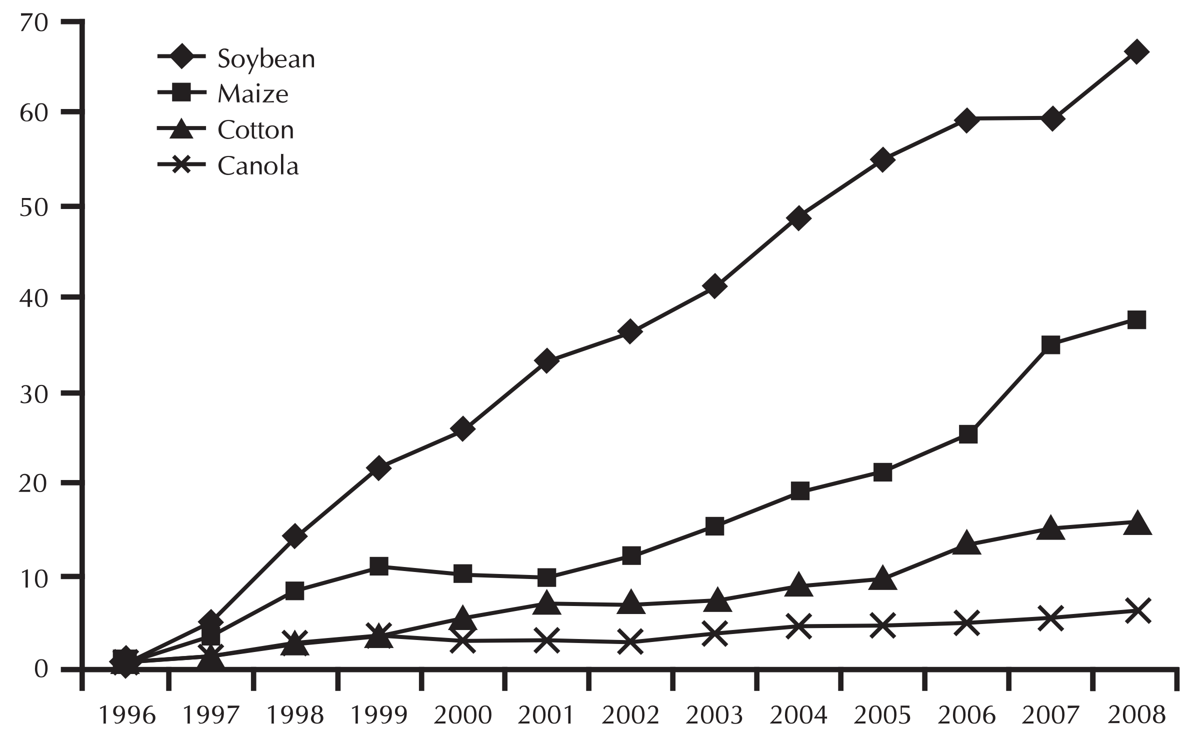
Some observers were of the opinion that the EU could have faced a problem with biotech feed had RR2 not been approved for import to the EU on 4 December 2008. Given that the USA, Argentina and Brazil were planning to adopt the new higher yielding RR2 soybean in an asynchronous mode versus the EU, this could have caused a problem. RR2 was approved by China in September 2008. On September 29, 2008, the EU failed to approve the soybean event named MON 89788 thus leaving it for the ministers to decide. On 20 November, 2008, Ministers 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. The MON 89788 RR soybean application then returned to the European Commission, and was approved by default, on 4 December 2008.

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 only be 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 is estimated that meat production could fall by up to 35% and 44% respectively, and the price of non-biotech soybean could escalate in the market place.

Distribution of Biotech Crops, by Crop

The distribution of the global biotech crop area for the four major crops is illustrated in Figure 23 and Table 30 for the period 1996 to 2008. It clearly shows the continuing dominance of biotech soybean occupying 53% of the global area of global biotech crops in 2008; the entire biotech soybean hectarage is herbicide tolerant RR®soybean. Biotech soybean retained its position in 2008 as the biotech crop occupying the largest area globally, occupying 65.9 million hectares in 2008, 13% higher than 2007; soybean also had the top year-to-year growth rate for any biotech crop at 13%. Biotech maize had the second highest area at 37.3 million hectares. Biotech cotton reached 15.5 million hectares in 2008 and grew at the third highest rate of 3% between 2007 and 2008 mainly due to the 1.4 million hectare increase in India in 2008, offset by a decrease of 750,000 million hectare in the USA. Sugar beet is an important new biotech crop in the USA in 2008 and occupied approximately 0.3 million hectares, which is equivalent to a very high adoption of 59% in its first-year launch. Canola grew at the second highest rate of 7% between 2007 and 2008, and has the lowest absolute area of the four-biotech crops at 5.9 million hectares grown in Canada and the USA. RR®alfalfa, first grown in 2006, occupied 102,000 hectares equivalent to approximately

Figure 23. Global Area of Biotech Crops, 1996 to 2008: by Crop (Million Hectares)



Source: Clive James, 2008.

Table 30. Global Area of Biotech Crops, 2007 and 2008: by Crop (Million Hectares)

	2007	%	2008	%	+/-	%
Soybean	58.6	51	65.8	53	7.3	+13
Maize	35.2	31	37.3	30	2.1	+6
Cotton	15.0	13	15.5	12	0.5	+3
Canola	5.5	5	5.9	5	0.4	+7
Sugar beet	--	--	0.3	<1	0.3	--
Alfalfa	<0.1	<1	0.1	<1	--	--
Papaya	<0.1	<1	<0.1	<1	<0.1	--
Others	<0.1	<1	<0.1	<1	<0.1	--
Total	**114.3**	**100**	**125.0**	**100**	**+12.3**	**+9.4**

Source: Clive James, 2008.

5% of the 1.3 million hectare seeded in the USA in 2008, with no further planting taking place 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 virus resistant papaya is also grown on approximately 3,550 hectares in China which also grows about 400 hectares of Bt poplar.

Distribution of economic benefits for the four major biotech crops for the first 12 years of commercialization 1996 to 2007 were as follows: herbicide tolerant soybean US$21.8 billion, Bt cotton US$12.7 billion, Bt maize US$5.4 billion, herbicide tolerant canola US$1.8 billion, herbicide tolerant maize US$1.5 billion, herbicide tolerant cotton US$0.8 billion, and the balance in virus resistant papaya and squash for a total of approximately US$44 billion (Brookes and Barfoot, 2009, forthcoming).

Distribution of economic benefits for the major biotech crops for 2007 only were as follows: herbicide tolerant soybean US$4.0 billion, Bt cotton US$3.3 billion, Bt maize US$2.1 billion, herbicide tolerant maize US$0.4 billion, herbicide tolerant canola US$0.4 billion, herbicide tolerant cotton <US$0.1 billion for a total of US$10.2 billion (Brookes and Barfoot, 2009, forthcoming).

Biotech soybean

In 2008, the global hectarage of herbicide tolerant soybean was 65.8 million hectares, up significantly by 7.3 million hectares from 2007 at 58.6 million hectares. The significant increases resulted from the following significant changes at the country level. First, the largest increase by far, equivalent to 41% of the global biotech crop hectarage in 2008, was in the USA at 4.4 million hectares of soybean planting; this was the largest reported increase for any biotech crop in any country in 2008. Secondly, a significant increase of 2.2 million hectares in Argentina which was expected to plant an all time record hectarage of soybean at 18.1 million hectare which is virtually 100% RR® biotech. Thirdly, there was a substantial first time hectarage of 600,000 hectares in Bolivia. Lastly, modest increases in three countries including Canada (0.2 million hectares), and a 100,000 hectare increase in each of Uruguay and Paraguay. These five significant increases were offset by a 2% decrease in Brazil equivalent to 300,000 hectares. The 65.8 million hectares of biotech soybean worldwide is equivalent to 70% of the global 95 million hectares of soybean. In Brazil in 2008, 65% of the 21.9 million hectare soybean crop was estimated to be RR®soybean, up from 64% in 2007. In the USA, herbicide tolerant soybean hectarage in 2008 occupied 28.6 million hectares of the 30.2 million hectare crop. In Argentina, continued growth is projected to result in 18.1 million hectares in 2008, up significantly from 15.9 million hectares in 2007; virtually all the Argentinean national soybean hectarage is planted with herbicide tolerant soybean. Paraguay reported 2.6 million hectares of herbicide tolerant soybean in 2007 and this area increased in 2008 to 2.7 million hectares, equivalent to a 95% adoption of the 2.8 million hectare crop, up from 93% in 2007. Canada planted about 75% of its national soybean hectarage of 1.2 million hectares with herbicide tolerant soybean in 2008. Uruguay's herbicide tolerant soybean continued to occupy

100% of the national soybean hectarage of 575,000 hectares in 2008. South Africa biotech soybean hectarage increased to approximately 184,000 hectares in 2008 compared with 145,000 hectares in 2007. Mexico increased its hectarage of RR®soybean slightly from 4,000 hectares in 2007 to 10,000 hectares in 2008. Of the global hectarage of 95 million hectares grown in 2008, an impressive 70% or 65.8 million hectares were RR®soybean. Biotech soybean is grown in 10 of the 25 biotech crop countries worldwide.

The increase in income benefits for farmers growing biotech soybean during the twelve year period 1996 to 2007 was US$21.8 billion and for 2007 alone, US$4.0 billion (Brookes and Barfoot, 2009, forthcoming).

Biotech maize

In 2008, biotech maize increased by 6% or 2.1 million hectares to 37.3 from 35.2 million hectares in 2007. It is noteworthy that of the 18 countries growing biotech maize in 2008 there were increases in every single country, except Argentina which reported a decrease associated with a reduction in total maize plantings. The largest increase in any country in 2008 is in Brazil, which is expected to plant 1.3 million hectares of Bt maize for the first time in two seasons. Approximately 40% of the 1.3 million hectares is planted in the summer season, and 60% in the safra season with planting starting in December 2008 and continuing through to 2009; note that the second season safra crop is classified as a 2008 crop given that planting begins in December 2008. Despite lower total plantings of maize in the USA in 2008, the increased adoption rate resulted in an increase of over 900,000 hectares of biotech maize. An important feature of biotech maize in the USA in 2008 was stacking which will be discussed in the section on traits. Modest increases were reported by the other 16 countries growing Bt maize in 2008 with only one country, Argentina, reporting a decrease as previously discussed.

An increase of 21% was reported for all seven EU countries, which grew Bt maize in 2008. Of the global hectarage of 157 million hectares of maize grown in 2008, almost a quarter, 24% or 37.3 million hectares, were biotech maize and grown in 17 of the 25 biotech crop countries worldwide.

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, the increased usage of customized maize for ethanol production, which consumed 29% of maize in the USA in 2008, up from 24% in 2007, is expected to increase to 41% by 2015.

The increase in income benefits for farmers growing biotech maize during the 12 years (1996 to 2007) was US$7.0 billion and US$2.4 billion for 2007 alone (Brookes and Barfoot, 2009, forthcoming).

Biotech cotton

The area planted to biotech cotton globally in 2008 was up by 0.5 million hectares, equivalent to a 3% growth over 2007, reaching 15.5 million hectares globally and equivalent to 46% of the global area of 34 million hectares in 2008. Most of the growth was in India (1.4 million hectares), followed with a modest increase in Australia (87,000 hectares), with small increases in Mexico, Colombia and South Africa, whilst there was no change in China. The largest decrease (0.730 million hectares) was in the USA, with a significant decrease in Brazil and a small decrease in Argentina. These decreases in biotech cotton are consistent with reports that world cotton hectarage decreased by 6% in 2008 as a result of lower prices relative to other major crops, including soybean and maize, increased cost of inputs particularly fertilizer and pesticides. Significant declines in hectarage were reported for the USA (14% reduction in hectares), Brazil (10%), India (4%), and Pakistan (3%). The USA recorded the biggest percentage drop with plantings of upland cotton at 3.66 million hectares in 2008, approximately 15% down from the 4.2 million hectares planted in 2007, the lowest hectarage since 1989. In September 2008, the ICAC provided a global overview for the 2008/09 season and noted that, "Cotton prices fell sharply in September, affected by the crisis in the U.S. financial system." The Cotlook A Index dropped from 78 cents per pound on September 1 to 68 cents per pound on September 30. World cotton production is expected to decline by 6% to 24.7 million tons in 2008/09, due mainly to competition from alternative crops. The production drop is driven by the United States, but the 2008/09 crops are also expected to be smaller in Turkey, Brazil and Egypt. Cotton production is projected to increase in Australia and Pakistan. World cotton mill use is expected to decline by 1% in 2008/09 to 26.0 million tons, due to slower global economic growth and higher prices of cotton relative to polyester. World imports are forecast to be almost stable, at 8.4 million tons. In spite of lower U.S. production, large accumulated stocks could maintain U.S. exports around 3 million tons.

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 2008. It is marketed as a single gene and also as a stacked product with insect resistance in Bollgard®II. Biotech cotton hectarage in China was 3.8 million hectares, the same as in 2007 with an adoption rate of 68% compared with 69% in 2007. It is estimated that in 2008, 7.1 million small resource-poor farmers planted and benefited from Bt cotton in China, farming, on average, approximately one-half hectare. Notably, the public sector in China has invested significantly in crop biotechnology and has developed Bt cotton varieties that share the market with varieties developed by the international private sector. The simultaneous marketing of biotech crops from the public and private sectors is unique to China at this time but is expected to also become more prevalent in India as biotech crops are developed by government supported public sector institutions. It is notable that in 2008, the biotech cotton area in India again exceeded the Bt cotton in China. In 2008, biotech hybrid cotton in India, the largest cotton growing country in the world, occupied 7.6 million hectares of approved Bt cotton increasing by an impressive 23% gain between 2007 and 2008, despite almost optimal levels of adoption which reached 82% in 2008. The advantages of Bt cotton hybrid in India are significant and a substantial increase is projected again for 2008 due to significant gains in production, economic, environmental, health and social benefits. Notably, Burkina Faso grew 8,500 hectares of Bt cotton (Bollgard®II) for the first time in 2008 and hopes to increase this area to more than 150,000 hectares in 2009.

Of the global hectarage of 35 million hectares of cotton grown in 2008, almost one half, 46% or 15.5 million hectares were biotech cotton and grown in 10 of the 25 biotech crop countries worldwide.

The increase in income benefits for farmers growing biotech cotton during the twelve year period 1996 to 2007 was US$13.6 billion and US$3.3 billion for 2007 alone (Brookes and Barfoot, 2009, forthcoming).

Biotech canola

The global area of biotech canola in 2008 is estimated to have increased by a modest 0.4 million hectares, from 5.5 million hectares in 2007 to an estimated 5.9 million hectares in 2008. There was a significant increase of over 350,000 hectares in Canada whereas there was no change in the area of biotech canola in the USA. Notably, Australia grew approximately 10,000 hectares herbicide tolerant biotech canola for the first time after a protracted debate at the national level (Table 24). In Canada, by far the largest grower of canola globally, the adoption of herbicide tolerant canola has consistently increased reaching 86% in 2008 with only 1% of the crop now conventional, compared with 2% in 2007; the balance of 13% is made up of a product developed through mutagenesis rather than biotechnology. Only three countries currently grow biotech canola, Canada, the USA, and Australia, but the global acreage and prevalence could increase significantly in the near term in response to the likely increased use of canola for biodiesel. Less than 1% of the canola crop in Canada was used for biodiesel in 2008 and this is expected to increase as high as 2% in 2012 when new biodiesel plants come on stream.

Of the global hectarage of 30 million hectares of canola grown in 2008, 20%, or 5.9 million hectares were biotech canola grown in Canada, the USA and Australia.

The increase in income benefits for farmers growing biotech canola during the twelve year period 1996 to 2007 was US$1.8 billion and US$0.4 billion for 2007 alone (Brookes and Barfoot, 2009, 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 October 2008, resumption of RR®alfalfa plantings was pending subject to a decision by the regulatory authorities in the USA.

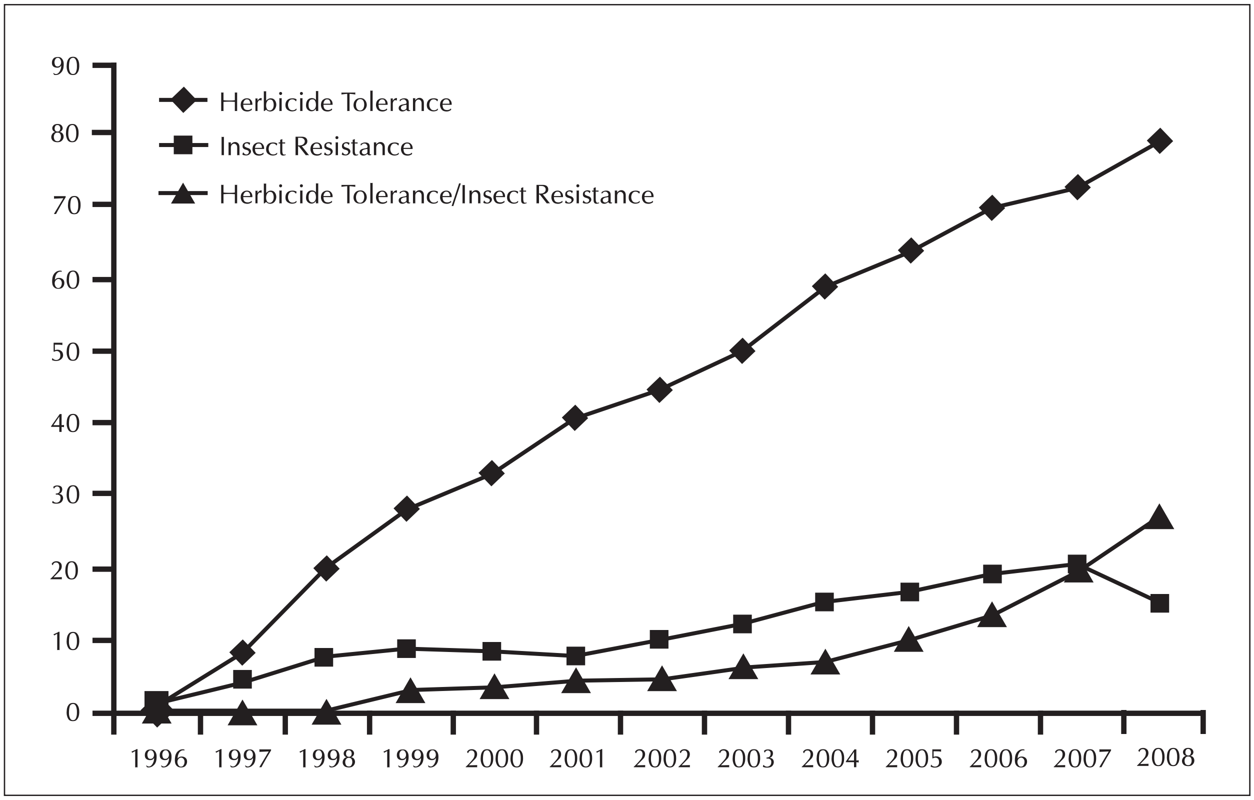
Other biotech crops

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, there were approximately 4,500 hectares of PRSV resistant papaya and 400 hectares of Bt poplars, with 20,000 seedlings prepared for planting in 2009.

