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International Service for the Acquisition of Agri-biotech Applications

EXECUTIVE SUMMARY

BRIEF 37

Global Status of Commercialized Biotech/GM Crops: 2007

by

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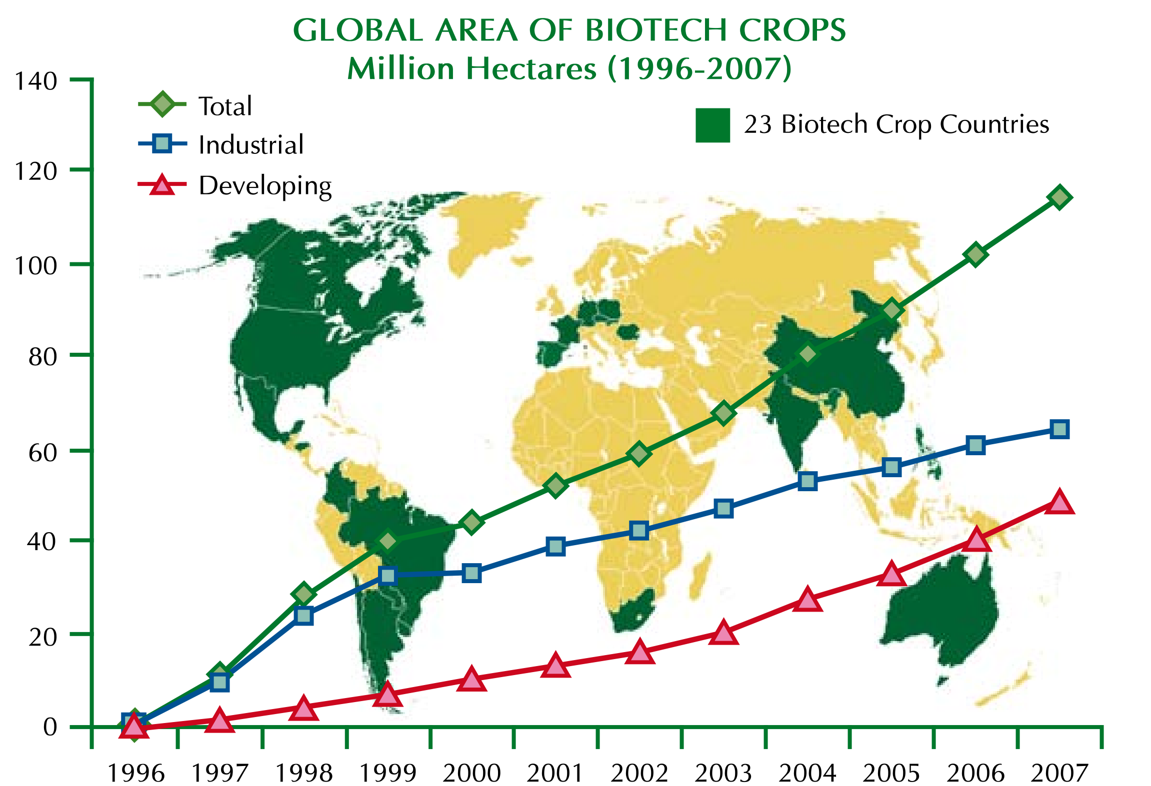

Increase of 12%, 12.3 million hectares (30 million acres), between 2006 and 2007.

Source: Clive James, 2007.