Distribution of Biotech Crops, by Trait

During the thirteen year period 1996 to 2008, herbicide tolerance has consistently been the dominant trait (Figure 24). In 2008, herbicide tolerance, deployed in soybean, maize, canola, cotton, sugar beet and alfalfa occupied 79.0 million hectares or 63% of the 125 million hectares of biotech crops planted globally (Table 31); this compares with 72.2 million hectares equivalent to 63% in 2007. RR®Flex cotton, introduced in a significant launch in the USA and Australia for the first time in 2006, continued to grow in 2008. It is noteworthy that an entirely new herbicide tolerant crop, RR®sugar beet was grown for the first time in the USA in 2008. In contrast to the 72.2 million hectares of herbicide tolerant crops, there was much less Bt maize and cotton crops, 19.1 million hectares, but the fast-growing category was the stacked traits which reached 26.9 million hectares in 2008, up from 21.8 million hectares in 2007. Biotech crops with Bt genes occupied 15% of the global biotech area in 2008, compared with 22% 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 31). It is significant that the stacked traits in maize and cotton increased by a substantial 23% in 2008 (Table 31), the highest of all trait categories. The increase of stacked traits in maize, was over 170% between 2006 and 2008 increasing from 9.0 million hectares in 2006 to over 24 million hectares in 2008. This significant increase in stacked traits in maize reflects the needs of farmers who have to simultaneously address the multiple yield constraints associated with various 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.

Figure 24. Global Area of Biotech Crops, 1996 to 2008: by Trait (Million Hectares)



Source: Clive James, 2008.

Table 31. Global Area of Biotech Crops, 2007 and 2008: by Trait (Million Hectares)

Trait	2007	%	2008	%	+/-	%
Herbicide tolerance	72.2	63	79.0	63	+6.8	+9
Stacked traits	21.8	19	26.9	22	+5.1	+23
Insect resistance (Bt)	20.3	18	19.1	15	-1.2	-6
Virus resistance/Other	<0.1	<1	<0.1	<1	<0.1	<1
Total	**114.3**	**100**	**125.0**	**100**	**+10.7**	**+9.4**

Source: Clive James, 2008.

The deployment of stacked traits of Bt and herbicide tolerance is becoming increasingly important and is most prevalent in the USA with 102.6 million "trait hectares" in 2008, compared with only 87.1 million hectares planted, equivalent to an 18% year-on-year growth. Globally, the USA has by far the largest area of stacked traits at 25.5 million hectares, equivalent to 95% of global, with the other eleven countries collectively planting approximately 1.4 million hectares of stacked traits and reporting the following hectarages: Canada (0.4 million hectares), South Africa (0.3 million hectares), Argentina (0.2 million hectares), Philippines (0.2 million hectares), Australia (0.1 million hectares), with Mexico, South Africa, 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. 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 on 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.

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 2008. 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 32 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 gaining 20% to occupy almost half, 48%, of all biotech maize in the USA. Canada was the only other country to plant approximately 50,000 hectares of the maize triple stack in 2008. In the USA in 2008, 75% of

Table 32. Adoption of Single, Double and Triple Stacked Traits in Biotech Maize in the USA in 2007 and 2008

Trait	2007	2008	Change in 2008 +/-
Single	37%	22%	- 15%
Double	35%	30%	- 5%
Triple	28%	48%	+ 20%

Source: Compiled by Clive James, 2008.

biotech cotton featured the stacked traits for insect resistance and herbicide tolerance. In Australia in 2008, 87% of the biotech cotton had stacked traits for insect resistance and herbicide tolerance.

Distribution of economic benefits at the farm level by trait, for the first twelve years of commercialization of biotech crops 1996 to 2007 was as follows: herbicide tolerant soybean US$21.8 billion, Bt cotton US$12.7 billion, insect resistant maize US$5.5 billion, herbicide tolerant canola US$1.8 billion, herbicide tolerant maize US$1.5 billion, and herbicide tolerant cotton US$848 million, for a total of approximately US$44.4 billion (Brookes and Barfoot, 2009, forthcoming). For 2007 alone, the benefits were as follows: herbicide tolerant soybean US$4.0 billion, Bt cotton US$3.3 billion, insect resistant maize US$2.0 billion, herbicide tolerant canola US$0.4 billion, herbicide tolerant maize US$0.4 billion, and herbicide tolerant cotton US$25 million, for a total of approximately US$10.2 billion (Brookes and Barfoot, 2009, forthcoming).

Dominant Biotech Crops in 2008

Herbicide tolerant soybean continued to be the dominant biotech crop grown commercially in ten countries in 2008; listed in order of hectarage, the ten countries were: USA, Argentina, Brazil, Paraguay, Canada, Bolivia, Uruguay, South Africa, Mexico and Chile. Globally, herbicide tolerant soybean occupied 65.8 million hectares, representing 53% of the global biotech crop area of 125 million hectares for all crops (Table 33). The second most dominant biotech crop was maize with

Table 33. Dominant Biotech Crops in 2008 (Million Hectares)

Crop	2007	2008	% Biotech in 2008
Herbicide tolerant Soybean	58.6	65.8	53
Stacked traits Maize	18.8	24.5	20
Bt Cotton	10.8	11.9	9
Bt Maize	9.3	7.1	6
Herbicide tolerant Canola	5.5	5.9	5
Herbicide tolerant Maize	7.0	5.7	4
Stacked traits Cotton	3.2	2.6	2
Herbicide tolerant Cotton	1.1	1.0	1
Herbicide tolerant Sugar beet	--	0.3	<1
Herbicide tolerant Alfalfa	0.1	0.1	<1
Others	<0.1	<0.1	<1
Total	**114.3**	**125.0**	**100%**

Source: Clive James, 2008.

stacked traits, which occupied 24.5 million hectares, and equivalent to 20% 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. It is noteworthy that maize with stacked traits occupied a total of 24.5 million hectares compared with 18.8 million hectares in 2007, a year-to-year substantial increase of 30% – the highest for any biotech crop, which reflects the large increase of maize with stacked traits in the USA in 2008. The third most dominant crop was Bt cotton, which occupied 11.9 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 7.1 million hectares, equivalent to 6% of global biotech area and was planted in 16 countries in descending order of hectarage – Argentina, USA, Brazil, South Africa, Uruguay, Canada, the Philippines, Spain, Czech Republic, Romania, Chile, Portugal, Germany, Poland, Slovakia and Egypt. The fifth most dominant crop was herbicide tolerant canola, occupying 5.9 million hectares, 11% more area in 2008 than 2007 and planted in Canada, the USA, Australia and Chile. The sixth most dominant crop was herbicide tolerant maize occupying 5.7 million hectares, equivalent to 5% of global biotech crop area and planted in seven countries – the USA, South Africa, Argentina, Canada, the Philippines, Honduras, 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 three other crops listed in Table 33 occupied 1% or less of global biotech crop area and include, in descending order of area: herbicide tolerant cotton grown in the USA, Argentina, Australia, Mexico, South Africa and Colombia on 1.0 million hectares, herbicide tolerant sugar beet grown on 0.3 million hectares in the USA and Canada in 2008; herbicide tolerant alfalfa grown on 0.1 million hectares in the USA in 2008. The “Others” category, with a total of less than 1000 hectares, includes virus resistant papaya and squash in the USA, Bt poplars and biotech papaya, sweet pepper and tomato in China.

Global Adoption of Biotech Soybean, Maize, Cotton and Canola

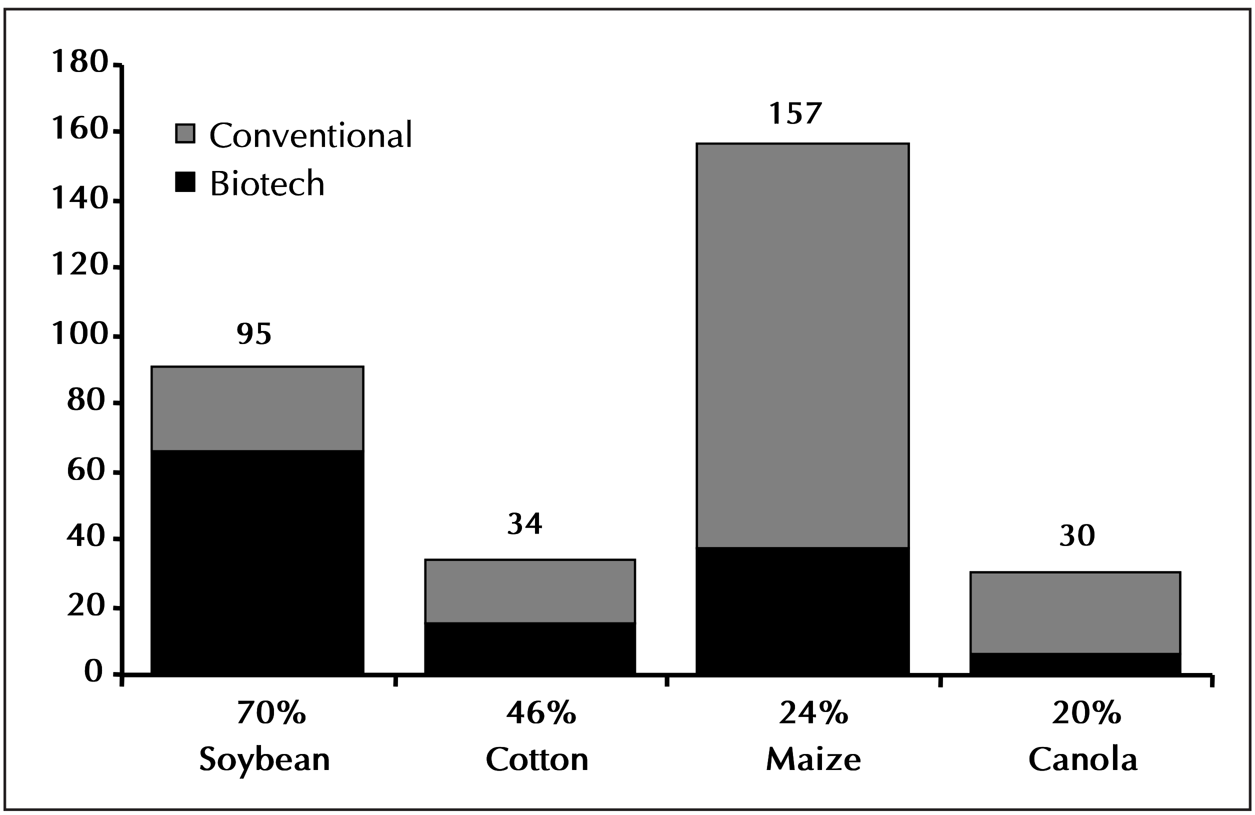
Another way to provide a global perspective of the status of biotech crops is to characterize the global adoption rates as a percentage of the respective global areas of the four principal crops – soybean, cotton, maize and canola – in which biotechnology is utilized (Table 34 and Figure 25). The data indicate that in 2008, 70% of the 95 million hectares of soybean planted globally were biotech – an increase over 2007. Of the 34 million hectares of global cotton, 46% or 15.5 million hectares were biotech in 2008 compared with 43% or 15.0 million hectares planted to biotech cotton in 2007. Of the 157 million hectares of maize planted in 2008, 24% or 37.3 million were biotech maize. Finally, of the 30 million hectares of canola grown globally in 2008, 20% was herbicide tolerant biotech

Table 34. Biotech Crop Area as Percentage of Global Area of Principal Crops, 2008 (Million Hectares)

Crop	Global Area*	Biotech Crop Area	Biotech Area as % of Global Area
Soybean	95	65.8	70
Cotton	34	15.5	46
Maize	157	37.3	24
Canola	30	5.9	20
Others	--	0.5	--
Total	**316**	**125.0**	**40**

Source: Clive James, 2008. *FAO 2007 hectarage

Figure 25. Global Adoption Rates (%) for Principal Biotech Crops, 2008 (Million Hectares)



Source: Clive James, 2008.

canola, equivalent to 5.9 million hectares. If the global areas (conventional plus biotech) of these four crops are aggregated, the total area is 316 million hectares, of which 40%, equivalent to 125 million hectares, were biotech in 2008 – up from 38% in 2007.

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 316 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.

The Global Value of the Biotech Crop Market

In 2008, the global market value of biotech crops, estimated by Cropnosis, was US$7.5 billion, (up from US$6.9 billion in 2007) representing 14% of the US$52.72 billion global crop protection market in 2008, and 22% of the approximately US$34 billion 2008 global commercial seed market. The US$7.5 billion biotech crop market comprised of US$3.6 billion for biotech maize (equivalent to 48% of global biotech crop market, up from 47% in 2007), US$2.8 billion for biotech soybean (37%, same as 2007), US$0.9 billion for biotech cotton (12%), and US$0.2 billion for biotech canola (3%). Of the US$7.5 billion biotech crop market, US$5.7 billion (76%) was in the industrial countries and US$1.8 billion (24%) 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$49.8 billion, which when rounded off to $50 billion is a historical landmark for the global biotech crop market (Table 35). The global value of the biotech crop market is projected at approximately US$8.3 billion for 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.

Table 35. The Global Value of the Biotech Crop Market, 1996 to 2008

Year	Value (Million of $US)
1996	115
1997	842
1998	1,973
1999	2,703
2000	2,734
2001	3,235
2002	3,656
2003	4,152
2004	4,663
2005	5,248
2006	6,151
2007	6,872
2008	7,479
Total	**49,823**

Source: Cropnosis, 2008 (Personal Communication).

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 2008, an additional **30** countries, totaling **55** 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 **670** approvals have been granted for 144 events for 24 crops. Thus, biotech crops are accepted for import for food and feed use and for release into the environment in 30 countries, including major food importing countries like

[1] *http://www.agbios.com*

Japan, which do not plant biotech crops. Of the 55 countries that have granted approvals for biotech crops, Japan tops the list followed by USA, Canada, Mexico, South Korea, Australia, the Philippines, New Zealand, the European Union and China. Maize has the most events approved **(44)** followed by cotton **(23)**, canola **(14)**, and soybean **(8)**. 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 insect resistant maize (MON810) and herbicide tolerant maize (NK603), both with **21** approvals, and insect resistant cotton (MON531/757/1076) with **16** approvals worldwide.

Concluding Comments

2008 was an uncertain year for farmers globally with high prices of oil and increased demand for food and feed at the beginning of the year driving fuel and input prices for fertilizers and pesticides as well as commodity prices to unprecedented high levels, and impacting farmers planting biotech crops in the temperate northern hemisphere in the first quarter of 2008. The receding prices of oil and commodities towards the end of 2008 coupled with the global financial crisis, tightening credit and uncertainty impacted on farmers in the southern hemisphere, in countries like Brazil, which planted in November and December of 2008.

As a result of the consistent and substantial economic, environmental and welfare benefits offered by biotech crops, millions of small and resource-poor farmers around the world continued to plant more hectares of biotech crops in 2008, the thirteenth year of commercialization. Progress was made on several important fronts in 2008 with: significant increases in hectarage of biotech crops; increases in both the number of countries and farmers planting biotech crops globally; substantial progress in Africa, where the challenges are greatest; increased adoption of stacked traits and the introduction of a new biotech crop. These are very important developments given that biotech crops can contribute to some of the major challenges facing global society, including: food security, high price of food, sustainability, alleviation of poverty and hunger, and help mitigate some of the challenges associated with climate change. The highlights in 2008 are summarized below.

- **Number of countries planting biotech crops soars to 25 – a historical milestone – a new wave of adoption of biotech crops is contributing to a broad-based and continuing hectarage growth of biotech crops globally**

It is noteworthy that in 2008, the number of biotech countries planting biotech crops reached the historical milestone of 25 countries (Table 3 and Figure 4). The number of countries electing to grow biotech crops has increased steadily from 6 in 1996, the first year of commercialization, to 18 in 2003 and 25 in 2008. A new wave of adoption of biotech crops is fueled by several factors, which are contributing to a broadly based global growth in biotech crops. These factors include: an increase in the number of biotech countries (3 new biotech countries in 2008): significant progress in Africa, the continent with the greatest challenge with an increase from 1 country in 2007 to 3 countries in 2008 with South Africa being joined by Burkina Faso and Egypt; Bolivia planting biotech soybean for the first time; additional biotech crops being deployed in biotech countries already growing biotech crops (Brazil planting Bt maize, and Australia biotech canola, for the first time); a new biotech crop, biotech sugar beet deployed in the USA and Canada; and significant growth in stacked traits in cotton and maize, increasingly deployed by 10 countries worldwide. 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. Notably in 2008, accumulatively the second billionth acre (800 millionth hectare) of a biotech crop was planted. In 2008, developing countries out-numbered industrial countries by 15 to 10, and this trend is expected to continue in the future with 40 countries, or more, expected to adopt biotech crops by 2015, the final year of the second decade of commercialization. By coincidence, 2015 also happens to be the Millennium Development Goals 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.

- **Progress in Africa – two new countries plant biotech crops for the first time**

Africa is home to over 900 million people representing 14% of the world population and is the only continent in the world where food production per capita is decreasing and where hunger and malnutrition afflicts at least one in three Africans. It is noteworthy that two of the three new countries that planted biotech crops for the first time in 2008 were from Africa, the continent with the greatest and most urgent need for crop biotechnology. For the first twelve years of commercialization of biotech crops, 1996 to 2007, South Africa has long been the only country on the African continent to benefit from commercializing biotech crops. Africa is recognized as the continent that represents by far the biggest challenge in terms of adoption and acceptance. Accordingly, the decision in 2008 by Burkina Faso to grow 8,500 hectares of Bt cotton for seed multiplication and initial commercialization and for Egypt to commercialize 700 hectares of Bt maize for the first time was of strategic importance for the African continent. For the first time, there is a lead country commercializing biotech crops in each of the three principal regions of the continent: South Africa in southern and eastern Africa; Burkina Faso in west Africa; and Egypt in north Africa. This broad geographical coverage in Africa is of strategic importance in that it allows the three countries to become role models in their respective regions and for more African farmers to become practitioners of biotech crops and to be able to benefit directly from "learning by doing", which has proven to be such an important feature in the success of Bt cotton in China and India. In December 2008, Kenya, a pivotal biotech crop country in east Africa, enacted a Biosafety Law (pending signature by the President as of end of December 2008), which will facilitate the adoption of biotech crops.

- **Bolivia becomes the ninth country in Latin America to adopt biotech crops**

Bolivia is the eighth largest grower of soybean in the world and is no longer disadvantaged compared with its neighbors, Brazil and Paraguay, which have benefited substantially for many years from herbicide tolerant RR®soybean. Bolivia becomes the ninth country in Latin America to benefit from the extensive adoption of biotech crops. Bolivia planted 600,000 hectares of RR®soybean in 2008.

- **Global hectarage of biotech crops continues strong growth in 2008 – reaches 125 million hectares, or more precisely, 166 million "trait hectares"**

In 2008, the global hectarage of biotech crops continued to grow strongly reaching 125 million hectares, up from 114.3 million hectares in 2007. This translates to an "apparent growth" of 10.7 million hectares (the sixth largest increase in 13 years) or 9.4% measured in hectares, whereas the "actual growth", measured more precisely in "trait hectares", was 22 million hectares or 15% year-on-year growth, approximately double the "apparent growth". In 2008, global growth in "trait hectares" increased by an impressive 15% or 22 million hectares from 143.7 million "trait hectares" in 2007 to 166 million "trait hectares" in 2008. Measuring in "trait hectares" is similar to measuring air travel (where there is more than one passenger per plane) more accurately in "passenger miles" rather than "miles". Thus in 2008, global growth in "trait hectares" increased from 143.7 million "trait hectares" in 2007 to 166 million "trait hectares". As expected, more of the growth in the early-adopting countries is now coming from the deployment of "stacked traits" (as opposed to single traits in one variety or hybrid), as adoption rates measured in hectares reach optimal levels in the principal biotech crops of maize and cotton. SmartStax™ biotech maize, with 8 genes for several traits, is expected to be commercialized in the USA in 2010, only two years from now. Similarly, biotech cotton occupies more than 90% of the national area in the USA, Australia and South Africa, with double-stacked traits occupying 75% of all biotech cotton in the USA, 81% in Australia and 83% in South Africa. It is evident that stacked traits have already become a very important feature of biotech crops, and accordingly it is important to measure growth more precisely in "trait hectares" as well as hectares. Notably, the 74-fold hectare increase between 1996 and 2008 makes biotech crops the fastest adopted crop technology in agriculture.

- **In 2008, accumulated hectarage of biotech crops for the period 1996 to 2008 exceeded 2 billion acres (800 million hectares) for the first time – it took 10 years to reach the first billion acres but only 3 years to reach the second billion acres – of the 25 countries planting biotech crops, 15 were developing and 10 industrial**

It took 10 years before the first one billionth acre of biotech crops was planted in 2005 – however it took only three years before the second billionth acre (800 millionth hectare) was planted in 2008. It is projected that 3 billion acres will be exceeded in 2011 with over 4 billion accumulated acres (1.6 billion hectares) by 2015, the Millennium Development Goals year. In 2008, the number of countries planting biotech crops increased to 25, comprising 15 developing countries and 10 industrial countries. The top eight countries each grew more than 1 million hectares; in decreasing order of hectarage they were; USA (62.5 million hectares), Argentina (21.0), Brazil (15.8), India (7.6), Canada (7.6), China (3.8), Paraguay (2.7), and South Africa (1.8 million hectares). Consistent with the trend for developing countries to play an increasingly important role, it is noteworthy that India with a high 23% growth rate between 2007 and 2008 very narrowly displaced Canada for the fourth ranking position globally in 2008. **The remaining 17 countries which grew biotech crops in 2008 in decreasing order of hectarage were:** Uruguay, Bolivia, Philippines, Australia, Mexico, Spain, Chile, Colombia, Honduras, Burkina Faso, Czech Republic, Romania, Portugal, Germany, Poland, Slovakia and Egypt. The strong growth in 2008 provides a very broad and stable foundation for future global growth of biotech crops. The strong growth across all continents in 2008 provides a very broad and stable foundation for future global growth of biotech crops. The growth rate between 1996 and 2008 was an unprecedented 74-fold increase making it the fastest adopted crop technology in recent history. This high adoption rate is a strong vote of confidence from millions of farmers who have made approximately 70 million individual decisions in 25 countries over a 13-year period to **consistently continue to plant higher hectarages of** biotech crops, year-after-year, after gaining first-hand insight and experience with biotech crops on their own or neighbor's fields. High re-adoption rates of close to 100% reflect farmer satisfaction with the products that offer substantial benefits ranging from more convenient and flexible crop management, to lower cost of production, higher productivity and/or higher net returns per hectare, health and social benefits, and a cleaner environment through decreased use of conventional pesticides, which collectively contributed to a more sustainable agriculture. The continuing rapid adoption of biotech crops reflects the substantial and consistent benefits for both large and small farmers, consumers and society in both industrial and developing countries.

- **A new biotech crop, RR®sugar beet, was commercialized in two countries, the USA and Canada**

In 2008, a new biotech crop, RR® herbicide tolerant sugar beet, was introduced for the first time globally in the USA plus a small hectarage in Canada. Notably, of the total US national hectarage of 437,246 hectares of sugar beet, a substantial 59% (the highest ever percent adoption for a launch) or 257,975 hectares were planted with RR® biotech sugar beet in 2008, the launch year; the percentage adoption in 2009 is expected to be close to 90%. The success of the RR®sugar beet launch has positive implications for sugarcane, (80% of global sugar production is from cane) for which several biotech traits are at an advanced stage of development in several countries.

- **Five countries, Egypt, Burkina Faso, Bolivia, Brazil and Australia introduced, for the first time, biotech crops that have already been commercialized in other countries**

Egypt, Burkina Faso, Bolivia, Brazil and Australia introduced for the first time biotech crops that have already been commercialized in other countries: Egypt introduced Bt maize, Burkina Faso Bt cotton, and Bolivia RR®soybean. Additional biotech crops were introduced by countries already planting biotech crops with Brazil, planting Bt maize and Australia, planting biotech canola for the first time. In 2008, the breadth and depth of the global deployment of the principal biotech crops was impressive and provides a solid foundation for further growth in the remaining seven years of the second decade of commercialization 2009 to 2015. In 2008, 17, or two-thirds of the 25-biotech countries planted biotech maize (same as 2007), 10 countries planted biotech soybean (up from 9), 10 countries planted biotech cotton (up from 9) and 3 countries planted biotech canola (up from 2 in 2007). In addition, two countries, the USA and China grew virus resistant papaya, two countries, Australia and Colombia grew biotech carnation, plus a small hectarage of Bt poplar in China, and biotech squash and alfalfa in the USA.

- **Adoption by crop**

Biotech soybean continued to be the principal biotech crop in 2008, occupying 65.8 million hectares or 53% of global biotech area, followed by fast-growing biotech maize (37.3 million hectares at 30%), biotech cotton (15.5 million hectares at 12%) and biotech canola (5.9 million hectares at 5% of the global biotech crop area).

- **Adoption by trait**

From the genesis of commercialization in 1996 to 2008, herbicide tolerance has consistently been the dominant trait. In 2008, herbicide tolerance deployed in soybean, maize, canola, cotton and alfalfa occupied 63% or 79 million hectares of the global biotech area of 125 million hectares. For the second year running in 2008, the stacked double and triple traits occupied a larger area (26.9 million hectares, or 22% of global biotech crop area) than insect resistant varieties (19.1 million hectares) at 15%. The stacked trait products were by far the fastest growing trait group between 2007 and 2008 at 23% growth, compared with 9% for herbicide tolerance and -6% for insect resistance.

- **Stacked traits – an increasingly important feature of biotech crops – 10 countries planted biotech crops with stacked traits in 2008**

Stacked products are a very important feature and future trend, which meets the multiple needs of farmers and consumers and these are now increasingly deployed by ten countries – USA, Canada, the Philippines, Australia, Mexico, South Africa, Honduras, Chile, Colombia, and Argentina (7 of the ten are developing countries), with more countries expected to adopt stacked traits in the future. A total of 26.9 million hectares of stacked biotech crops were planted in 2008 compared with 21.8 million hectares in 2007. In 2008, the USA led the way with 41% of its total 62.5 million hectares of biotech crops stacked, including 75% of cotton, and 78% of maize; the fastest growing component of stacked maize in the USA was the triple stacks conferring resistance to two insect pests plus herbicide tolerance. Double stacks with pest resistance and herbicide tolerance in maize were also the fastest growing component in 2008 in the Philippines doubling from 25% of biotech maize in 2007 to 57% in 2008. Biotech maize with eight genes, named SmartStax™, is expected to be released in the USA in 2010 with eight different genes coding for several pest resistant and herbicide tolerant traits. Future stacked crop products will comprise both agronomic input traits for pest resistance, tolerance to herbicides and drought plus output traits such as high omega-3 oil in soybean or enhanced pro-Vitamin A in Golden Rice.

- **Number of biotech crop farmers increased by 1.3 million in 2008, reaching 13.3 million globally in 25 countries – notably 90%, or 12.3 million, were small and resource-poor farmers in developing countries**

In 2008, the number of farmers benefiting from biotech crops globally in 25 countries reached 13.3 million, an increase of 1.3 million over 2007. Of the global total of 13.3 million beneficiary biotech farmers in 2008, (up from 12 million in 2007), remarkably over 90% or 12.3 million (up from 11 million in 2007) were small and resource-poor farmers from developing countries; the balance of 1 million were large farmers from both industrial countries such as the USA and Canada and developing countries such as Argentina and Brazil. Of the 12.3 million small and resource-poor farmers, most were Bt cotton farmers, 7.1 million in China (Bt cotton), 5.0 million in India (Bt cotton), and the balance of 200,000 in the Philippines (biotech maize), South Africa (biotech cotton, maize and soybeans often grown by subsistence women farmers) and the other eight developing countries which grew biotech crops in 2008. **The largest increase in the number of beneficiary farmers in 2008 was in India where an additional 1.2 million small farmers planted Bt cotton which now occupies 82% of total cotton, up from 66% in 2007.** The increased income from biotech crops for small and resource-poor farmers represents an initial modest contribution towards the alleviation of their poverty. During the second decade of commercialization, 2006 to 2015, biotech crops have an enormous potential for contributing to the Millennium Development Goals of reducing poverty by 50% by 2015.

- **Up to 10 million more small and resource-poor farmers may be secondary beneficiaries of Bt cotton in China**

A recent seminal paper (Wu *et al.,* 2008) reports that **the use of Bt cotton to control cotton bollworm in six northern provinces in China was associated with up to a substantial ten-fold suppression of cotton bollworm infestations in crops other than cotton, which are also hosts of cotton bollworm;** these crops include, maize, soybean, wheat, peanuts, vegetables, and other crops. In contrast to cotton, which occupies 3 million hectares farmed by 5 million farmers in the six provinces, these other crops occupy a much larger area of 22 million hectares and are farmed by 10 million farmers. Bt cotton has provided substantial control of cotton bollworm. Although damage caused by cotton bollworm in these other crops (secondary hosts) will almost certainly be less than on cotton (primary host), there is, given the magnitude of suppression (up to a ten-fold suppression of larvae), a potential for benefits that could, for example, result in the need for less insecticides on these other crops, which further studies could explore. Should further studies confirm that suppression of cotton bollworm on these other hosts results in benefits, it follows that the impact of Bt cotton is not limited to cotton and that up to 10 million more farmers could be "secondary" beneficiaries of Bt cotton in the six northern provinces of China. The initial findings reported by Wu *et al.* (2008) could be important for two reasons. Firstly, Bt cotton may have a broader and more significant impact than its documented direct impact on the cotton crop. Secondly, the findings may also apply to other countries, such as India, where small and resource-poor farmers practice similar mixed cropping systems by small farmers and where there is, like China, extensive adoption of Bt cotton to control bollworm.

- **Biotech crops have improved the income and quality of life of small resource-poor farmers and their families and contributed to the alleviation of their poverty – case studies are cited from India, China, South Africa, and the Philippines**

In India in 2008, 5 million small farmers **(up from 3.8 million farmers in 2007) benefited from planting 7.6 million hectares of Bt cotton, equivalent to a high adoption rate of 82%**. Benefits will vary according to varying infestation levels in different years and locations. However, on average conservative estimates for small farmers (Gandhi and Namboodori, 2006) indicated that yield increased by 31%, insecticide application decreased by 39%, and profitability increased by 88% equivalent to US$250 per hectare. In addition, in contrast to the families of farmers planting conventional cotton, families of Bt cotton farmers enjoyed emerging welfare benefits including more prenatal care and assistance with at-home births for women plus a higher school enrollment of their children, a higher percentage of whom were vaccinated.

In China, based on studies conducted by the Center for Chinese Agricultural Policy (CCAP), it was concluded that, on average, small farmers adopting Bt cotton increased yield by 9.6%, reduced insecticide use by 60%, with positive implications for both the environment and the farmers' health, and generated a substantial US$220 per hectare increase in income which made a significant contribution to their livelihood as the income of many cotton farmers can be as low as US$1 per day. In China in 2008, 7.1 million small and resource-poor farmers benefited from Bt cotton.

In South Africa, a study published in 2005 (Gouse *et al.,* 2005) involved 368 small and resource-poor farmers and 33 commercial farmers, the latter divided into irrigated and dry land maize production systems. The data indicated that under irrigated conditions, Bt maize resulted in an 11% higher yield (from 10.9 to 12.1 MT/ha), a cost savings in insecticides of US$18/ha equivalent to a 60% cost reduction, and an increase income of US$117/ha. Under rainfed conditions, Bt maize resulted in an

11% higher yield (from 3.1 to 3.4 MT/ha), a cost saving on insecticides of US$7/ha equivalent to a 60% cost reduction, and an increased income of US$35/ha.

In the Philippines, at least 200,000 small farmers gained from biotech maize in 2008. A socio-economic impact study (Gonzales, 2005), reported that for small farmers, 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 years, 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.

- **Five principal developing countries China, India, Argentina, Brazil and South Africa are exerting leadership, and driving global adoption of biotech crops – benefits from biotech crops are spurring strong political will and substantial new investments in biotech crops**

The five principal developing countries committed to biotech crops, span all three continents of the South: they are India and China in Asia, Argentina and Brazil in Latin America and South Africa on the African continent – collectively they represent 2.6 billion people or 40% of the global population, with a combined population of 1.3 billion who are completely dependent on agriculture, including millions of small and resource-poor farmers and the rural landless, who represent the majority of the poor in the world. The increasing collective impact of the five principal developing countries is an important continuing trend with implications for the future adoption and acceptance of biotech crops worldwide. The five countries are reviewed in detail in Brief 39 including extensive commentaries on the current adoption of specific biotech crops, impact and future prospects. R&D investments in crop biotechnology in these countries are substantial, even by multinational company standards. Notably in 2008, China committed an additional US$3.5 billion over twelve years with Premier Wen Jiabao (Chairman of the State Council/Cabinet of China) expressing China's strong political will for the technology when addressing the Chinese Academy of Sciences in June 2008, ***"to solve the food problem, we have to rely on big science and technology measures, rely on biotechnology, rely on GM."*** Dr. Dafang Huang, former Director of the Biotechnology Research Institute of the Chinese Academy of Agricultural Sciences (CAAS) concluded that ***"Using GM rice is the only way to meet the growing food demand"*** (Qiu, 2008).

President da Silva of Brazil has also demonstrated the same strong political will for biotech crops and committed public funds of the same order of magnitude as China with several of its own products being advanced for approval through Brazil's national agricultural research organization, EMBRAPA. Similarly, India is investing approximately US$300 million additional public funding to support its stable of approximately 15 biotech crops, the first of which, a public sector developed Bt cotton variety, was approved in 2008. Political will and support for biotech crops in India is high as evidenced by the following statement by India's Minister of Finance Dr. P. Chidambaram, who called for an emulation of the remarkable Indian biotech Bt cotton success story 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, 2007). It is notable that the strategically important concept of South-South collaboration is already being realized between China and India with the first Bt cotton developed by China, already being marketed and adopted in India; this is a first indication of a very important new trend that is of great significance.

- **Political will and support for biotech crops to contribute to more affordable food and food security**

In 2007 and 2008, the price of oil skyrocketed from approximately US$70 a barrel at the beginning of 2007, to a high of almost US$140 in mid 2008 and plummeted to US$42 in December 2008. The increased price of oil resulted in steep increases in the price of fuel, fertilizers and crop inputs such as pesticides. These increases coupled with increased global demand exacerbated by production of biofuel led to unprecedented high prices for commodities. Rice tripled in price from about US$400 per ton in January 2007 to over US$1,000 in the spring of 2008 and declined to US$550 a ton by December 2008. Similarly maize increased from about US$200 a ton in early 2007 to a high of almost US$300 and is now down to US$160 a ton. Soybean moved from a low of US$460 a ton to a high of close to US$600 and is now down to just over US$300 a ton. With the exception of cotton and maize the price of commodities in December 2008 were generally significantly higher than early 2007 (Figure 1), and most economists opine that they will not decline to the long time lows of 2006. 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.

Biotech crops can play an important role by contributing to food security and more affordable food through increasing supply (by increasing productivity per hectare) and coincidentally decreasing cost of production (by a reduced need for inputs, less ploughing and fewer pesticide applications) which in turn also requires less fossil fuels for tractors, thus mitigating some of the negative aspects associated with climate change. Of the increase of US$44 billion in farmer income from biotech crops between 1996 and 2007, 44% or US$19 billion was due to an increase in production of 32 million tons and 56% or US$25 billion was due to coincidental reduction in cost of production (Brookes and Barfoot, 2009, forthcoming). If biotech crops had not been used in the period 1996 to 2007, an additional 43 million hectares would have been required to produce the additional 141 million tons produced from biotech crops. Thus, biotechnology has already made a contribution to higher productivity and lower costs of production of current biotech crops and has enormous potential for the future when the staple of rice and wheat, as well as pro-poor food crops such as cassava, will benefit from biotechnology.

The benefits that biotech crops offer in terms of more affordable food has significantly renewed the interest of global society in biotech crops and in some cases is expediting the commercialization of biotech crops already under consideration. Thus, several countries in Asia, including China, India, and the Philippines are assigning higher priority to the field testing of biotech rice with a view to expediting commercialization. The renewed support for biotech rice and other biotech crops in Asia parallels a momentum of global endorsement of biotech crops. The following are examples of declared support and expression of political will in favor of biotech crops principally because of their potential to contribute to food security, more affordable food prices, and for mitigating some of the challenges associated with climate change.

G8 members meeting in Hokkaido Japan in July 2008 recognized the significance of the important role that biotech crops can play in food security. The G8 leaders' statement on biotech crops (G8, 2008) reads as follows, ***"accelerate research and development and increase access to new agricultural technologies to boost agriculture production; we will promote science-based risk analysis, including the contribution of seed varieties developed through biotechnology."***

The European Commission stated that, ***"GM crops can play an important role in mitigating the effects of the food crisis"*** (Adam, 2008).

The World Health Organization (WHO) has emphasized the importance of biotech crops because of their potential to benefit the public health sector by providing more nutritious food, decreasing its allergenic potential and also improving the efficiency of production systems (Tan, 2008).

Sir David King, former scientific advisor to the UK's Prime Minister, stressed that, ***"GM is the only technology available to solve the world food price crisis"*** (Cookson, 2008).

Helen Ferrier, the chief scientific advisor to the National Farmers Union in the UK concurred with Sir David King. She advocated that, ***"European farmers should have the choice of using this technology if they wish. With high input prices and increasing global competition the majority of our members would like to receive the benefits of GM crops"*** (Cookson 2008).

President Bingu Wa Mutharika of Malawi who is also the Minister for Education, Science and Technology chaired the cabinet meeting in July 2008 that approved the National

Biotechnology Policy that provides a framework for effective implementation of biotechnology programs and activities in Malawi. In a foreword to the policy, the President said, ***"his government recognized the pivotal role biotechnology can play towards economic growth and poverty reduction."*** He said, ***"biotechnology will facilitate Malawi's speedy attainment of capacity to be food secure, create wealth and achieve socio-economic development as stipulated in the Malawi Growth and Development Strategy (MGDS) and Vision 2020."*** The Policy provides an enabling framework to promote and regulate the development, acquisition and deployment of relevant biotechnology products to reposition Malawi from being a predominantly importing and consuming economy to a manufacturing and exporting one. It therefore creates a conducive environment that allows biotechnology business to flourish. With the Biosafety Act already in place since 2002, the approval of the policy is expected to hasten the country's plans to advance biotech crops.