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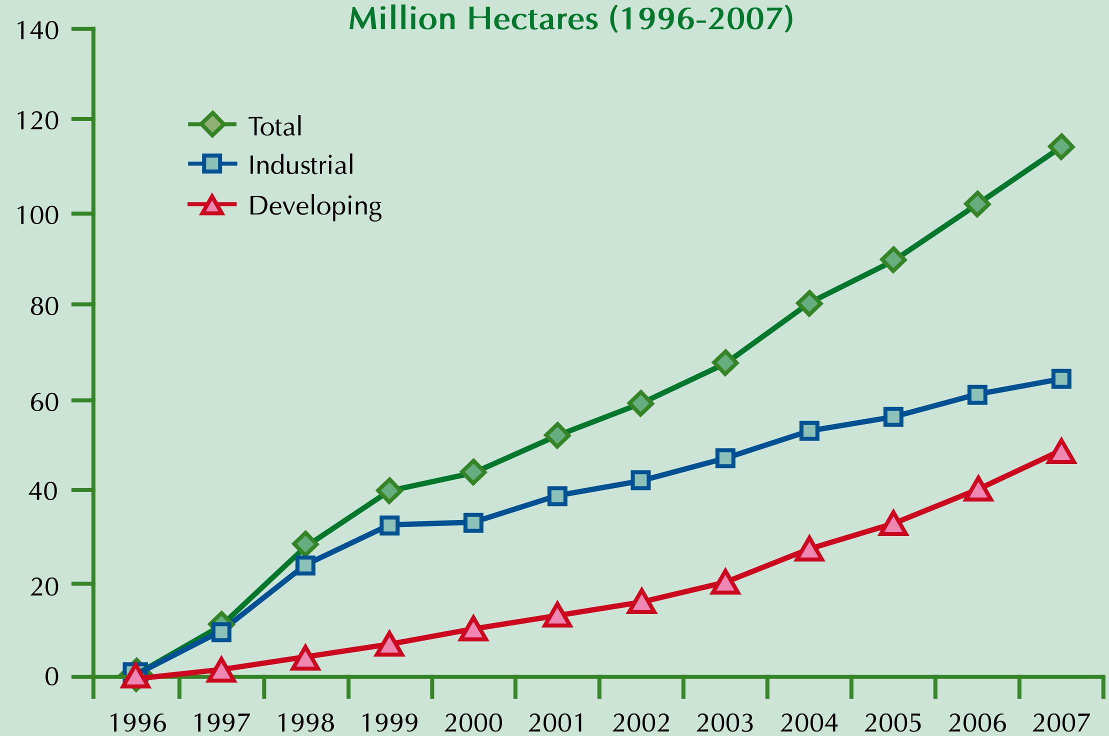
Global Status of Commercialized Biotech/GM Crops: 2007
The First Dozen Years, 1996 to 2007

As a result of consistent and substantial benefits during the first dozen years of commercialization from 1996 to 2007, farmers have continued to plant more biotech crops every single year. In 2007, for the twelfth consecutive year, the global area of biotech crops continued to soar. Remarkably, growth continued at a sustained double-digit growth rate of 12%, or 12.3 million hectares (30 million acres) – the second highest increase in global biotech crop area in the last five years – reaching 114.3 million hectares (282.4 million acres). The first dozen years of biotech crops have delivered substantial economic and environmental benefits to farmers in both industrial countries and developing countries, where millions of poor farmers have also benefited from social and humanitarian benefits which have contributed to the alleviation of their poverty. In order to more accurately account for the prevalent and increasing use of two or three "stacked traits", which confer multiple benefits in a single biotech variety, adoption growth is more precisely measured when expressed as "trait hectares", rather than hectares – this is similar to measuring air travel in "passenger miles" rather than miles. Growth measured in "trait hectares" between 2006 (117.7 million) and 2007 (143.7 million) was 22%, or 26 million hectares, reflecting the actual growth between 2006 and 2007, which is approximately double the apparent growth of only 12%, or 12.3 million hectares, when conservatively measured in hectares.

In 2007, the number of countries planting biotech crops increased to 23, and comprised 12 developing countries and 11 industrial countries; they were, in order of hectarage, USA, Argentina, Brazil, Canada, India, China, Paraguay, South Africa, Uruguay, Philippines, Australia, Spain, Mexico, Colombia, Chile, France, Honduras, Czech Republic,