Hon. William Ruto, Minister for Agriculture, Kenya at the official opening of the Workshop on Development of A Communication Strategy for the COMESA Region, 14th August 2008, Nairobi stressed that, ***"The effects of biotechnology are likely to bear results including better crop yields, less environmental degradation, early detection and control of animal diseases, as well as the development of innovative food products, such as foods with improved nutritional value, longer shelf life, better taste and safety. Biotechnology offers Africa an opportunity to increase food security by offering tools that may be used to contribute to addressing agricultural production constraints."***

Prof. Shaukat Abdulrazak, Executive Secretary, Kenya National Council for Science and Technology (NCST) at the official opening of the 1st all Africa Congress on Biotechnology Nairobi Kenya, September, 2008 highlighted that, ***"The application of safe biotechnology aimed at developing new products that are useful in many spheres of life, has proved to be one of the best options for development in view of rising demands caused by human population increase. The potential benefits from the use of genetically modified organisms in the areas of agriculture, human health, animal production, trade, industry, and environmental management are clearly recognized."***

Hon. Eng. Hilary Onek, Minister of Agriculture, Uganda, at the launch of the Open Forum for Agricultural Biotechnology in Africa (OFAB-Uganda), 14 December 2007, said that, ***"Biotechnology provides practical answers to some of the greatest challenges mankind faces at the dawn of a new millennium, such as hunger and malnutrition. It is an accessible and exciting new development that is already improving the way people live."*** Addressing scientists, he said, ***"Let us give our African farmers an opportunity of choice."***

Hon. Fred Jachan Omach, State Minister of Finance, Uganda during the April 2008 Cabinet approval of the National Biotechnology and Biosafety Policy, underscored the importance of the policy arguing that ***"biotechnology was one of the frontiers of agricultural and industrial research in the world today and that Uganda should not be left behind in these new technological advancements."*** The policy's goal towards the safe application of biotechnology will be one of the instruments in poverty eradication, improvement of health care, food security, industrialization and the protection of the environment. Hon. Omach further stated that, ***"the approval of the policy was imperative given that the country had already established an ultra-modern National Agricultural Biotechnology Center, where genetic modification of cotton, bananas and other crops for resistance to diseases and pests are being conducted."***

Mr. Sharad Pawar, the Indian Union Minister of Agriculture and Consumers Affairs, Food and Public Distribution, recognized biotechnology as a key factor in agricultural development in the coming decades. While inaugurating the National Seminar on "Seed and Crop Technologies for Doubling Agricultural Production", organized by the National Seed Association of India (NSAI) from 8-9th August, 2008, he stressed that, ***"application of biotechnology in agriculture holds enormous promise in developing crop varieties with higher level of tolerance to biotic and abiotic stresses"*** (Pawar, 2008a).

Dr. M.S. Swaminathan, India, recipient of the first World Food Prize, also known as 'The Father of the Green Revolution' in India, said that ***"Biotechnology can offer new ways to address climate change. Drought tolerance can be built into crops, for instance rice, by transferring genes."*** Dr. Swaminathan also said that, ***"Opportunities abound by combining traditional and modern technologies like genetic modification and marker assisted selection."***

Premier Wen Jiabao, China, Chair of the State Council/Cabinet, addressed the Chinese Academy of Agricultural Sciences in June 2008 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 represents strong political will and support for biotech crops from China's cabinet. Premier Wen Jiabao announced a new US$3.5 billion R&D initiative for biotech crops in July 2008. Chinese observers interpret this to mean that biotech rice will be approved in the near term, possibly after the approval of biotech phytase maize, developed by the Chinese Academy for Agricultural Sciences (CAAS).**

These expressions of strong political will for biotech crops from politicians, policy makers, and the farming community, has not gone unnoticed in the developing countries including Africa where the challenge to the introduction of biotech crops is greatest but also where the need for more affordable food is greatest. Notably, two countries in Africa have decided to plant biotech crops for the first time in 2008 because of the multiple and significant benefits they offer. Burkina Faso, an important cotton growing country in francophone West Africa, approved commercialization of Bt cotton, joining the fast-growing global group of biotech countries – a very important development for Africa. Burkina Faso's decision followed the earlier decision of Egypt in May 2008 to commercialize a biotech crop, Bt maize, for the first time. Thus, on the African continent, South Africa, the only country to plant biotech crops prior to 2008, is now joined by Egypt and Burkina Faso to notably increase the number of biotech crop growing countries in Africa in 2008 to 3, compared with only one in 2007.

Not surprisingly, the renewed interest in biotech crops has been captured by the global media which has highlighted the contribution that biotech crops are currently making, and can make in the future to modulate escalating food prices and the new challenges associated with climate change. Thus, the Financial Times devoted a whole page on 10 July 2008 to an article entitled ***"A time to sow? GM food curb cost of staples"*** (Cookson, 2008). The Economist published a full page article in July 2008 entitled **"The next green revolution"** (Anonymous, 2008).

- **All seven EU countries increased their Bt maize hectarage in 2008, resulting in an overall increase of 21% to reach over 100,000 hectares**

In 2008, of the 27 countries in the European Union, seven officially planted Bt maize on a commercial basis. The seven EU countries listed in order of biotech hectarage of Bt maize were Spain, Czech Republic, Romania, Portugal, Germany, Poland and Slovakia.

- **Contribution of biotech crops to Sustainability – the multiple contributions of biotech crops have enormous potential**

The World Commission on the Environment and Development defined sustainable development as follows: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987).

To-date, biotech crops have contributed to sustainable development in several significant ways, listed and summarized below:

1. Contributing to food security and more affordable food (lower prices)
2. Conserving biodiversity
3. Contributing to the alleviation of poverty and hunger
4. Reducing agriculture's environmental footprint
5. Mitigating climate change and reducing greenhouse gases (GHG)
6. Contributing to the cost-effective production of biofuels
7. Contributing to sustainable economic benefits

1. Contributing to food security and more affordable food (lower prices)

Biotech crops can play an important role by contributing to food security and more affordable food through increasing supply (by increasing productivity per hectare) and coincidentally decreasing cost of production (by a reduced need for inputs, less ploughing and fewer pesticide applications) which in turn also requires less fossil fuels for tractors, thus mitigating some of the negative aspects associated with climate change. **Of the economic gains of US$44 billion during the period 1996 to 2007, 44% were due to substantial yield gains, and 56% due to a reduction in production costs. In 2007, the total crop production gains globally for the 4 principal biotech crops (soybean, maize, cotton and canola) was 32 million metric tons, which would have required 10 million additional hectares had biotech crops not been deployed. The 32 million tons of increased crop production from biotech crops in 2008 comprised 15.1 million tons of maize, 14.5 million tons of soybean, 2.0 million tons of cotton lint and 0.5 million tons of canola. For the period 1996-2007, the production gains were 141 million tons, which (at 2007 average yields) would have required 43 million additional hectares had biotech crops not been deployed** (Brookes and Barfoot, 2009, forthcoming). Thus, biotechnology has already made a contribution to higher productivity and lower costs of production of current biotech crops and has enormous potential for the future when the staples of rice and wheat, as well as pro-poor food crops such as cassava will benefit from biotechnology.

Progress with control of abiotic stresses is expected in the near term with drought tolerance becoming available by 2012, or earlier in the USA, and in Sub Saharan Africa by 2017, where maize is the staple food. Rice, the most important food crop of the poor in the world offers a unique opportunity for increasing supply and hence cheaper food (Bt rice) and also for providing more nutritious food (Golden Rice). A new family of input and output traits will not only increase yield but provide more nutritious food, such as soybean with omega-3 oil and Golden Rice enriched with pro-vitamin A, expected to be approved by 2012. Given that rice is the most important food crop in the world and especially since it is the most important food crop of the poor of the world, the most critical event that can contribute to global food security is the expected approval of biotech Bt rice by China in the next 24 months. Extensive multi-locational field trials of biotech rice have been completed in China and the product is being considered for commercial release. Field trials are already underway in India and many countries in Asia have research programs, which would be expedited to deliver biotech rice products following approval by China. Biotech rice, awaiting approval in China, has enormous potential to contribute to food security, lower food prices and alleviation of poverty.

2. Conserving biodiversity

Biotech crops are a land-saving technology, capable of higher productivity on the current 1.5 billion hectares of arable land, and thereby can help preclude deforestation and protect biodiversity in forests and in other in-situ biodiversity sanctuaries. Approximately 13 million hectares of biodiversity-rich forests are lost in developing countries annually. During the period 1996 to 2007 biotech crops have already precluded the need for an additional area of 43 million hectares of crop land, and the potential for the future is enormous.

3. Contributing to the alleviation of poverty and hunger

Fifty percent of the world's poorest people are small and resource-poor farmers, and another 20% are the rural landless completely dependent on agriculture for their livelihoods. Thus, increasing income of small and resource-poor farmers contributes directly to the poverty alleviation of a large majority (70%) of the world's poorest people. To-date, biotech cotton in India, China and South Africa and biotech maize in the Philippines and South Africa has already made a significant contribution to the income of over 12 million poor farmers, and this can be enhanced significantly in the remaining 7 years of the second decade of commercialization, 2006 to 2015. Biotech maize is already delivering benefits to a modest number of small farmers in more than half a dozen developing countries and has enormous potential for further deployment between now and 2015. Crops such as biotech eggplant, being developed in India, the Philippines, and Bangladesh are expected to be approved in 2009 and used almost exclusively by up to 2 million small farmers. Focusing on a pro-poor agenda for orphan crops such as cassava, sweet potato, sorghum, and vegetables will allow a diversified and balanced crop biotech program to be developed that is specifically targeted at alleviation of poverty and hunger. Biotech maize is already delivering benefits to a modest number of small farmers in more than half a dozen developing countries and has enormous potential for further deployment between now and 2015. Of special significance is biotech rice which has the potential to benefit 250 million poor rice households in Asia, (up to 1 billion people based on 4 members per household) growing on average only half a hectare of rice with an income as low as US1 per day – they are some of the poorest people in the world.

It is evident that much progress has been made in the first thirteen years of commercialization of biotech crops, but progress to-date is just the "tip of the iceberg" compared with potential progress in the second decade of commercialization, 2006-2015. It is a fortunate coincidence that the last year of the second decade of commercialization of biotech crops, 2015, is also the year of the Millennium Development Goals (MDG). This offers a unique opportunity for the global biotechnology community, from the North and the South, the public and the private sectors, to define in 2009 the contributions that biotech crops can make to the Millennium Development Goals and a more sustainable agriculture in the future – this gives the global biotech crop community six years to work towards implementing an action plan for biotech crops that can deliver on the MDG goals of 2015.

4. Reducing agriculture's environmental footprint

Conventional agriculture has impacted significantly on the environment and biotechnology can be used to reduce the environmental footprint of agriculture. Progress in the first decade includes a significant reduction in pesticides, saving on fossil fuels, and decreasing CO_2 emissions through no/less ploughing, and conserving soil and moisture by optimizing the practice of no till through application of herbicide tolerance. The accumulative reduction in pesticides for the period 1996 to 2007 was estimated at 359,000 metric tons of active ingredient (a saving of 9% in pesticides), which is equivalent to a 17.2% reduction in the associated environmental impact of pesticide use on these crops, as measured by the Environmental Impact Quotient (EIQ) – a composite measure based on the various factors contributing to the net environmental impact of an individual active ingredient (a.i.). The corresponding data for 2007 alone was a reduction of 77,000 metric tons a.i (equivalent to a saving of 18% in pesticides) and a reduction of 29% in EIQ (Brookes and Barfoot, 2009, forthcoming).

Increasing efficiency of water usage will have a major impact on conservation and availability of water globally. Seventy percent of fresh water is currently used by agriculture globally, and this is obviously not sustainable in the future as the population increases by almost 50% to 9.2 billion by 2050; in developing countries the current agricultural usage of fresh water is even higher at 86%. Other biotech crop applications that will become available towards the end of the second decade, 2006 to 2015, are crops with increased nitrogen efficiency, which have implications in mitigating global warming and the pollution of aquifers and deltas, such as the Mekong, with nitrogen related pollutants. The first biotech maize hybrids with a degree of drought tolerance are expected to be commercialized by 2012, or earlier in the USA, in the more drought-prone states of Nebraska and Kansas where yield increases of 8 to 10% are projected. Notably, the first tropical drought tolerant biotech maize is expected by 2017 for Sub Saharan Africa (see the chapter on "Drought tolerance in maize: an emerging reality" in the abridged version in the companion document to the Executive Summary and the full referenced text on drought in maize in the body of Brief 39). The advent of drought tolerance in temperate maize in the industrial countries will be a major milestone and will be of even greater significance in tropical maize in Sub Saharan Africa, Latin America and Asia. Drought tolerance has also been incorporated in several other crops including wheat, which has performed well in initial field trials in Australia, with the best lines yielding 20% more than their conventional counterparts. Drought tolerance is expected to have a major impact on more sustainable cropping systems worldwide, particularly in developing countries where drought is more prevalent and severe than industrial countries.

5. Mitigating climate change and reducing greenhouse gases (GHG)

The important and urgent concerns about the environment have implications for biotech crops, which can potentially contribute to a reduction of greenhouse gases and help mitigate climate change in two principal ways. First, permanent savings in carbon dioxide emissions through reduced use of fossil-based fuels, associated with fewer insecticide and herbicide sprays; in 2007 this was an estimated saving of 1.14 billion kg of carbon dioxide (CO_2), equivalent to reducing the number of cars on the roads by 0.5 million. Secondly, additional savings from conservation tillage (need for less or no ploughing facilitated by herbicide tolerant biotech crops) for biotech food, feed and fiber crops, led to an additional soil carbon sequestration equivalent in 2007 to 13.1 billion kg of CO_2, or removing 5.8 million cars off the road. Thus, in 2007 the combined permanent and additional savings through sequestration was equivalent to a saving of 14.24 billion kg of CO_2, or removing 6.3 million cars from the road (Brookes and Barfoot, 2009, forthcoming).

Droughts, floods, and temperature changes are predicted to become more prevalent and more severe, and hence there will be a need for faster crop improvement programs to develop varieties and hybrids that are well adapted to more rapid changes in climatic conditions. Several biotech tools, including tissue culture, diagnostics, genomics, molecular marker-assisted selection (MAS) and genetic engineering of crops can be used collectively for 'speeding the breeding' and help mitigate the effects of climate change. Biotech crops are already contributing to reducing CO_2 emissions by precluding the need for ploughing a significant portion of cropped land, conserving soil and particularly moisture, reducing pesticide spraying as well as sequestering CO_2.

6. Contributing to the cost-effective production of biofuels

Biotechnology can be used to cost effectively optimize the productivity of biomass/hectare of first generation food/feed and fiber crops and also second-generation energy crops. This can be achieved by developing crops tolerant to abiotic stresses (drought/salinity/extreme temperatures) and biotic stresses (pests, weeds, diseases), and also to raise the ceiling of potential yield per hectare through modifying plant metabolism. There is also an opportunity to utilize biotechnology to develop more effective enzymes for the downstream processing of biofuels. In the USA, Ceres has just released biotech-based non-transgenic hybrids of switchgrass and sorghum with increased cellulose content for ethanol production and has transgenic varieties under development.

7. Contributing to sustainable economic benefits

The most recent survey of the global impact of biotech crops for the period 1996 to 2007 (Brookes and Barfoot, 2009, forthcoming), estimates that the global net economic benefits to biotech crop farmers in 2007 alone was US$10 billion (US$6 billion for developing countries and US$4 billion for industrial countries). The accumulated benefits during the period 1996 to 2007 was US$44 billion with US$22 billion each for developing and industrial countries. These estimates include the very important benefits associated with the double cropping of biotech soybean in Argentina.

In summary, collectively, the above seven thrusts represent a significant contribution to sustainability and the potential for the future is enormous.

- **National economic growth – potential contribution of biotech crops in developing countries**

The 2008 World Bank Development Report “Agriculture for Development” (World Bank, 2008) notes that two-thirds of the world’s agricultural added value is created in developing countries, where agriculture is an important sector. The report classified countries into three categories: a) Agricultural-based countries where agriculture on average contributes one-third of GDP, and employs two-thirds of the labor force. This category has over 400 million poor people, mainly in Sub Saharan Africa and over 80% of the poor are involved in agriculture. b) The transforming countries – this category includes China, India, Indonesia and Romania. On average, agriculture contributes 7% to GDP but over 80% of the poor are in the rural areas, with most of them involved in agriculture. This category has 2.2 billion rural people. About 98% of the enormous rural population of South Asia, 96% of East Asia and the Pacific and 92% of the Middle East and North Africa are in transforming countries. c) Urbanized countries are the category where agriculture is least important, contributing 5% or less to GDP, and where poverty is mostly urban.

In the absence of agricultural growth, national economic growth is not possible in the agricultural-based countries and plays a critical role in the transforming countries where there is a rural population of 2.2 billion, mainly involved in agriculture and representing over 80% of the poor. Thus, on a global context, of the 5.5 billion people in the developing countries, 3 billion (approximately half the worlds’ population) live in rural areas and 2.5 billion are in agricultural households, of which 1.5 billion households are small and resource-poor. The World Bank report concluded that, ***“Using agriculture as the basis for economic growth in the agricultural based countries requires a productivity revolution in small holder farming.”*** Crops are the principal source of food, feed and fiber globally producing approximately 6.5 billion metric tons of food, feed and fiber annually. The annals of history confirm that technology can make a substantial contribution to crop productivity and production and spur rural economic growth. The best examples are the introduction of the new technology of hybrid maize in the USA in the 1930s, and the green revolution for rice and wheat in the developing countries, particularly in Asia in the 1960s. The semi-dwarf wheat was the new technology that provided the engine of rural and national economic growth during the green revolution of the 1960s, which saved 1 billion people from hunger and for which Norman Borlaug was awarded the Nobel Peace Prize in 1970. Today at 94 years young, Norman Borlaug is again the most credible the most famous advocate for the new technology of biotech crops and is an enthusiastic patron of ISAAA.

The first generation of biotech crops has benefited developing countries from all three continents. In 2008, over 12 million small resource-poor farmers were beneficiaries, mainly in China, India, the Philippines and South Africa. A philanthropic private–public sector partnership WEMA (Water Efficient Maize for Africa) involving Monsanto and CIMMYT and national programs in Africa plans to deliver the first drought tolerant biotech maize in 2017. WEMA is financed by the Bill and Melinda Gates Foundation and has the potential to deliver immense value for small and poor agricultural-based countries in Sub Saharan Africa. Due mainly to the lack of regulation, with the exception of South Africa, Sub Saharan countries have not benefited from biotech crops that have delivered consistent and significant benefits to many other developing countries in Latin America and Asia. The biotech Bt rice already developed and field tested in China has the potential to increase net income by approximately US$100 per hectare for the 110 million poor rice households in China, equivalent to 440 million people, based on an average of 4 per household in the rural areas of China.

In summary, biotech crops have already demonstrated their capacity to increase productivity and income significantly and hence can serve as an engine of rural economic growth that can contribute to the alleviation of poverty for the world's small and resource-poor farmers during a global financial crisis.

- **In 2008, more than half the world's population lived in the 25 countries, which planted 125 million hectares of biotech crops, equivalent to 8% of the 1.5 billion hectares of all the cropland in the world**

Biotech crops generated significant and multiple benefits worth over US$10 billion globally in 2007. More than half (55% or 3.6 billion people) of the global population of 6.6 billion live in the 25 countries where biotech crops were grown in 2008 and generated significant and multiple benefits worth over US$10 billion globally in 2007. Notably, more than half (52% or 776 million hectares) of the 1.5 billion hectares of cropland in the world is in the 25 countries where approved biotech crops were grown in 2008. The 125 million hectares of biotech crops in 2008 represents 8% of the 1.5 billion hectares of cropland in the world.

- **Need for appropriate cost/time-effective regulatory systems that are responsible, rigorous and yet not onerous, requiring only modest resources that are within the means of most developing countries**

The most important constraint to the adoption of biotech crops in most developing countries that deserves highlighting is the lack of appropriate cost-effective and responsible regulation systems that incorporate all the knowledge and experience of 13 years of regulation. Current regulatory systems in most developing countries are usually unnecessarily cumbersome and in many cases it is impossible to implement the system to approve products which can cost up to US$1 million or more to deregulate – this is beyond the means of most developing countries. The current regulatory systems were designed more than ten years ago to meet the initial needs of industrial countries dealing with a new technology and with access to significant resources for regulation which developing countries simply do not have – the challenge for developing countries is "how to do a lot with little." With the accumulated knowledge of the last 13 years, it is now possible to design appropriate regulatory systems that are responsible, rigorous and yet not onerous, requiring only modest resources that are within the means of most developing countries – this should be assigned top priority.

Today, unnecessary and unjustified stringent standards designed to meet the needs of resource-rich industrial countries are denying the developing countries timely access to products such as Golden Rice, whilst millions die unnecessarily in the interim. This is a moral dilemma, where the demands of regulatory systems have become "the end and not the means". Malawi in Southern Africa is one of many countries that are becoming increasingly aware of the critical need for an appropriate effective regulatory framework and a national biotechnology policy. President Bingu Wa Mutharika, of Malawi who is also the Minister for Education, Science and Technology chaired the cabinet meeting in July 2008 that approved the National Biotechnology Policy, which in conjunction with the Biosafety Act of 2002, provides a regulatory framework for effective implementation of biotechnology programs and activities in Malawi. In a foreword to the policy, the President said, ***"government recognized the pivotal role biotechnology can play towards economic growth and poverty reduction".*** He said, ***"biotechnology will facilitate Malawi's speedy attainment of capacity to be food secure, create wealth and achieve socio-economic development as stipulated in the Malawi Growth and Development Strategy (MGDS) and Vision 2020."*** The Policy provides an enabling framework to promote and regulate the development, acquisition and deployment of relevant biotechnology products to reposition Malawi from being a predominantly importing and consuming economy to a manufacturing and exporting one. It therefore creates a conducive environment that allows biotechnology business to flourish. With the Biosafety Act already in place since 2002, the approval of the policy is expected to hasten the country's plans to advance biotech crops.

- **Drought tolerance in conventional and biotech maize - an emerging reality**

Given the pivotal importance of drought tolerance, ISAAA invited Dr. Greg O. Edmeades, former leader of the maize drought program at CIMMYT, to contribute a timely global overview on the status of drought tolerance in maize, in both conventional and biotech approaches, in the private and public sector, and to discuss future prospects in the near, mid and long term. The contribution by G.O. Edmeades **"Drought tolerance in maize: an emerging reality",** supported by key references, is included in Brief 39 as a special feature to highlight the enormous global importance of the drought tolerance 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. **Drought tolerance conferred through biotech crops is viewed as the most important trait that will become available in the second decade of commercialization, 2006 to 2015, and beyond, because it is by far the single most important constraint to**

increased productivity for crops worldwide. Drought tolerant biotech/transgenic maize, is the most advanced of the drought tolerant crops under development, and is expected to be launched commercially in the USA in 2012, or earlier. Notably, a private/public sector partnership hopes to release the first biotech drought tolerant maize by 2017 in Sub Saharan Africa where the need for drought tolerance is greatest.

- **Biofuel production in the USA in 2008**

In the USA in 2008, biofuel production was mainly ethanol from maize, with some biodiesel from oil crops. It is estimated that production from 29% of the total maize area in the USA in 2008 was used for ethanol, up from 24% in 2007. Accordingly, it is estimated that in 2008, 8.7 million hectares of biotech maize was devoted to ethanol production, up from 7 million hectares in 2007. Corresponding estimates for biodiesel in the USA indicate that in 2008, 475 to 500 million gallons of biodiesel will be produced. Approximately 3.5 million hectares of biotech soybean (7% of total biotech soybean plantings) will be used for biodiesel production; this compares with 3.43 million hectares (13% of total plantings) in 2007. It is further estimated that approximately 5,000 hectares of canola was used for biodiesel. In summary, a total of just over 12.2 million hectares were used in the USA in 2008 for biofuel production, of which about 70% was maize for ethanol.

- **Number of products approved globally for planting and import – 25 countries have approved planting and another 30 have approved import for a total of 55 countries**

While 25 countries planted commercialized biotech crops in 2008, an additional 30 countries, totaling 55, 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 670 approvals have been granted for 144 events for 24 crops. Thus, biotech crops are accepted for import for food and feed use and for release into the environment in 30 countries, including major food importing countries like Japan, which do not plant biotech crops. Of the 55 countries that have granted approvals for biotech crops, Japan tops the list followed by USA, Canada, Mexico, South Korea, Australia, the Philippines, New Zealand, the European Union and China. Maize has the most events approved (44) followed by cotton (23), canola (14), and soybean (8). The event that has received regulatory approval in most countries is the herbicide tolerant soybean event GTS-40-3-2 with 23 approvals (EU=27 counted as 1 approval only), followed by insect resistant maize (MON810) and herbicide tolerant maize (NK603) both with 21 approvals, and insect resistant cotton (MON531/757/1076) with 16 approvals worldwide. An up-to-date listing of all 670 approvals is detailed in Appendix 1 of Brief 39. It is notable that in 2008 both Japan and South Korea imported biotech maize for use as food for the first time. The stimulus for this was the unaffordability of the premium price for conventional maize versus biotech maize. The approvals by Japan and South Korea may be the forerunners of similar decisions by other countries importing biotech maize, including the EU.

- **The Global Value of the Biotech Crop Market – for 2008 it was valued at US$7.5 billion in 2008, with an accumulated value of US$50 billion for the period 1996 to 2007**

In 2008, the global market value of biotech crops, estimated by Cropnosis, was US$7.5 billion, (up from US$6.9 billion in 2007) representing 14% of the US$52.72 billion global crop protection market in 2008, and 22% of the approximately US$34 billion 2008 global commercial seed market. The 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$49.8 billion, which when rounded off to US$50 billion is a historical landmark for the global biotech crop market. The global value of the biotech crop market is projected at approximately US$8.3 billion for 2009.

Future Prospects

Outlook for the remaining seven years of the second decade of commercialization of biotech crops, 2006 to 2015

The future adoption of biotech crops in developing countries in the period 2009 to 2015 will be dependent mainly on a troika of major issues: first, establishment and effective operation of appropriate, responsible and cost/time-effective regulatory systems; second, strong political will and support for the adoption of biotech crops that can contribute to a more affordable and secure supply of food, feed and fiber – suffice to note that in 2008 broad and substantial political will was evident for biotech crops, particularly in developing countries; and third, a continuing and expanding supply of appropriate biotech crops that can meet the priority needs of more developing countries in Asia, Latin America and Africa.

The outlook for biotech crops in the remaining 7 years of the second decade of commercialization, 2006 to 2015, looks promising. In 2005, ISAAA projected that the number of biotech crop countries, hectarage and beneficiary farmers would all double by 2015 with the potential for number of farmers ranging from a minimum of 20 million to multiples thereof depending on when biotech rice is first approved. From 2009 to 2015, 15 or more biotech crop countries are projected to plant biotech crops for the first time, taking the total number of biotech crop countries globally to 40 in 2015, in line with the 2005 ISAAA projection. These new countries may include three or four in Asia; three or four in eastern and southern Africa; three to four in West Africa; and one to two in North Africa and the Middle East. In Latin/Central America and the Caribbean, nine countries are already commercializing biotech crops, leaving less room for expansion, however there is a possibility that two to three countries from this region may plant biotech crops for the first time between now and

2015. In eastern Europe, up to six new biotech countries is possible, including Russia, which has a biotech potato at an advanced stage of development, which also has potential in several countries in eastern Europe. Western Europe is more difficult to predict because the biotech crop issues in Europe are not related to science and technology considerations but are of a political nature and influenced by ideological views of activist groups.

The comparative advantage of biotech crops to produce more affordable and better quality food to ensure a safe and secure supply of food globally augurs well for a doubling of hectarage to 200 million hectares of biotech crops by 2015 for two principal reasons.

Firstly, there is considerable potential for increasing the biotech adoption rate of the four current large hectarage biotech crops (maize, soybean, cotton, and canola), which collectively represented 125 million hectares of biotech crops in 2008 out of a total potential hectarage of 315 million hectares; this leaves almost 200 million hectares for potential adoption with biotech crops. Deployment of biotech rice as a crop and drought tolerance as a trait are considered seminal for catalyzing the further adoption of biotech crops globally. In contrast to the first generation biotech crops that realized a significant increase in yield and production by protecting crops from losses caused by pests, weeds, and diseases, the second generation biotech crops will offer farmers additional new incentives for further increasing yield. RR2 soybean, to be launched in 2009, is the first of many such second-generation products. RR2 will further enhance yield by 7 to 11% as a result of genes that code for increased yield *per se*. Quality traits will also become more prevalent providing a much richer mix of traits for deployment in conjunction with a growing number of input traits.

Secondly, between now and 2015 there will be several new biotech crops that will occupy small, medium and large hectarages globally and featuring both agronomic and quality traits as single and stacked trait products. By far, the most important of the new biotech crops that are now ready for adoption is biotech rice: principally the pest/disease resistant biotech rice extensively field tested in China and awaiting approval by the Chinese regulatory authorities; and Golden Rice expected to be available in 2012. Rice is unique even amongst the three major staples (rice, wheat and maize) in that it is the most important food crop in the world and more importantly, it is the most important food crop of the poor in the world. Over 90% of the world's rice is grown and consumed in Asia by some of the poorest people in the world – the 250 million Asian households/families whose resource-poor rice farmers cultivate on average a meager half a hectare of rice. Several other medium hectarage crops are expected to be approved before 2015 including: potatoes with pest and/or disease resistance and modified quality for industrial use; sugarcane with quality and agronomic traits; and disease resistant bananas. Some biotech orphan crops are also expected to become available. For example, Bt eggplant may become available as the first biotech food crop in India within the next 12 months and has the potential to benefit up to 1.4 million small and resource-poor farmers. Vegetable crops such as biotech tomato, broccoli, cabbage and okra which require heavy applications of insecticides (which can be reduced substantially by a biotech product) are also under development. Pro-poor biotech crops such as biotech cassava, sweet potato, pulses and groundnut are also candidates. It is noteworthy that several of these products are being developed by public sector national or international institutions in the developing countries. The development of this broad portfolio of new biotech crops augurs well for the continued global growth of biotech crop, which ISAAA projected to reach 200 million hectares by 2015 grown by a minimum of 20 million farmers or more.

The second decade of commercialization, 2006-2015, is likely to feature significantly more growth in Asia and Africa compared with the first decade, which was the decade of the Americas, where there will be continued vital growth in stacked traits, particularly in North America, and strong growth in Brazil. Adherence to good farming practices with biotech crops, such as rotations and resistance management, will remain critical as it has been during the first decade. Continued responsible stewardship must be practiced, particularly by the countries of the South, which will be the major new deployers of biotech crops in the second decade of commercialization of biotech crops, 2006 to 2015. The use of biotechnology to increase efficiency of first generation food/feed crops and second-generation energy crops for biofuels presents both opportunities and challenges. Whereas biofuel strategies must be developed on a country-by-country basis, food security should always be assigned the first priority and should never be jeopardized by a competing need to use food and feed crops for biofuel. Injudicious use of the food/feed crops, sugarcane, cassava and maize for biofuels in food insecure developing countries could jeopardize food security goals if the efficiency of these crops cannot be increased through biotechnology and other means, so that food, feed and fuel goals can all be adequately met. The key role of crop biotechnology in the production of biofuels is to cost-effectively optimize the yield of biomass/biofuel per hectare, which in turn will provide more affordable fuel. However, by far the most important potential contribution of biotech crops will be their contribution to the humanitarian Millennium Development Goals (MDG) of ensuring a secure supply of affordable food and the reduction of poverty and hunger by 50% by 2015.

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 notes 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 big challenge is to transform this problem of a 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. It is encouraging to witness the growing "political will" for biotech crops at the G8 international level and at the national level in developing countries. This growing political will and conviction of visionaries and lead farmers for biotech crops is particularly evident in several of the lead developing countries highlighted in this Brief. Failure to provide the necessary political will and support for biotech crops at this time will risk many developing countries missing out on a one-time window of opportunity and as a result become permanently disadvantaged and non-competitive in crop productivity. This has dire implications for the hope of alleviating poverty for 1 billion resource-poor farmers and the rural landless whose livelihoods and indeed survival is largely dependent on improved yields of crops which are the principal source of food and sustenance for over 5 billon people in the developing world, a significant proportion of whom are extremely poor and desperately hungry – a situation that is morally unacceptable in a just society.

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Feature Article On

Drought Tolerance in Maize

Introduction

ISAAA is pleased to present a special feature on the status of drought tolerance in conventional and biotech maize by Dr. Greg O. Edmeades.

The proverb "Water is the staff of life" reminds us that water is important and precious. Agriculture currently uses over 70% (86% in developing countries) of the fresh water in the world. Water tables are dropping fast in countries like China, and water supplies will continue to shrink worldwide as global population will grow from the current 6.7 billion to more than 9 billion people by 2050. Whereas people drink only 1 to 2 liters a day, the food and meat we eat in a typical day takes 2,000 to 3,000 liters to produce (Pollack, 2008). Both conventional and biotechnology approaches are required to develop crops that use water more efficiently and are more tolerant to drought. Given the lack of water and its cardinal role in crop production it follows that tolerance to drought and efficient water usage should be assigned the highest priority in developing future crops. The situation will be further exacerbated as global warming takes its toll, with weather expected to become generally drier and warmer, and as competition for water intensifies between people and crops.

Drought tolerance conferred through biotech crops is viewed as the most important trait that will be commercialized in the second decade of commercialization, 2006 to 2015, and beyond, because it is by far the single most important constraint to increased productivity for crops worldwide. Drought tolerant biotech/transgenic maize, is the most advanced of the drought tolerant crops under development, and is expected to be launched commercially in the USA in 2012. Notably, a Private/Public sector partnership hopes to release the first biotech drought tolerant maize by 2017 in sub Saharan Africa where the need for drought tolerance is greatest.

Given the pivotal importance of drought tolerance, ISAAA invited Dr. Greg O. Edmeades, former leader of the maize drought program at CIMMYT, to contribute a timely global overview on the status of drought tolerance in maize, in both conventional and biotech approaches, in the private and public sector, and to discuss future prospects in the near, mid and long term. The contribution by G.O. Edmeades, "Drought tolerance in maize: an emerging reality", supported by key references, is included in Brief 39 as a special feature to highlight the enormous global importance of the drought tolerance 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. In order to provide the contribution by G.O. Edmeades a broader distribution, an abridged unreferenced version, is featured as a companion document to the Executive Summary of Brief 39, with more of a focus on biotech approaches than conventional, more on the activities of the private sector than the public sector, and on sub Saharan Africa, where there is considerable work on drought underway because of the urgent humanitarian need to boost the yields of maize, which is the staple food for more than 300 million people, a significant proportion of whom is suffering from hunger and malnutrition.

Drought Tolerance in Maize: An Emerging Reality
by G.O. Edmeades

1. Drought and maize: the scope of the problem

Maize is the third most important cereal under global cultivation, after wheat and rice. Maize grain yields in the temperate developed world average 8.2 ton/ha vs. 3.5 t/ha in tropical less developed countries (FAOSTAT, 2008). In both production environments drought is the most important abiotic stress constraining and destabilizing maize grain production, and is one of several reasons for the differences between mean production levels of temperate vs. tropical regions. In both regions water deficits occur unpredictably throughout the season. Within-field variability in soil texture and depth means that plant-available soil water also varies, and this can result in yield variation of up to 10-fold in a relatively dry year. Since farmers usually plant a single variety in any given field, this implies a need for a good level of drought tolerance in the large majority of hybrids and varieties grown under rainfed conditions.

Most of the 160 m ha of maize grown globally is rainfed, and annual yield losses to drought are thought to average around 15% of potential yield on a global basis. Transient randomly timed water deficits act as a significant limitation to yield in the US Corn Belt in 20% of years. Losses are somewhat greater in tropical countries that rely on a relatively unpredictable rainy season for crop growth, and are somewhat less in temperate areas where irrigation is more common and where rainfall is more evenly distributed throughout the season (Edmeades *et al.,* 2006).

Production in drought-prone regions such as southern and eastern Africa or West Africa shows a strong dependence on seasonal rainfall totals (Heisey and Edmeades, 1999). Maize is a staple food for more than 300 million people in sub-Saharan Africa, and a number of countries in these geographic regions often experience drought in the same season, creating regional food shortages that cannot easily be alleviated by cross-border trade. For example, Bänziger and Araus (2007) reported that the production of maize in southern Africa fluctuated from 12.5 million tons in 1992 (a drought year) to 23.5 m tons in 1993. They noted also that between 2003 and 2005 the World Food Program spent US$1.5 bn to alleviate food shortages due to drought and crop failure in sub-Saharan Africa alone. Drought-tolerant maize could play a significant part in meeting the Millennium Development Goals of “halving by 2015 the share of people suffering from extreme poverty and hunger.”

Why not simply irrigate the crop? The prospects of adding additional irrigated land on which maize will be grown are rather dim, given that irrigated land area is projected to increase at a rate roughly equal to or less than the population growth rate. Growth in irrigated area will mostly be in Asia, and most will be dedicated to higher value crops. Energy cost to pump ground water has recently doubled in some countries. Thus additional maize production will be needed from the drought-prone “marginal” areas of both temperate and tropical countries, but especially in sub-Saharan Africa (Heisey and Edmeades, 1999). Given the recent rise in international maize and fertilizer prices, there is mounting pressure to increase yield and yield stability in environments where there are real risks to production from drought.

Variability in rainfall (and hence in drought) seems likely to increase as the effects of climate change are more fully felt. As temperatures rise and rainfall patterns change, additional losses of maize grain may approach 10 million tons/year (Jones and Thornton, 2003), currently worth almost US$5 bn. These trends can be seen already in parts of Central America where rainfall may fall by more than 50% over the next century (Neelin *et al.,* 2006). Drought and heat tolerant crops will play an increasingly important part in adapting to this variation and to the long term underlying trend towards a hotter and probably drier production environment (World Bank, 2007). As a rough rule of thumb, it has been estimated that 25% of losses due to drought can be eliminated by genetic improvement in drought tolerance, and a further 25% by application of water-conserving agronomic practices, leaving the remaining 50% that can only be met by irrigation (Edmeades *et al.,* 2006).

2. How maize responds to drought stress

Typical visual symptoms of drought stress in maize are a loss of turgor, a change in color from a healthy green to grey, and an increased degree to leaf rolling, especially in lower leaves. These changes are associated with stomatal closure and a reduction in photosynthesis per plant, resulting in a slowing of growth. If this occurs when the crop is within 1-2 weeks of flowering, ear growth slows as assimilate flow declines and a delay in silk emergence relative to anthesis takes place, generating a large anthesis-silking interval (ASI). As stress intensifies, leaf senescence begins at the base of the plant and spreads to the whole canopy. Drought-affected ears are small, with fewer, smaller kernels. If stress is severe at flowering, ears may completely abort and the plant becomes barren.

Where water is limiting biomass production, it is helpful to think of grain yield as the product of three factors: the amount of water available to the plant for transpiration (W); the efficiency with which water is converted to biomass (water use efficiency, WUE); and efficiency with which that biomass is converted to grain (harvest index, HI) (Passioura, 1977). One clear way of increasing the flow of assimilates to the developing ear, and to offset some of the effects of early leaf senescence, is for the plant to capture more soil water (W). Each of these terms can affect grain yield, and all can be altered. One way to increase W is for the plant to develop deep roots reaching further into the subsoil. Provided roots are not restricted by a zone of compaction or acid soil, and the soil has wetted to this depth, deeper rooting will increase W. Deeper roots are needed rather than more roots, and differences in rooting depth and water extraction have been reported among hybrids (Edmeades *et al.,* 2006), though the trait is slow and laborious to measure in the field. Water supply to the crop can also be increased by minimizing weed competition and planting the maize crop at its optimum density. W may also be increased by the capacity of the plant to adjust osmotically and therefore "suck" more water from the soil (Chimenti *et al.,* 2006), though this is not considered an important mechanism in tropical maize. WUE in maize is maximized by maintaining healthy leaves with high levels of nutrients, and delaying leaf senescence and the effects of leaf aging on photosynthetic efficiency. Genetic variation for both root morphology and staygreen may be insufficient to ensure significant changes in yield from conventional plant breeding focused on these two traits (Edmeades *et al.,* 2006).