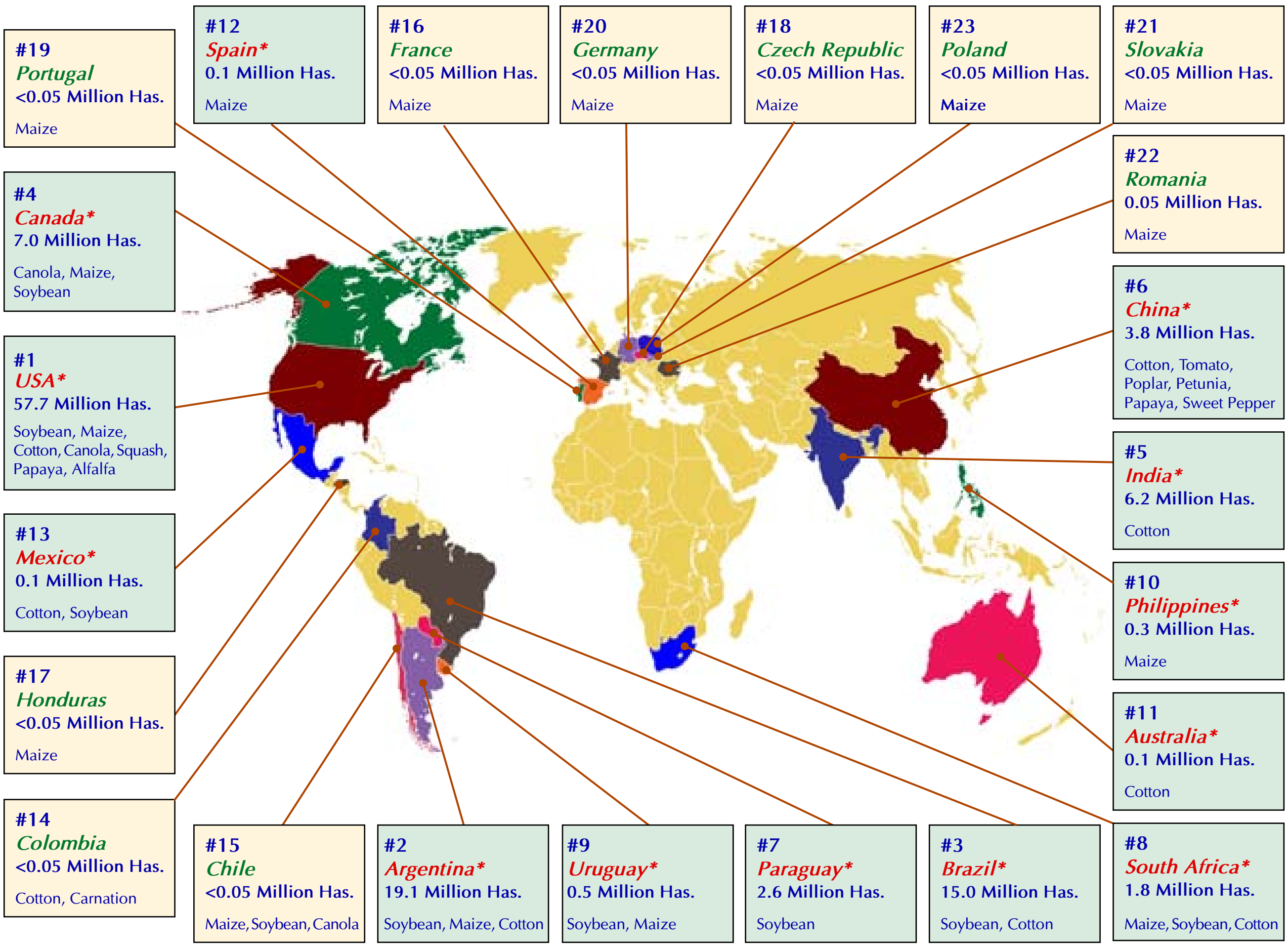
GLOBAL AREA OF BIOTECH CROPS
Million Hectares (1996-2007)



Increase of 12%, 12.3 million hectares (30 million acres), between 2006 and 2007.

Source: Clive James, 2007.

Biotech Crop Countries and Mega-Countries*, 2007



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

Source: Clive James, 2007.