Harvest index (HI) is often reduced by drought. Among the cereals, maize is unusually susceptible to water stress at flowering when kernels are being set. In part this is caused by its floral structure, where male flowers (tassels and anthers) are physically separated from female flowers (ears and silks). Maize is normally cross-pollinated, so pollen must travel some distance before it lands on a silk. Under stress, ear growth slows more rapidly than tassel growth, and a visual symptom of this is the Anthesis-Silking Interval (ASI). With very uniform hybrids, this delay is sometimes sufficient for silks to emerge after pollen shedding has declined, and pollination may fail because of a pollen shortage. Generally however, the slow growth of the ear is linked directly to a failure of kernel set, and in extreme cases the entire plant may be barren. Thus, in susceptible genotypes, kernel set is affected by stress that occurs 10-14 days either side of anthesis. The reduction in grain yield under drought is more strongly associated with an increase in barrenness and a decline in kernel number per ear than with a reduction in weight per kernel or any other secondary visual symptom (Edmeades *et al.,* 2000; Barker *et al.,* 2005).

The strong dependence of grain yield on ASI when the crop is grown under stress during flowering and grain filling suggests that events at flowering play a critically important part in yield stability (or lack of it) under drought. Fortunately, there appears to be adequate variability for this trait even among elite hybrids (Fig. 1). The correlation between ASI and grain yield (GY) under stress at flowering is often -0.4 to -0.7 (Bolaños and Edmeades, 1996). This relationship is ubiquitous in maize, having been observed among elite Corn belt hybrids, tropical varieties and landraces. However, ASI is considered to be an external indicator of the ability of the genotype to partition more of its currently forming biomass to the developing ear at flowering, thus helping to ensure its reproductive success. Much modern crop improvement has sought to increase biomass flow to the developing ear by having tassels and ears develop synchronously so kernel set is stabilized and grain yield is increased, and ASI is one trait that is extensively used for this purpose. In highly selected temperate maize, improvement in yield has been attributed in part to increases in stress tolerance, in part through this mechanism (Tollenaar and Wu, 1999; Duvick *et al.,* 2004).

When the maize plant has successfully set kernels, these need to fill using photosynthesis occurring after flowering or from assimilates stored in the stem before or shortly after flowering. The maintenance of an active leaf area to intercept light and convert it to biomass during grain

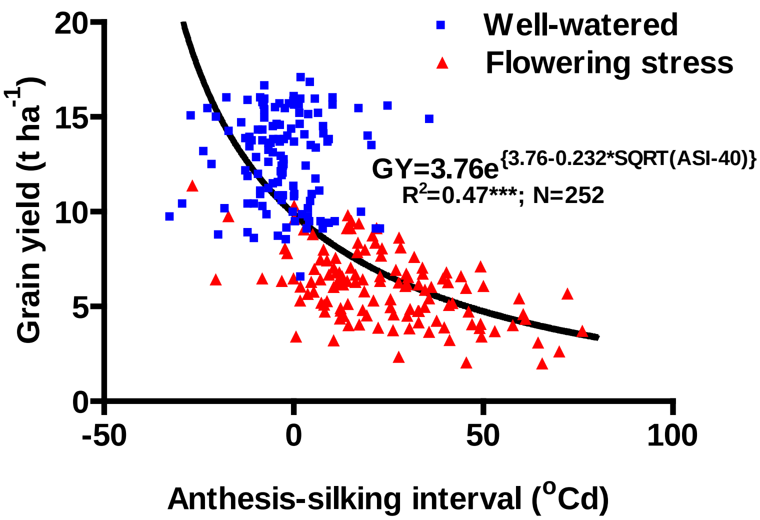

Figure 1. Relationship between grain yield and anthesis-silking interval (in heat units) for 126 elite Corn Belt hybrids grown under two water regimes (Campos *et al.,* 2004).

filling is essential to this process. A delay in leaf senescence under stress, known as staygreen, is an important genetic adaptation to drought stress. Associated with this is resistance to photo-oxidation of chlorophyll (or bleaching) by bright sunshine when the leaf loses its turgor. Prolonged water stress during grain filling, and accelerated leaf senescence caused by drought results in small kernels, and those near the tip of the ear will often abort, causing a further decline in HI.

3. Development of drought-tolerant products

a. What is needed for successful product development?

For breeders to successfully improve a crop for drought tolerance they first must be able to access heritable genetic variation for tolerance. Experience suggests that stress tolerant alleles are present at low frequencies in most elite breeding populations, so these populations should be evaluated first. Unimproved sources such as landraces, while sometimes possessing unique alleles, are often poorly adapted, difficult to evaluate, and are low yielding. Genetic variation can be considered as variation for grain yield per se, for the components of yield such as kernel weight and number, or for the physiological components (secondary traits) that contribute to the formation of yield under drought stress.

There are many putative drought-tolerance traits that have been documented, but useful secondary traits are those that are correlated with yield under stress, cheap and fast to measure, genetically variable and highly heritable, stable in expression and not associated with yield loss under unstressed conditions (Barker *et al.,* 2005). Relatively few meet these criteria. For maize the strongest associations with improved grain yield under stress, in descending order, have been with: an absence of barrenness; increased kernel number per plant and per ear; a short ASI; increased leaf erectness; reduced canopy temperature; and increased visual staygreen and kernel weight (Bolaños and Edmeades, 1996). Many other traits are currently under consideration, but it is critically important that each shows its contribution to yield or yield stability in the context of a practical field breeding program where hundreds of genotypes may need to be evaluated daily. Where multiple traits are measured per genotype as well as grain yield, most breeders combine these data into a selection index that also includes grain yield under stress. In order to make it worthwhile measuring anything other than yield itself, the heritability the index must exceed that of grain yield alone, and there is good empirical evidence that an index comprising yield, barrenness, ASI, staygreen and leaf rolling under drought meets this criterion.

A second requirement for a breeder is an environment where stress intensity, timing and frequency can be reliably managed to expose genetic variation for traits season after season. Traditionally selection for stable yield has been through multilocation yield trials within the target population of environments (TPE). Patterns of drought are not repeatable, giving rise to genotype x year interactions that are hard to unravel. Most breeders now opt for managed drought stress environments (MSEs) that represent the intensity and timing of an important type of drought stress in that TPE. These are rain-free testing sites that allow stringent control of the nature, timing and intensity of water stress though the application of irrigation. Increased interplant and interplot variability normally occurs under stress, so emphases on secondary traits and precision phenotyping are needed (Barker *et al.,* 2005). Well-irrigated control plantings are normally used to monitor changes in yield potential. Statistical methods of removing spatial trends in data are normally required, but there is no substitute for careful selection and management of experimental sites. Marker-aided selection (MAS) has helped reduce the volume of testing that needs to be done under managed drought stress, but the genotype-phenotype associations upon which MAS is based require precise reliable phenotyping. This is also the case when validating utility of new genes and constructs when transgenic products are under development.

b. *Product development in the public sector*

For the past 35 years CIMMYT has undertaken selection for drought tolerance in tropical maize using rain-free tropical locations plus irrigation to create its MSEs. These studies have been extensively described elsewhere (Bolaños and Edmeades, 1996; Edmeades *et al.,* 2000; Bänziger *et al.,* 2006; Edmeades, 2006). In summary, recurrent selection was conducted for 2-8 cycles in six improved tropical populations, normally under well-watered and two distinct drought stress regimes in Mexico. Use of an index during selection increased yield, and reduced ASI, barrenness and leaf senescence under drought. Evaluations in multilocation trials under optimal, water stress and low N environments showed consistent gains averaging 166 and 99 kg ha-1 cycle-1 under drought and optimal conditions, and concomitant reductions in ASI and barrenness (Table 1). In dry environments gains were significantly greater than those in comparable populations improved through multilocation testing alone. Gains from selection under drought MSEs transferred well to other environments such as moderately low N. In a subsequent test C0 and the corresponding most advanced cycle of three populations were tested under stress at Pioneer test sites varying from 19 to 35ºN latitude. Even though adaptation was poor, gains averaged 132 kg ha-1 cycle-1, and showed a non-significant interaction with yield level (Fig 2). This suggests that selection resulted in a fundamental change in floral behavior and reproductive efficiency through changes in biomass partitioning to and within the ear.

Based on these promising results, the locus of selection was moved to southern Africa in 1997. Selection methods were modified to always screen under low N, drought stress at flowering and optimal conditions, and were applied in a regular maize breeding program. All yield trials, including around 1000 early generation hybrids were tested under these carefully managed MSEs, and data used during advancement decisions. Emphasis was placed on grain yield and secondary traits whose heritability remained high under stress. Selection was based on indices that included all sites, and was designed to maintain or increase yields under unstressed conditions. A number of national research programs have also adopted this methodology and provided MSEs that were used to validate genetic gains obtained from testing in CIMMYT's key selection centers in Zimbabwe and Kenya (Bänziger and Araus, 2007).

Significantly larger yield gains have been realized in southern Africa compared with Mexico. When CIMMYT-selected hybrids were compared with current commercial hybrids across 36-65 sites ranging in yield from 1 to 10 t/ha they showed a 13-20% yield advantage in the 1-5 ton/ha yield range, this advantage declining to 3-6% in the 5-10 t/ha yield range. The greater superiority in lower yielding environments almost certainly reflects the emphasis on these conditions during selection of CIMMYT germplasm (Bänziger *et al.,* 2006). The success of this approach has resulted in the Drought Tolerant Maize for Africa Project (DTMA), funded by the Bill and Melinda Gates Foundation. This project is using conventional selection and MAS to improve drought tolerance in maize germplasm adapted to the drier sub-Saharan maize environments. The project involves CIMMYT, IITA and 11 national programs in western, eastern and southern Africa. Phenotyping is concentrated in well-developed MSEs established in Kenya, Zimbabwe and Nigeria, and in Mexico for upstream gene and QTL discovery studies.

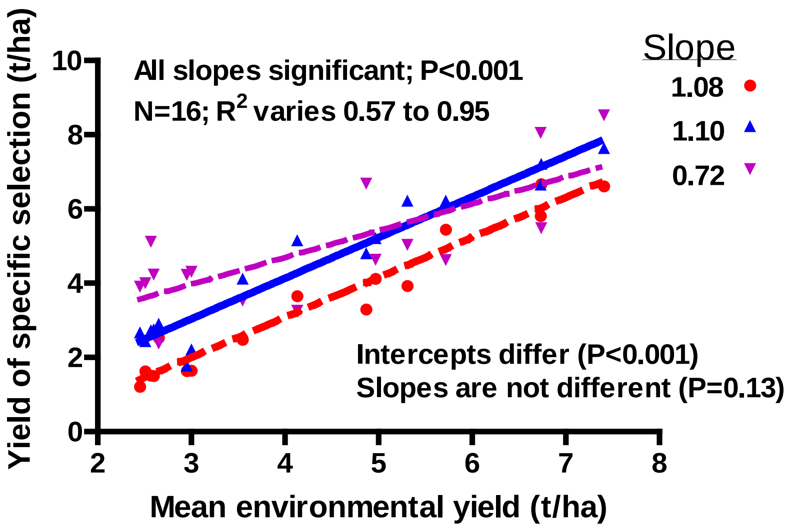

Figure 2. Yield of unselected and selected versions of a tropical population when grown in environments to which it was not adapted. Yields of York Dryland Synthetic, a broadly adapted Corn Belt synthetic, are given as reference. C0 and C6 differed by > 1 t ha-1 across the whole yield range.

Table 1. Selection gains in six tropical maize populations. Four were evaluated at 3-6 water stressed (SS) sites, at 5-8 well-watered (WW) sites, or at two low N sites in 1992-4, and two (DTP1, DTP2) were evaluated at one low N, SS or WW location in 2002-3. Symbols *, **, ns signify significant rate of change per selection cycle at P<0.01, P< 0.05 or P>0.05 (Edmeades, 2006).

Population	Cycles selected	Yield			ASI	Ears plant-1
		SS	kg ha^{-1} cyc^{-1}	Low N	SS d cyc^{-1}	SS No. cyc^{-1}
La Posta Seq.	3	229**	53 ns	233**	-1.2**	0.07**
Pool 26 Seq.	3	288**	177**	207**	-1.5**	0.08**
Tuxpeño Seq.	8	80**	38**	86**	-0.4**	0.02**
Pool 18 Seq.	2	146**	126**	190**	-2.1**	0.05**
DTP1	6	170*	83 ns	218*	-0.6**	0.03**
DTP2	9	81*	117 ns	64 ns	-0.3**	0.01*
Mean gain		166	99	166	-1.0	0.04
Yield relative to unstressed		30%	100%	59%	30%	30%

Molecular breeding for improved drought tolerance has also been studied by CIMMYT scientists and more recently by the Generation Challenge Program (GCP). A significant QTL discovery program has identified a number of QTL associated with ASI, barrenness, and a wide array of putative secondary traits. A drought maize consensus linkage map of key traits, based on 40 evaluations of progenies from six tropical maize crosses, has been established (Sawkins *et al.,* 2006), but shows large QTL x population interactions. The cross-specificity of QTLs and the absence of QTLs with large effects have rendered this approach less useful in identifying "universal" QTL than anticipated. Nonetheless, MAS has been used to successfully transfer the short ASI trait from a donor to a relatively drought susceptible line, CML247, resulting in crosses which exceeded yields of the original CML247 by 2-4 times under stress (Ribaut *et al.,* 2002). The molecular component of the DTMA project is the successor to this research, and a large database of phenotypic and molecular data is currently being assembled based on excellent field trials at the MSEs in Zimbabwe and Kenya (DTMA, 2008). Large-effect QTLs for grain yield under drought have however been identified in rice (Bernier *et al.,* 2007), and the search for similar large-effect QTLs continues in maize.

Public sector efforts in delivering drought tolerance via transgenes are few, because of the costs involved in development and deregulation. Africa Harvest Biotech Foundation Int. (AHBFI) has recently gained access to YPT transgenic technology from Performance Plants Inc. (see below) for generating drought tolerant white maize for Africa. AHBFI and PPI plan to develop and yield test YPT transformants in those sub-Saharan countries with established biosafety protocols, though it is unclear if there is a regulatory package associated with this gene. AHBFI has no direct access to managed stress testing sites or a seed distribution network in sub-Saharan Africa, except possibly through cooperating national research programs.

c. Product development in the private sector

i. *Conventional:* it is important to acknowledge the significant improvement in drought tolerance that has occurred in temperate commercial hybrids adapted to the US Corn Belt. Although we briefly consider evidence for this from hybrids developed by Pioneer, the trends over time are likely be very similar in commercial products released by the other leading commercial seed companies.

   A subset of 18 Era hybrids (Duvick *et al.,* 2004) was evaluated at a single plant density in a rain-free summer location in Chile over two seasons. These were commercially important releases between 1953 and 2001 (3 hybrids per decade), developed through extensive multi-environment testing in the target environment. Water was withdrawn in five distinct but overlapping windows of stress from flowering to physiological maturity, and grain yields were reduced by 36-71% compared with the irrigated control. Rates of gain in grain yield (Figure 3A) over time were greatest under unstressed conditions (196 kg ha-1 yr-1), moderate under flowering stress (120 kg ha-1 yr-1), and least (52 kg ha-1 yr-1) in late-grainfill stress. This contrasts with the relatively consistent gains observed in tropical selection studies where MSEs were used during progeny evaluation, and performance under stress was heavily weighted during selection. Gains in ASI were greater under flowering stress (Figure 3B). Yield gains were accompanied by an increase in kernels per plant, due mainly (60%) to reduced barrenness and less (40%) to increased kernels per fertile ear. Weight per kernel showed no gain under terminal stress, but significant gain under irrigation. A similar trend was observed in staygreen (Figures 3C and D), suggesting that the lack of progress observed in weight per kernel and in staygreen under drought stress were linked causally.

In a study of the full set of 54 Era hybrids in Woodland, CA, under two plant densities Cooper *et al.* (2006) reported similar trends. In this study, stress was imposed only at flowering and throughout grainfilling and was less severe than in Chile. Gains under

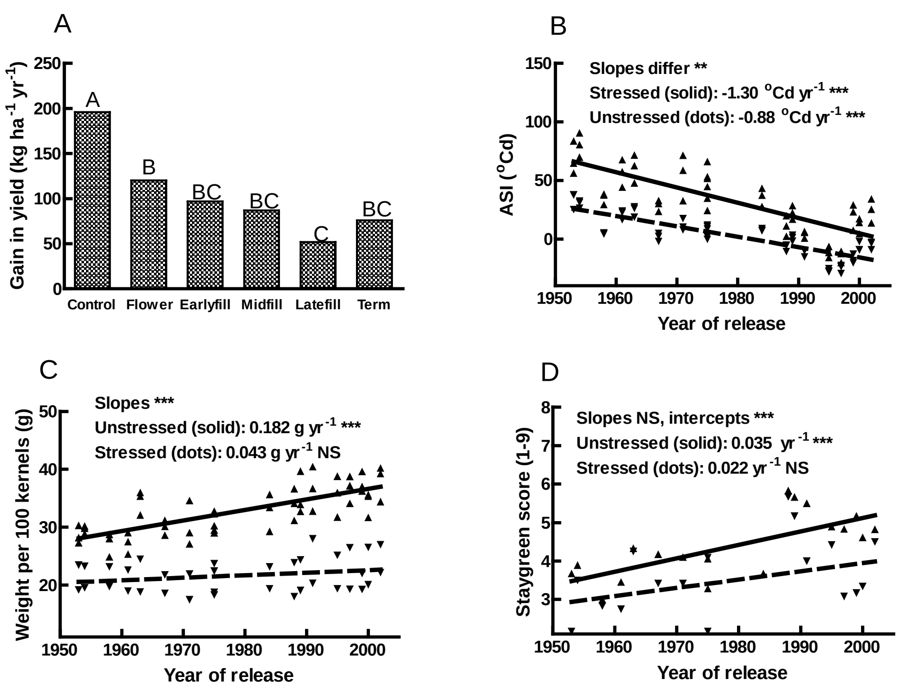

Figure 3. Gains from selection; A: grain yield, where different letters on columns indicate significant differences; B: ASI, with drought at flowering (N=54); C: weight per kernel, under terminal drought (N=36-54); D: Staygreen score under terminal drought (N=18) (Edmeades, 2006).

irrigated conditions were around 50% those observed in Chile, though gains under the two Woodland stress regimes were similar to those reported from Chile.

It is clear that progress in drought tolerance has been made through selection based on very extensive multi-environment trials. These results confirm that elite germplasm contains a low frequency of drought adaptive alleles, and increasing their frequency does not necessarily cost yield potential. Gains were almost exclusively through increases in kernel set under mid-season stress, initially from reduced barrenness and later from improved kernel set per ear. Progress in tolerance to terminal drought has been relatively small, probably because genetic variation for staygreen and root growth during grain fill was lacking in the original population.

Molecular breeding methods, including transformation of genes from other species, and marker-aided selection based on gene-phenotype associations within the species, should further speed progress for these traits. Precision phenotyping of critical processes with high repeatability (c. 0.5-0.7) and conducted in MSEs is needed for molecular breeding based on gene-phenotype associations. Crosbie *et al.* (2006) and Eathington *et al.* (2007) have indicated that the use of markers during marker-aided recurrent selection (MARS) has virtually doubled the rate of genetic gain in Monsanto's maize populations. It is very effective at increasing the frequency of favourable marker alleles in a population. It comes at a cost: programs have about a 7-fold increase in data collected compared with a conventional selection program, and with MARS selections are made 3-4 times per year instead of the usual 1-2 (Bernardo, 2008). Pioneer's "mapping as you go" presumably offers similar rates of increase in genetic gain in the context of a regular pedigree breeding program (Podlich *et al.,* 2004).

Association genetics and whole genome scans are showing considerable promise in identifying key regions associated with drought tolerance. Because these techniques rely on a dense marker map (usually of SNPs), extensive bioinformatics capacity and large-scale precision phenotyping, they are mainly restricted to the big commercial seed companies (Crosbie *et al.,* 2006; Eathington *et al.,* 2007; Bernardo, 2008). There is little doubt that MARS, mapping as you go, and association mapping methods, when applied to improving yield under drought, will be effective at increasing the rate of genetic gain for yield under drought over conventional selection, provided that they are accompanied by precise phenotyping. Gene-phenotype associations are only as reliable as the phenotyping on which they are based.

ii. *Transgenic:* A survey of published literature and of company websites was undertaken, but does not reveal the detail and extent of private sector investments in transgenic research for drought tolerance. The following is a general idea of the level of activity by a few leading companies based on their public disclosures. Drought tolerance is a complex trait, and a suitable transgenic strategy may well rely on transcription factors affecting a number of genes, or several transgenes engineered into the same construct.

Monsanto is considered to be a leader in transgenic research for drought tolerance in maize, and is scheduled to commence commercial sales of a transgenic drought tolerant product in 2012, and the trait is now in Phase III of testing. Published papers suggest that this transgene was identified from Arabidopsis and the maize homolog was then overexpressed in maize to provide a gene offering 8-22% yield improvement (average: 15%) under a drought stress that reduces yields by about 50%. More recent statements have downplayed these yield gains slightly. The level of improvement depends on the genetic background of the recipient hybrid, and it probably varies with the environment. It does not appear to reduce yields under unstressed conditions – an important requirement for a successful transgene in North America, though the vast majority of transgenes that have been tested carry some yield drag. A recent publication by Nelson *et al.* (2007) describes the procedure which Monsanto has generally followed in gene discovery, though it seems unlikely that the gene described (At *NF-YB1*) is the commercial candidate. The lead candidate almost certainly affects the strength of the source (i.e. photosynthesis) rather than the sink (kernel setting, flowering). The regulatory approval process for North America, Japan and the EU is under way, and permission has been given to test this event in South Africa. Additional classes of transgenes imparting abiotic stress tolerance currently being examined by Monsanto include chaperone proteins belonging to the family of cold stress proteins, CspA and CspB (Castiglioni *et al.,* 2008). It seems likely that Monsanto's second generation of drought transgenes, already listed in their trait pipeline, will include candidates from this general class of genes. Monsanto has recently signed an agreement with BASF to further develop drought tolerant germplasm, and it appears that BASF is channelling all its drought-tolerance transgene candidates through Monsanto's seed delivery system.

Pioneer Hi-Bred has conducted an active research program on transgene-based drought tolerance. In 2003-4 Pioneer claimed to have identified an effective transgene that increased kernel setting under stress occurring at flowering, but this product line has been dropped. Pioneer is now testing a possible candidate for a 2013 release. The mode of action of this transgene is not known. Pioneer has good testing sites under managed stress in Chile and California, but no similarly developed locations in sub-Saharan Africa. It can, however, distribute improved seed effectively in that region. The company describes three stages in its release procedure for drought tolerant germplasm. Stage 1 is of carefully screened current elite hybrids showing exceptional drought tolerance (example: 33D11), with products available now. A second stage product relies on native genes selected using directed MAS, with products ready in 2-3 years; the third generation would combine conventional selection with one or more transgenes and deliver a product in 5+ years. This approach implies complementarity between conventionally selected and transgenic drought tolerance mechanisms. New breeding techniques that can shorten selection cycles and speed progress include a non-destructive analysis of DNA from a seed sliver cut by laser from the seed. Pioneer is collaborating with Evogene, an Israeli company specializing in computational genomics to identify putative drought tolerance genes.

Syngenta has a relatively smaller research effort in drought tolerance. They have recently signed a research agreement with Performance Plants Inc. for access to their yield protection technology (YPT). Their website gives no details of when a commercial product involving transgenic drought tolerance may be launched, but it will likely be after 2014. Their testing sites under managed stress are significantly less developed than those of Monsanto and Pioneer, and Syngenta has a weak seed distribution network in sub-Saharan Africa.

Other suppliers of candidate genes include BASF who has a research agreement with Monsanto. BASF purchased the Belgian company CropDesign in 2005 and this provided access to drought tolerance genes for rice. Dow has allied itself with Syngenta, and may supply variants of the yield stabilizing gene coding ADP glucose pyrophosphorylase to Syngenta for testing. Dow also has agreements with Monsanto on multi-gene transformation technology (up to 8 transgenes at a time). Bayer is researching genes that reduce the drought-induced oxidant load that leads to tissue damage (e.g., PARP). It is unclear how this product will be marketed commercially. In general all three companies rely on the major seed companies to provide introgression, field testing and regulatory services. Evogene Ltd. has signed licensing agreements with Pioneer and Monsanto. Performance Plants Inc. (PPI) is a small Canadian company that has recently patented its Yield Protection Technology (YPT) that relies on engineered versions of Arabidopsis's farnesyl transferase genes. These increase sensitivity to ABA, closing stomates rapidly when the plant stresses, and have shown good activity in canola, but only modest effects in maize under drought. PPI has research agreements established with Syngenta and Pioneer, and claims that a drought tolerant variety of maize has been field tested for 2 years. Other candidates include members of the DREB/CBF transcription factor family (Yamaguchi-Shinozaki *et al.,* 2006). While these appear effective at the seedling stage their value for increased grain yield in maize or wheat in the field has yet to be demonstrated conclusively, and over-expression leads to stunting.

There are many other putative drought genes. Most have been tried in maize by transnational seed companies and found to be ineffective under drought in adult field-grown plants, or they have an unacceptable yield drag under optimal conditions. Very few have regulatory packages associated with them. Identification of commercial-quality transgenes that enhance both survival under drought and production under adequate water supply remains a lengthy, tedious and expensive process, but one whose success rate is rapidly improving as genomics and computational biology begin to deliver new analytical tools. Unfortunately progress in rapidly and cheaply measuring phenotypes is occurring at a much slower rate.

4. Product delivery: its challenges and opportunities

The distribution and adoption of drought tolerant germplasm is an obvious step towards impact in farmers' fields, yet it is often a major constraint to the use of these technologies. In developed countries adoption will depend mainly on the price of seed, superior and stable yield under drought that occurs at any time throughout the growing season, and competitive yield under unstressed conditions. Seed price and easy seed availability are especially important for resource-poor farmers who have little capacity to accommodate risk, even though they are fully aware of profitability considerations (Heisey and Edmeades, 1999). The occurrence of drought is itself a significant risk, and any new technology that requires additional cash outlay for seeds at the start of the season may impose an unacceptable risk to a farm family's resources. On the other hand, loss of yield potential under well-watered conditions is of less importance than in developed farm economies. Where a farmer can purchase open-pollinated variety (OPV) seed from a neighbour, or retain seed from the previous harvest, seed costs are minimized, so in drought-prone environments this is often the course of action taken. The purchase of hybrid seed each crop season is an example of a cost that many small-scale farmers in risky production areas are unable to justify, even though it can be demonstrated that the risks of crop failure are subsequently reduced by using stress-tolerant hybrids or varieties.

Private seed companies remain the means of choice to distribute drought tolerant germplasm, provided sufficient profit can be made from hybrids marketed into lower yielding and riskier drought-prone regions. Ideally, hybrids with their higher cost of seed should target those areas where mean yields are 2-4 t/ha or greater, leaving the lower yielding areas to OPVs (Pixley, 2006). However, average maize yields in sub-Saharan Africa are 1.6 t/ha (FAOSTAT, 2008), suggesting that hybrids will be used on the higher yield potential areas subject to moderate stress only. Until mean yield levels increase substantially, there remains a need for a diversity of seed systems that deliver drought tolerant germplasm – including NGOs, government agencies, universities and private seed companies.

The deployment of drought tolerance in the form of hybrids has many benefits. Commercial seed quality and seed treatments are generally better than those of home stored seed, thus reducing risk of failed plantings. Heterosis is a form of stress tolerance in its own right (Betrán *et al.,* 2003; Edmeades *et al.,* 2006), so hybrids are generally more drought tolerant than OPVs.

The generation and sale of hybrid maize seed, as opposed to seed of OPVs, has provided the foundation for a viable and stable seed industry in a number of developing countries, and is considered an essential step in the development of a stable seed industry.

Public and private seed companies in less developed countries are hampered by a lack of trained staff and quality-enhancing competition, credit constraints, a weak infrastructure for distributing and marketing product, and inappropriate seed policies. As a consequence, the maize seed industry in much of sub-Saharan Africa is still unable to offer consistent and well-tested hybrid seed options to small-scale farmers (Tripp, 2001).

Transgenic drought tolerance is likely to encounter additional adoption challenges in less developed countries (Tripp, 2001). The immediate constraint is the lack of an established regulatory framework in many developing countries. At present transgenic crops can be field tested and marketed only in three sub-Saharan countries because regulations governing the safe field testing and stewardship of transgenic crops are not yet in place elsewhere. James (2007) considers the lack of appropriate cost-effective and responsible regulation based on a common sense approach to the actual risks involved is the most important constraint to the deployment of genetically modified crops. Present systems are modelled on risks that experience suggests were overestimated, are onerous and expensive to implement, and beyond the reach of the vast majority of private and public seed institutions in the less developed world. Thus, the precautionary principle on transgenic crop regulation in its present form is hurting resource-poor farm families – the very people it was designed to protect.

A second challenge lies with adoption when transgenic crops look the same as their normal counterparts in terms of seed and product. If the hybrid is generally superior agronomically, adoption usually occurs through word of mouth, and not necessarily because it is a drought tolerant product. If its superiority is evident only in dry years this will require a major branding approach – something that the hybrid seed industry is skilled at executing. The complexity of managing, breeding and exercising stewardship over transgenic crops suggests that seed supply is beyond the capacity of most farmer groups, and beyond a number of Government seed agencies in less developed countries. Tripp (2001) concludes that investments in public biotechnology must be matched by policies that encourage commercial seed system development that empowers the farmers to fully utilize this new technology through improved seed and accurate product information. For transgenic drought tolerant maize to achieve anything like its potential in sub-Saharan Africa where it is desperately needed, these changes need to occur at an accelerated pace.

a. Public sector

While the relatively small private seed sector is gaining experience and confidence in sub-Saharan Africa, innovative approaches are needed to ensure that seed of stress tolerant maize hybrids and varieties reach those most in need. As an intermediate step to generate confidence among farmers, CIMMYT and cooperating national programs and seed companies have successfully used the Mother-Baby trial system in southern and eastern Africa as a means of generating farmer participation in selection, adoption and seed production (Bänziger and DeMeyer, 2002). Systematic collaboration among institutions on farmer participatory variety selection has provided an effective method for production and dissemination of improved stress tolerant OPVs (Edmeades *et al.,* 2006). National programs, CIMMYT, IITA and private seed companies have collaborated to evaluate and then release seed in a number of countries, and the most promising of these new drought tolerant varieties, ZM521, is now thought to occupy over 1 million ha in SE Africa. The success of this combined selection, testing and seed distribution scheme has been the driving force behind the development and funding of the Drought Tolerant Maize for Africa (DTMA) Project. This project has an ambitious vision: Within 10 years, generate maize germplasm with 1 t/ha yield increase under drought stress conditions, increase average maize productivity under smallholder farmer conditions by 20-30% on adopting farms; and reach 30-40 million people in sub-Saharan Africa, potentially adding an annual average of US$160-200 million of grain in drought-affected areas. It involves extensive inter-institutional cooperation on policy advocacy, impact monitoring, training, varietal testing, seed release and scaled up seed production. The project is upgrading the drought tolerance of a number of widely used varieties as well as developing new varieties, and on-farm variety trials are being conducted at ~400 locations in target environments. A major goal is to engage and strengthen the emerging national or regional private seed sector. Around 80 seed companies operating in sub-Saharan Africa are actively participating in testing and marketing DTMA-generated drought tolerant hybrids and varieties, and in developing the trust of their clients. The project will develop inbreds and make them available to all who request the seed – on the principle that if a company has exclusive rights to a successful line it will not have to compete based on other factors important to customers and to the long term survival of the company. South Africa has a mature maize seed industry, and is providing advice to emerging companies in the rest of the region.

b. Private sector

Transnational maize seed companies (Monsanto, Pioneer, Syngenta, and to a lesser degree Pannar, SeedCo and Pacific Seeds) are represented in most of the larger, higher yield potential markets in the less developed world. They have an advantage over national seed companies in that they can transfer adapted germplasm from one region to another and reduce product development overheads. Furthermore, the larger transnationals have extensive research budgets and networks for positioning products that attract research agreements with suppliers of complementary technologies, such as candidate gene constructs. In short, they are uniquely positioned to develop and distribute high quality transgenic hybrid seed, and to position these hybrids in appropriate markets. The comparative advantage of transnationals will lessen only when regulatory requirements are less onerous, when MAS and MARS become less expensive, and when agreements on intellectual property can be negotiated more readily. However, because transnational seed companies operate only in the larger markets in areas where yields are relatively high, there is a good opportunity for national seed companies to establish a market niche comprising smaller market segments, and meet real needs through a balanced portfolio of stress tolerant hybrids and elite OPVs.

c. ***Private/public partnerships:***

Partnerships between private and public sector research organization are a strategy often proposed but rarely executed. Several successful private-public partnerships have been negotiated and managed by ISAAA. One important joint venture of this nature has recently been launched in eastern and southern Africa involving Monsanto as the main technology provider, CIMMYT as the source of key phenotyping sites and adapted maize germplasm, and national programs and seed companies as partners in testing and delivery of drought tolerant maize hybrids. The Water Efficient Maize for Africa Project (WEMA) is funded by the Bill and Melinda Gates Foundation, and is currently completing its first year of operation. The African Agricultural Technology Foundation (AATF), a Nairobi-based not-for-profit organization, will serve as the implementing agency, and will spearhead efforts to ensure regulatory compliance of Monsanto's drought tolerance transgene in target countries. This five year project deploys an elegant combination of new technologies directed at improving drought tolerance in maize germplasm adapted to a drought-prone region of eastern and southern Africa. It builds on the effectiveness of conventional selection for drought tolerance in maize as practiced by CIMMYT and national co-operators, using MAS to increase rates of genetic gain and Monsanto's lead transgene designed to provi de an incremental jump of around 15% in grain yield under drought. The Monsanto MAS technology is being used, based on whole genome selection, and could double rates of genetic gain for drought tolerance. Crosses between lines carrying the event and tropical lines from CIMMYT are taking place. The effect of the transgene should simply add to that obtained by CIMMYT through conventional selection, though it is untested in tropical maize backgrounds. The transgene is planned for release in Sub Saharan Africa in 2017. Monsanto is providing major contributions in kind through advanced techniques in MAS, and a royalty-free concession to seed companies who wish to use the transgenic trait. Target countries in eastern and southern Africa are South Africa, Mozambique, Kenya, Uganda and Tanzania. Impact from germplasm improved by MAS should be felt within 5 years, and from transgenic drought tolerant hybrids after 2017. This project presents a unique and important opportunity to bring modern technology to address drought tolerance for the poor, and will help put in place the regulatory procedures needed to bring other transgenes to this needy region.

5. The way forward

a. ***Expected rates of progress:***
The recent substantial investment by the Gates Foundation in developing and disseminating drought tolerant maize for sub-Saharan Africa has provided a tremendous impetus to stabilizing and improving maize production in this drought-prone region where maize forms a critically important part of the diet. This builds on a solid research effort led by CIMMYT (Bänziger *et al.,* 2006) spanning 35 years. Research of this nature is a relatively slow process, but there are real prospects of increasing the rate of improvement using new techniques. The use of MAS to increase the rate of genetic gain in both the DTMA and WEMA Projects could double the rate of genetic gain, and the availability of a transgene boosting grain yield under drought throughout the crop season opens exciting possibilities. These three approaches – conventional selection, MAS and genetic modification – will likely be additive in effect. The first two provide the prospect of steady improvement over time, and the 15% improvement offered by Monsanto's transgene could be matched by ~3-5 years of conventional + marker-aided selection. The transgene provides a one-off boost to yields obtained by MAS. However, if technology providers such as Monsanto, Pioneer, Syngenta or BASF are persuaded to release newly developed transgenes providing a similar boost to grain yield every 5 years or so, and if their effects are also additive (a good possibility with a complex trait like drought tolerance), then the cumulative effects of transgenes, MAS and conventional selection for drought tolerance can generate very significant improvements in grain yield (Figure 4). There are large investments being made in the development of genetically modified crops by the private sector in the USA and Europe, and these are being matched by public sector investments in China, India, Brazil and the USA. The recent announcement of a US$3.5 bn investment in genetically modified crops in China over the next decade is the most recent tangible example of this commitment (Stone, 2008).

b. ***Managed Drought Stress Environments, MSEs:*** Reliable drought phenotyping requires MSEs where drought stress is controlled and applied at the designated timing and intensity. The value of MSEs for efficient drought selection in maize has been consistently demonstrated over the past 20 years (Bänziger *et al.,* 2006). Progress can be made using multi-location testing at randomly selected sites in the target population of environments (Cooper *et al.,* 2006), but only if it is on a very large scale. For less developed countries this is not an efficient way of improving yield under water-limiting conditions. A further investment in centers of excellence in phenotyping for drought tolerance in the less developed world seems fully justified. This opens up the possibility of improving a range of crops for drought tolerance in addition to maize at the same location. It is an initiative that would boost operational efficiency, and should be seriously considered by the donor community.

c. ***New genetic variation, new methods:*** The lack of intraspecific genetic variation for staygreen under terminal drought stress, and for root depth management in maize has already been noted. Transgenic sources of new variation for these traits will likely be required, along with a careful physiological evaluation of the whole-plant effects of such transgenes. Multiple genes contained in single constructs allow for efficient stacking of traits. New molecular methods are under experimentation such as the use of mini chromosomes where a single heritable piece of the plant's own DNA that includes the centromere region is used to deliver several genes simultaneously (Varshney *et al.,* 2005). Small RNA fragments are emerging as powerful control elements of stress response in plants (Sunkar *et al.,* 2007).

d. ***Agronomic interventions:*** Improved crop management methods can complement the use of drought tolerant hybrids and contribute significantly to increasing and stabilizing yields under rainfed conditions or under irrigation where water supply is limited. Ensuring that planting densities are optimal, tillage is minimal, weeds are controlled and adequate fertilizer is applied at the right growth stage all increase water use efficiency (WUE). Water supply to the crop can be increased by water harvesting methods and the use of mulch (Heisey and Edmeades, 1999). Where irrigation is in short supply, deficit irrigation, or the application of water at less than the potential evapotranspiration rate, can increase water use efficiency (WUE) at little cost to yield. Partial root drying, where dry and wet regimes are alternated under irrigation to reduce water applied can elicit a drought-adaptive response and may save up to 25% of the water normally applied (Fereres and Soriano, 2007).

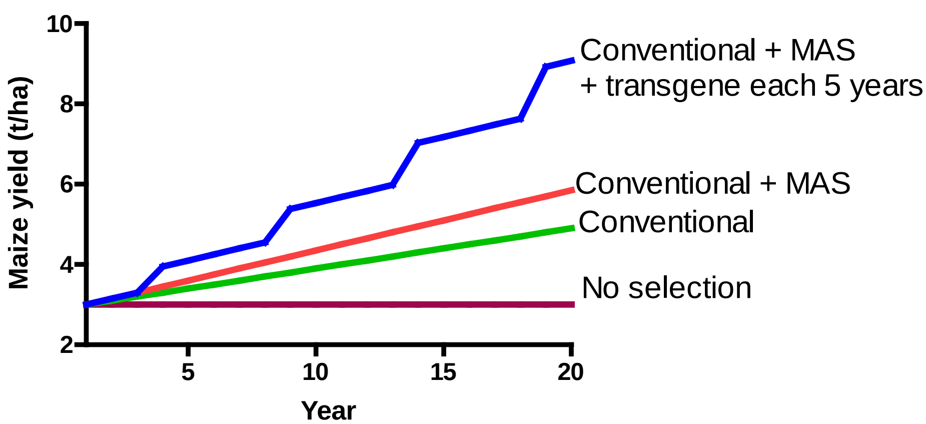

Figure 4. Projected cumulative genetic gain over a 20 years in maize being selected for drought tolerance using conventional selection methods (100 kg/ha/yr), conventional plus marked-aided selection (MAS) (150 kg/ha/yr) and conventional plus MAS plus a transgene introduced every 5 years. Each transgene boosts grain yield by a further 15%. Effects of each intervention are considered additive.

e. ***Regional regulatory and release initiatives:*** There is considerable potential for regional harmonization of regulatory procedures in regions like sub-Saharan Africa. If deregulation of a specific transgene has been approved by one country based on a thorough evaluation using standard protocols, this should normally be sufficient to deregulate that same construct and event when used in the same species in other countries in the region. Release of improved varieties and hybrids could be harmonized in a similar manner across countries sharing common agroecologies, e.g., West Africa.