Portugal, Germany, Slovakia, Romania and Poland. Notably, the first eight of these countries grew more than 1 million hectares each – the strong growth across all continents in 2007 provides a very broad and stable foundation for future global growth of biotech crops. The two new biotech crop countries in 2007 were Chile producing over 25,000 hectares of commercial biotech crops for seed export, and Poland, an EU country, growing Bt maize for the first time. The accumulated hectarage from 1996 to 2007 exceeded two thirds of a billion hectares for the first time at 690 million hectares (1.7 billion acres), with an unprecedented 67-fold increase between 1996 and 2007, 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. Thus, this is a strong vote of confidence from approximately 55 million individual decisions by farmers in 23 countries over a 12-year period to plant biotech crops, year after year, after gaining first-hand insight and experience with biotech crops on their own or neighbor's fields. Notably, 2007 marks the first year when the accumulated number of farmer decisions to adopt biotech crops has exceeded 50 million.

Table 1. Global Area of Biotech Crops in 2007: by Country (Million Hectares)

Rank	Country	Area (million hectares)	Biotech Crops
1*	USA*	57.7	Soybean, maize, cotton, canola, squash, papaya, alfalfa
2*	Argentina*	19.1	Soybean, maize, cotton
3*	Brazil*	15.0	Soybean, cotton
4*	Canada*	7.0	Canola, maize, soybean
5*	India*	6.2	Cotton
6*	China*	3.8	Cotton, tomato, poplar, petunia, papaya, sweet pepper
7*	Paraguay*	2.6	Soybean
8*	South Africa*	1.8	Maize, soybean, cotton
9*	Uruguay*	0.5	Soybean, maize
10*	Philippines*	0.3	Maize
11*	Australia*	0.1	Cotton
12*	Spain*	0.1	Maize
13*	Mexico*	0.1	Cotton, soybean
14	Colombia	<0.1	Cotton, carnation
15	Chile	<0.1	Maize, soybean, canola
16	France	<0.1	Maize
17	Honduras	<0.1	Maize
18	Czech Republic	<0.1	Maize
19	Portugal	<0.1	Maize
20	Germany	<0.1	Maize
21	Slovakia	<0.1	Maize
22	Romania	<0.1	Maize
23	Poland	<0.1	Maize

* 13 biotech mega-countries growing 50,000 hectares, or more, of biotech crops
Source: Clive James, 2007.

In 2007, the USA, followed by Argentina, Brazil, Canada, India and China continued to be the principal adopters of biotech crops globally, with the USA retaining its top world ranking with 57.7 million hectares (50% of global biotech area) spurred by a growing market for ethanol with the biotech maize area increasing by a substantial 40% – this was partially offset by smaller decreases in biotech soybean and cotton. Notably, 63% of biotech maize, 78% of biotech cotton, and 37% of all biotech crops in the USA in 2007 were stacked products containing two or three traits that delivered multiple benefits. 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, with more countries expected to adopt stacked traits in the future.

Biotech crops achieved a very important milestone in 2007 with humanitarian implications – the number of small and resource-poor farmers benefiting from biotech crops in developing countries exceeded 10 million for the first time. Of the global total of 12 million beneficiary biotech farmers in 2007, (up from 10.3 million in 2006), over 90% or 11 million (up significantly from 9.3 million in 2006) were small and resource-poor farmers from developing countries; the balance of 1 million were large farmers from both industrial countries such as Canada and developing countries such as Argentina. Of the 11 million small farmers, most were Bt cotton farmers, 7.1

million in China (Bt cotton), 3.8 million in India (Bt cotton), and the balance of 100,000 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 2007. This initial modest contribution of increased small farmer income from biotech crops towards the Millennium Development Goals of reducing poverty by 50% by 2015 is a very encouraging and important development, which has enormous potential in the second decade of commercialization, 2006 to 2015.

During the period 1996 to 2007, the proportion of the global area of biotech crops grown by developing countries has increased consistently every single year. In 2007, 43% of the global biotech crop area, (up from 40% in 2006), and equivalent to 49.4 million hectares, was grown in developing countries where growth between 2006 and 2007 was substantially higher (8.5 million hectares or 21% growth) than industrial countries (3.8 million hectares or 6% growth). It is noteworthy that 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. Each of the five countries, reviewed in the following paragraphs, have benefited in a different way from biotech crops.