6. Conclusions

Considerable progress has been made over the past 35 years in directed selection for drought tolerance in maize, building on the gains in this trait arising from multi-location testing during selection. The availability of high quality managed stress environments where small phenotypic differences can be repeatably detected has coincided with the advent of molecular breeding, and marker-assisted selection and genetic modification depend heavily on accurate phenotyping for their success. These tools offer real opportunities for "speeding the breeding", but come at a cost. Fortunately well-resourced technology providers in the form of transnational seed companies have shown their willingness to share this technology, sometimes on a royalty-free basis. Linkages between supplier and users of these advanced breeding techniques have been facilitated by generous donor support, and this has been extended to the emerging seed industry in less developed areas such as sub-Saharan Africa. We have a confluence of several key processes that are essential components in the delivery of stable and high crop yields to resource-poor farm families. It is a unique opportunity that should not be squandered.

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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 2008. 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

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		
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	✓			
Cotton	*Gossypium hirsutum L.*	HT	LLCotton25	Bayer CropScience				2006	
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	

LEGEND

HT	Herbicide Tolerance	NIC	Nicotine reduction
IR	Insect Resistance	F	Fertility restored
VR	Virus Resistance	CPP	Cedar pollen peptide
FC	Modified flower color	CPP	Cedar Pollen Peptide
DR	Delayed ripening/altered shelf life	Plt Quality	Mod Amylase
Oil Content	Modified oil content	Flav Path	Flavonoid Biosynthetic Pathway
Lys	Enhanced Lysine content	*	The product has been approved for planting/cultivation but it is not necessarily in commercial production at present

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AUSTRALIA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
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		
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	

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 (10)

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	*Gyssoypium hirsutum L.*		CP4 EPSPS/NPT 11 (Mon 1445)	Monsanto Company	2008	✓		2008	2008
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	2008
Maize	*Zea mays L.*	IR	Mon 810	Monsanto Company	2008	✓		2008	2008
Maize	*Zea mays L.*	HT + IR	BT11	Syngenta Seeds Inc	2008	✓		2008	2008
Maize	*Zea mays L.*	HT	GA21	Monsanto Company	2008	✓		2008	2008
Maize	*Zea mays L.*	HT	NK 603	Monsanto Company	2008	✓		2008	2008
Maize	*Zea mays L.*	HT/IR	PAT/ cry1Fa2	Pioneer/Dow AgroSciences	2008	✓		2008	2008

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	

CANADA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Cotton	*Gossypium hirsutum L.*	HT	BXN	Calgene Inc.				1996	1996
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
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
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
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

CHINA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
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		
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		
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	✓			
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	

COLOMBIA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Carnation	*Dianthus caryophyllus*	FC	not available	Florigene Pty Ltd.	2000	✓			
Cotton	*Gossypium hirsutum L.*	IR	MON 531	Monsanto Company	2003	✓	2003	2003	
Cotton	*Gossypium hirsutum L.*	HT	MON 1445	Monsanto Company	2004	✓	2003	2004	
Maize	*Zea mays L.*	IR	MON 810	Monsanto Company	2002		2003		2006
Maize	*Zea mays L.*	IR	TC1507	Mycogen (c/o Dow AgroSciences); Pioneer (c/o Dupont)	2006			2006	2006
Maize	*Zea mays L.*	HT	NK 603	Monsanto Company			2004		
Soybean	*Glycine max L.*	HR	Mon-Ø4Ø32-6	Monsanto Company					2007

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

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		

EUROPEAN UNION (27 Member States)

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
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
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	✓			

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		CICR (ICAR) & UAS, Dharwad	2008	✓			

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

JAPAN

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
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	
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	2006			2005	2006
Maize	*Zea mayz L.*	IR + HT	SYN - EV176-9	Inc.	2007	✓	2007		
Maize	*Zea mays L.*	HT	B16 (DLL25)	Syngenta Seeds Inc.	1999	✓		1999	2000
Maize	*Zea mays L.*	HT	T14	Dekalb Genetics Corporation	2006			1997	2001
Maize	*Zea mays L.*	HT	T25	Bayer CropScience	2004	✓		2001	2003
Maize	*Zea mays L.*	HT	GA21	Bayer CropScience	1998	✓		1999	1999
Maize	*Zea mays L.*	HT/ HT	DP-098140-6	Monsanto Company	2007	✓			
Maize	*Zea mays L.*	HT	NK603	DuPont Inc.	2001	✓		2001	2001
Maize	*Zea mays L.*	HT + IR	176	Monsanto Company	1996			2001	1996
Maize	*Zea mays L.*	HT + IR	Bt11	Syngenta Seeds	1996			2001	1996
Maize	*Zea mays L.*	HT + IR	DBT418	Syngenta Seeds	1999			1999	
Maize	*Zea mays L.*	HT + IR	TC1507	Dekalb Genetics Corporation	2002	✓		2002	2002
Maize	*Zea mays L.*	IR	MON810	Mycogen (c/o Dow AgroSciences); Pioneer (c/o Dupont)	1996	✓		1997	1997
Maize	*Zea mays L.*	HT + IR	DAS-59122-7	Monsanto Company	2006	✓		2006	2006
Maize	*Zea mays L.*	HT + IR	MON88017	Dow AgroSciences LLC/Pioneer	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)	Monsanto Company	2008	✓		2007	
Maize	*Zea mays L.*	IR	SYN-IR6Ø4-5 (MIR604)	Dow AgroSciences LLC	2007	✓		2007	
Maize	*Zea mayz 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	Syngenta Seeds Inc	2006	✓		2005	2006
Maize	*Zea mays L.*	HT + IR	MON810 x MON88017	Dow AgroSciences LLC	2006	✓		2005	
Maize	*Zea mays L.*	HT + IR	SYN-BTØ11-1 x MON-ØØØ21-9	Monsanto Company	2007	✓		2007	
Maize	*Zea mays L.*	HT + IR	TC1507 x DAS59122-7 x NK603	Syngenta Seeds Inc.	2006	✓		2005	2006
Maize	*Zea mays L.*	HT + IR	MON89034	Dow AgroSciences LLC	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	Monsanto Company	2008	✓		2007	2008
Maize	*Zea mays L.*	IR	Mon 89034	Dow Agro Sciences LLC	2008	✓		2007	2008
Maize	*Zea mays L.*	IR	BT11 x MIR164x GA21	Monsanto Company				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	Syngenta Seeds Inc.				2008	
Maize	*Zea mays L.*	IR + HT	Mon 89034 x NK603	Monsanto Company				2008	

JAPAN

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
Maize	*Zea mays L.*	IR + HT	BT 11 x MIR604	Syngenta Seeds				2007	
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	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	✓			
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
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

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		
Cotton	*Gossypium hirsutum L.*	HT + IR	MON88913/ 15985	Monsanto Company				2006	
Cotton	*Gossypium hirsutum L.*	HT + IR	1445 x 531	Monsanto Company	2000	✓		2002	
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	

MEXICO

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food*	Feed
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		
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		
Sugar Beet	*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	2004	✓		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	
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	

NEW ZEALAND

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
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	
Sugar Beet	*Beta vulgaris*	HT	H7-1	Monsanto Company				2005	
Sugar Beet	*Beta vulgaris*	HT	GTS B77	Monsanto Company				2002	

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
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				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
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
Sugar Beet	*Beta vulgaris*	HT	H7-1	Monsanto Company				2005	2005
Sugar Beet	*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
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	
Sugar Beet	*Beta vulgaris*	HT	GTSB77	Novartis Seeds; Monsanto Company				2001	
Sugar Beet	*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 vulgaris*	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	2001	2001
Soybean	*Glycine max L.*	HT	GTS 40-3-2	Monsanto Company	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	
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	

SOUTH KOREA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
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	
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	
Sugar Beet	*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

TAIWAN

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
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	
Soybean	*Glycine max L.*	HT	GTS 40-3-2	Monsanto Company				2002	2002
Soybean	*Glycine max L.*	HT	A2704-12	Bayer CropScience				2007	

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		
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		

USA

Crop	Latin Name	Trait	Event	Developer	Environment	* Planting	Food/Feed	Food	Feed
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		
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	
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		
Melon	*Cucumis melo*	DR	A.B	Agritope Inc	1996		1997		
Papaya	*Carica papaya*	VR	55-1/63-1	Cornell University	1996	✓	1996		
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		
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		
Sugar Beet	*Beta vulgaris*	HT	H7-1	Monsanto Company	2005	✓	2004		
Sugar Beet	*Beta vulgaris*	HT	T120-7	Bayer CropScience	1998	✓	1998		
Sugar Beet	*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, 2007

$M	Herbicides	Insecticides	Fungicides	Others	Biotech	Total
North America	6,030	1,565	934	408	5,158	14,095
West Europe	3,273	1,186	2,852	619	9	7,939
East Europe	698	431	359	89	1	1,578
Japan	822	982	824	85	0	2,713
Industrial Countries	10,823	4,164	4,969	1,201	5,168	26,325
Latin America	3,236	1,974	1,833	280	1,068	8,391
Rest of Far East	2,109	1,858	1,100	152	279	5,498
Rest of World	633	1,371	391	89	357	2,841
Developing Countries	5,978	5,203	3,324	521	1,704	16,730
Total	**16,801**	**9,367**	**8,293**	**1,722**	**6,872**	**43,055**

Source: Cropnosis Agrochemical Service, 2008

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, 2007 (with over 100 Million $ Market)

Country	Agricultural Seeds	Vegetable Seeds	Total
Netherlands	186	854	1,040
USA	650	369	1,019
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
	695	354	1,049
Total	**4,171**	**2,227**	**6,398**

Table 2. Seed Imports (FOB) of Selected Countries, 2007 (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 Fed	157	33	190
Belgium	125	27	152
Japan	79	62	141
Poland	98	41	139
China	63	53	116
Hungary	92	17	109
Others	1,189	656	1,845
Total	**4,175**	**2,063**	**6,238**

Source: International Seed Federation
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

Why the IAASTD Failed

by

Robert Wager

Why the IAASTD Failed

by

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Agriculture is a man-made activity that has for millennia changed many forms of plants and animals to suit our needs. Today there is a strong lobby calling for a return to organic agriculture. This affluence-centered ideology can not effectively support the less fortunate or future pressures of a growing human population. It was the science and technology of the green revolution that helped feed the population as it rose from 3 billion to 6 billion.

With great promise the international community began a multiyear project designed to evaluate the role of agricultural science and technology with the goal to help reduce hunger, malnutrition and poverty. This International Assessment of Agricultural Science and Technology for Development (IAASTD) brought together people from many different walks of life. The first meeting was held in 2004 with 185 different groups represented. They included 45 governments, 86 NGO/civil societies, 29 co-sponsoring agencies (World Bank, UNESCO, UN-FAO, WHO etc) and representatives from international biotechnology companies.

The mission statement of the IAASTD promised to evaluate the relevance, quality and effectiveness of agricultural knowledge, science and technology (AKST) in reducing hunger, improving sustainability, improving nutrition, health and livelihood of the world rural populations.

The interim report of their findings was recently published [1]. In the four years since the inception of this project, the science of agriculture seems to have taken a backseat to ideology.

The IAASTD claims the report on AKST is: “an evidence-based guide for policy and decision-making.” However the suggestions of ‘perceived risks’ and ‘potential harm’ are in many of the paragraphs dealing with biotechnology even though the evidence of risks and harm are lacking.

The International Council for Science is likely the world’s largest collect of scientific opinion with most National Academies of Science and over 150 scientific organizations. In 2003 the ICSU published a very extensive review [2] of genetically modified (GM) crops and food.

The ICSU review looked at the following pertinent questions: Who needs GM Food? Are GM Foods Safe to eat? Will GMO’s affect the Environment?

The opinion of this truly global scientific organization is very clear when it states: “-- there is no evidence of any ill effects from the consumption of foods containing genetically modified ingredients” “There are also benefits [eg. vitamin content of rice] to human health coming from GM foods” “Pest tolerant crops can be grown with lower levels of chemical pesticides, resulting in reduced chemical residues in food and less exposure to pesticides.”

And with respect to the environment the ICSU report states: “there is no evidence of any deleterious environmental effects having occurred from the trait/species combinations currently available.”

Nevertheless the IAASTD report states: "As the general public has become increasingly interested in the linkages between agricultural production systems and human health, the list of food related health concerns has continued to grow. It includes uncertainty with regard to the effects of GMO's on human health."

In fact there is very little uncertainly. The science is very clear. However, a massive international anti-GMO campaign by many NGO's has planted the seeds of doubt in the public. There is no evidence to support these 'perceived risks' and therefore they have no place in the "evidence-based" IAASTD report.

The IAASTD review also states: "Emerging evidence indicates that organic farmers are able to sustain their livelihoods--" This may be true in some places, but certainly not on a global scale with a world population of over six billion. Nobel Laureate Dr. Norman Borlaug said it well when he said organic agriculture can only feed four billion people and he does not see two billion volunteers [to starve to death].

On average, organic agriculture produces only 70 percent of the yield of conventional agriculture. If we were to increase organic agriculture on a global scale as suggested in the IAASTD report we would have to put the remaining wilderness under the plow just to produce the same amount of food we do today. What would we do when the population reaches 7-8 billion? Clearly such a massive increase in organic agriculture at the expense of other forms of agricultural production would severely threaten global biodiversity and have profound negative impact on the environment world-wide.

Although North America has accepted GM crops and biotechnology the same can not be said for Europe. However it is not a difference in scientific opinion that blocks widespread adopt of biotechnology crops in Europe. In 2001 the European Commission released a report [3] on the safety of GM crops and food. Research over 15 years involving 81 projects and over 400 scientists concluded: "GM plants---have not shown any new risks to human health or the environment, beyond the usual uncertainties of conventional plant breeding. Indeed, the use of more precise technology and greater regulatory scrutiny probably make them safer than conventional plants and food."

There has been a misinformation campaign against genetically modified crops and food by NGO's that spans the past 15 years. No amount of positive research mattered to their campaigns. Statements made to the British House of Lords by the head of a large international NGO made it clear that this NGO's opposition to genetically modified crops and food is permanent regardless of any future scientific safety evaluations. This type of blind ideology does not fit anywhere in a scientific assessment. However, this particular NGO is very active in the IAASTD.

Every year millions of children suffer from vitamin A deficiency. Lack of this key vitamin in the diet causes 500,000 cases of blindness a year and up to 6000 deaths a day in the developing world. Researchers created a type of genetically modified rice with elevated levels of beta carotene (vitamin A precursor). International attempts to freely distribute this rice to subsistence farmers in the developing world have been blocked with overly cautious regulations.

There is no doubt that some of the NGO participants of the IAASTD have been very active in helping to create and implement regulatory road blocks to the free distribution of Golden Rice which is in direct conflict of one of the stated outcomes of increased nutrition by the IAASTD.

The authors of the IAASTD report are absolutely correct when they say: "choices we make at this junction in history will determine how we protect our planet and secure our future."

Yet there is no mention of the UN-FAO statement: Biotechnology would provide powerful tools for the sustainable development of agriculture and food production [4].

"Success [including alleviating malnutrition, reducing hunger and improving health] would require increased public investment in AKST, the development of supporting policy regimes." This IAASTD statement is completely opposed by the continued expansion of overly cautious, onerous regulations.

One estimate has it costing 20 million dollars to gain commercial certification of a single GM crop. This is far in excess of the abilities of public-funded research. The end result of these costly regulations is that biotechnology crops which would help the poor are not developed. Drought tolerance, salt tolerance and insect resistance are just three examples of genetically modified crops that could help farmers in developing countries. But extremely high costs of regulatory compliance keep these beneficial crops from being developed by public-funded research.

There is public-funded research in agricultural biotechnology programs in over 70 countries. This global research community was very disappointed with the draft IAASTD report. After reading the report the Public Research and Regulations Initiative stated: " We believe that the chapter [biotechnology] is written from a perspective that is so fundamentally different from what we believe should have been the perspective of such an evaluation, that a submission of comments on the many technical omissions and errors would not be meaningful."[5]

The unbalanced nature of the IAASTD report becomes even clearer when it states: "some long standing problems such as mycotoxins continue to significantly add to the health burden, especially of infants". It is very difficult to reconcile the statements of desire to improve nutrition and health with the complete omission of any statements of peer-reviewed data that consistently showed insect resistant GM maize has much lower levels of mycotoxins than either conventional or organic maize.

The IAASTD claims to want to reduce pesticide use but then refuses to acknowledge the massive reductions in pesticide use afforded by growing insect resistant GM crops. Interestingly, nowhere in the report is there any mention of the widespread use of highly toxic copper compounds in organic agriculture. It is very clear modern synthetic fungicides are far less harmful to the environment than these copper compounds which persist for decades.

Over 8 million farmers in the developing world now grow GM crops and each year sees a 20 percent increase. This adoption rate indicates there are real benefits of biotechnology crops for these farmers.

Scientific evidence shows substantial benefits of growing biotechnology derived crops. Yet the IASSTD warns against increasing education and training of farmers in the use of GM crops. It is hard to understand this position in light of the overwhelming scientific data in support of genetically engineered crops.

One of the most striking examples favouring organic agriculture in the IAASTD report is the suggestion that organic certification is threatened by pollen flow from GM crops. This is pure rhetoric directly from the organic food industry. During a time of unprecedented growth of both GM and organic agriculture there has not been a single case of loss of certification of an organic farmer as a result of pollen flow from neighbouring GM crops. In fact the International Federation of Organic Agriculture Movements does not advocate any testing for GM content.

The executive summary of the IAASTD report repeatedly advocates increases in organic agriculture without similar endorsements for biotechnology. This seems very strange as in the body of the report it states an alternative pathway forward with less biotechnology would mean "humanity would likely be more vulnerable to climate and other shocks and to increased natural resource scarcity".

Most of the 6000 year history of agriculture is by definition organic. This type of poor yield agriculture is exactly why we have significant problems with hunger, malnutrition, soil degradation and poverty in much of the developing world. To suggest organic agriculture is the best way to improve this defies logic and demonstrates how the reported "science-based" assessment of the IAASTD has been completely over-ridden by ideological based green-washing. It is very clear why those who work in the fields of agriculture biotechnology are so disappointed by the non science-based IASSTD report.

[1] International Assessment of Agricultural Knowledge, Science and Technology for Development http://www.agassessment.org/index.cfm?Page=Plenary&ItemID=2713

[2]International Council of Science http://www.icsu.org/2_resourcecentre/INIT_GMOrep_1.php4

[3] European Commisstion Research
http://ec.europa.eu/research/quality-of-life/gmo/index.html

[4] FAO Statement on Biotechnology. Food and Agriculture Organization http://www.fao.org/biotech/stat.asp

[5] Public Research and Regulation Initiative
http://www.pubresreg.org/

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