INDIA

India, the largest cotton growing country in the world, where 60 million people are impacted by cotton, reported 54,000 farmers growing 50,000 hectares of Bt cotton in 2002. Five years later in 2007 the Bt cotton area has soared to 6.2 million hectares grown by 3.8 million small and resource-poor farmers. Notably, more than 9 out of 10 farmers who grew Bt cotton in 2005 also grew it in 2006 and similarly for 2006 and 2007 – this confirms the trust and confidence of farmers in Bt cotton after experiencing its superior performance in their own fields. For the third consecutive year, India has reported the highest proportional increase of any biotech crop country in the world with an impressive gain of 63% in 2007. The reason for the spectacular growth in Bt cotton is that it has consistently delivered unprecedented benefits to farmers and to the nation. Bt cotton has increased yield by up to 50%, reduced insecticide sprays by half, with environmental and health implications, and increased income by up to US$250 or more per hectare, which has contributed to social benefits and the alleviation of their poverty. At the national level, increased farmer income from Bt cotton in 2006 was estimated at US$840 million to US$1.7 billion, production has almost doubled, and India, which used to have one of the lowest cotton yields in the world, is now an exporter rather than an importer of cotton. **India's Minister of Finance** recently cited the success of Bt cotton and advocated that ***"It is important to apply biotechnology in agriculture – what has been done with cotton must be done with food grains. The success achieved in cotton must be used to make the country self sufficient in rice, wheat, pulse and oilseed production."*** Mrs. Aakkapalli Ramadevi, is a woman subsistence farmer from Andhra Pradesh, who laboriously tills 3 acres (1.3 hectares), and is typical of a small and resource-poor farmer in India who has benefited from Bt cotton. Before the advent of Bt cotton she said ***"The yields were very low and we used to incur losses, so we were perpetually losing money – to sum it up, we were badly off and unable to afford anything properly".*** After planting Bt cotton for two years she says, ***"Finally, cotton cultivation has actually turned profitable."*** A study conducted in 2006 of 9,300 Bt cotton and non-Bt cotton households in 456 villages in India reports that women and children in Bt cotton households already have slightly more access to social benefits than non-Bt cotton households. Compared with women in non-Bt cotton households, women in Bt cotton households report slightly more antenatal visits and assistance with births at home, and their children have higher school enrollment and a higher proportion vaccinated. The story of Bt cotton in India is remarkable. With political will and farmer support in place, adoption is projected to continue increasing with Bt cotton plantings escalating from the current 66% to 80% or more. Coincidentally, new biotech products such as Bt eggplant, an important food and cash crop that can benefit up to 2 million small and resource-poor farmers, is in advanced large scale field trials, with expectations of approval in the near term.

CHINA

China, the biggest producer of cotton in the world introduced Bt cotton in 1996/1997, six years ahead of India. The story of Bt cotton in China is a remarkable experience of massive adoption of biotech crops by small farmers who represent some of the poorest people in the world – something that many critics of biotech crops in the early 1990s predicted could never happen. India, with 9.4 million hectares has almost twice the cotton area of China at 5.5 million hectares. Although India introduced Bt cotton in 2002, six years later than China, by 2006 India had planted 0.3 million hectares more Bt cotton than China, and 2.4 million hectares more than China in 2007. However, because cotton holdings are much smaller in China (average is 0.59 hectare) than India (1.63 hectares), the number of small farmers benefiting from Bt cotton in China in 2007 is almost twice as numerous (7.1 million) as in India (3.8 million). In 2007, Bt cotton was planted in China by 7.1 million small and resource-poor farmers on 3.8 million hectares, (up from 3.5 million hectares in 2006) which is equivalent to 69% of the 5.5 million hectares of all cotton planted in China. One of the important indicators that reflect farmers' confidence in any new technology 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 (CCAP) 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 between 2006 and 2007 in three provinces in China was 100%. Interestingly, of the 240 farmers surveyed, a few farmers in one village also grew one variety of non-Bt cotton in 2006 that they also grew in 2007. This confirms the fact that farmers wisely often want to compare the performance of the old and improved technologies side-by-side in their own fields – the same happened during the introduction of hybrid maize in the corn belt in the USA – farmers planted the best performing varieties next to the new hybrids until they were satisfied that hybrids consistently outperformed their old varieties and it took several years for hybrids to be universally adopted. Based on studies conducted by CCAP, on average at the farm level Bt cotton in China 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 lives as income of many cotton farmers is less than US$1 per day. **Niu Qingjun** is a typical Chinese cotton farmer, 42 years old, married with two children and 80% of the family income comes from cotton. The total size of his farm is 0.61 hectare and cotton is the only crop that he grows. Niu sums up his experience with Bt cotton: ***"We could not even plant cotton if there is not insect-resistance cotton (Bt cotton). We could not control bollworm infestation before planting insect-resistance cotton, even if spraying 40 times insecticide in 1997."*** Niu only sprayed insecticide 12 times in 2007, approximately half of the number of sprays he used on conventional cotton prior to the introduction of Bt cotton. The story of Bt cotton in China is well documented and is an important case study on the adoption of biotech crops by small and resource-poor farmers. China has also planted about one quarter of a million Bt poplars and in 2006 started to commercialize an approved virus resistant biotech papaya (a fruit/food crop) which has been developed by a Chinese university and grown on approximately 3,500 hectares – a virus resistant sweet pepper and delayed ripening tomato have also been approved for commercialization. With the exception of some varieties of Bt cotton, all the biotech crops commercialized in China have been developed by Chinese state institutions with public sector funding. Rice is the most important food crop in the world and importantly, it is also the most important food crop for the poor people of the world. In 2006, China grew 29.3 million hectares of rice equivalent to 20% of the world total of 150 million hectares. There are an estimated 250 million rice households in the world, and the vast majority of them are small and resource-poor farmers. There are an estimated 110 million rice households in China farming an average of 0.27 hectare of rice – these small and resource-poor rice farmers represent some of the poorest people in the world. China has the largest biotech rice program in the world. China's biotech rice is resistant to specific pests (insect borers) and diseases (bacterial blight) and is waiting approval after extensive field tests. Dr. Jikun Huang from the Center for Chinese Agricultural

Policy (CCAP) estimates that on the average, biotech rice increased yield by 2 to 6%, and reduced insecticide application by nearly 80% or 17 kg per hectare. At a national level, it is projected that biotech rice could deliver benefits of US$4 billion per year for China, plus environmental benefits that will contribute to a more sustainable agriculture and the alleviation of poverty for small and resource-poor farmers. Thus, together, Bt cotton and biotech rice have the potential of generating economic benefits of US$5 billion per year by 2010, for up to 110 million rice households in China. It is estimated that China has enhanced farm income from biotech cotton by US$5.8 billion in the period 1996 to 2006 and the benefits for 2006 alone are estimated at US$817 million. 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, feed and fiber security. China has a legion of public sector institutes and thousands of researchers devoted to crop biotechnology and over a dozen biotech crops are 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.

ARGENTINA

Argentina is one of the six "founder biotech crop countries", which commercialized RR® soybean in 1996, the first year of global commercialization. Argentina remains the second largest grower of biotech crops in the world, growing 19.1 million hectares in 2007, comprising 19% of global biotech crop hectarage. In 2007, the year-over-year increase, compared with 2006, was 1.1 million hectares, equivalent to an annual growth rate of 6%. Of the 19.1 million hectares of biotech crops in Argentina in 2007/08, 16.0 million hectares were planted to biotech soybean, 2.8 million hectares to biotech maize and approximately 400,000 hectares to biotech cotton. Unlike India and China, farms in Argentina are large and it is a major exporter of grain and oil seeds. A recent analysis concluded that biotech crops in Argentina, particularly RR® soybean, generated a significant increase in farmer income, worth approximately US$20 billion in the decade 1996 to 2005, created a million new jobs, more affordable soybean for consumers, and significant environmental benefits, particularly the practice of no till for conserving soil and moisture which importantly allows double cropping of biotech soybean (Trigo and Cap, 2006)[1]. The rapid adoption in Argentina was the result of several factors including: a well-established seed industry; a regulatory system that provided a responsible, timely, and cost-effective system for approving biotech products; and a technology with high impact. The total direct benefits for Argentina in the first decade, 1996 to 2005, were as follows: US$19.7 billion for herbicide-tolerant soybean for the period 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 for the three crops. Biotech crops have generated multiple and significant benefits for Argentina in the first decade of commercialization. The challenge for Argentina is to sustain its world ranking at number 2 in the second decade, 2006 to 2015, in the face of increased competition from many more countries which did not participate actively in the first decade of commercialization.

BRAZIL

Brazil has both large farms, and small and resource-poor farmers, particularly in the poor North East of the country and under the current administration, alleviation of poverty in the rural area is a high priority. In 2007, Brazil retained its position as the third largest adopter of biotech crops in the world, estimated at 15.0 million hectares, of which 14.5 million hectares were planted to RR® soybean and 500,000 hectares planted with a single gene Bt cotton, grown for the second time in 2007. Considering both percentage and absolute growth, the year-over-year

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1 *Trigo, E.J. and E.J. Cap. 2006. "Ten Years of Genetically Modified Crops in Argentine Agriculture", ArgenBio, Buenos Aires, Argentina.*

growth of 30% between 2006 (11.5 million hectares) and 2007 (15.0 million hectares) was the second highest in the world after India; the increase of 3.5 million hectares in 2007 was the largest absolute increase for any biotech crop country in the world. Brazil is currently the second largest producer of soybeans in the world after the USA and expected to become the first in the future – in 2007, Brazil offset a reduction in biotech soybean hectarage in the USA. Brazil is the third largest producer of maize in the world and the first biotech maize varieties have received initial clearance and are expected to have final approval for planting in 2008/09. Brazil is also the sixth largest producer of cotton, the tenth largest grower of rice (3.7 million hectares) and the only major producer of rice outside Asia. In addition, Brazil is also the largest sugarcane producer in the world with 6.2 million hectares and uses approximately half of its national sugarcane area to produce sugar and the other half for the production of ethanol for biofuels. After the USA, Brazil was the second biggest producer of ethanol in the world in 2007 and one of few countries that is self-sufficient in both fossil fuels and biofuels in which it is a world leader. To date, the introduction of biotech crops in Brazil has suffered significant delays because of legal and judicial restraining orders delaying the deployment of approved biotech crops. A 2007 study by Dr. Anderson Galvão Gomes, has estimated the benefits lost to Brazilian farmers because of delayed approval 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 a practical bench mark for adoption, the study concluded that delayed approval of RR® soybean in Brazil for the period 1998 to 2006 cost farmers US$3.10 billion and cost technology developers an additional US$1.41 billion, for a total of US$4.51 billion in lost benefits. The total potential benefits for both farmers and technology developers during the period 1998 to 2006 was US$6.6 billion of which only US$2.09 billion, equivalent to 31%, was realized. Thus, US$4.51 billion was lost due to legal delays which were a significant sacrifice for Brazil as a nation and the major losers were farmers. However, recent commitments by the current administration of funds totaling Real 10 billion equivalent to US$7 billion (60% public and 40% private), and prorated at US$700 million per year for the next ten years, demonstrates strong political will and support for biotechnology by the Brazilian government. Moreover, a significant part of the US$7 billion is to be devoted to biofuels and agriculture. In November 2007 President Luis Inacio Lula da Silva of Brazil announced a US$23 billion investment in a four-year "Plan for Action for Science, Technology and Innovation." One of the four thrusts of the Plan 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 material and humanitarian benefits. The political will of the troika needs to be integrated to establish a nuclear group that will work together to gain the support of global society for harnessing and optimizing the contribution of biotech crops for the alleviation of poverty and hunger for resource-poor farmers by 2015 – 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. In summary, Brazil has become a world leader in the adoption of biotech crops with continued significant growth expected in RR® soybean hectarage, rapid expansion in Bt cotton supplemented with herbicide tolerance, substantial opportunities on the 13 million hectares of maize from 2008 onwards, new opportunities for its 3.7 million hectares of rice, as well as the enormous potential with biotech sugarcane for its emerging role as a world leader and exporter of bioethanol.

SOUTH AFRICA

South Africa is the only country on the continent of Africa to commercialize biotech crops. It is ranked number eight in the world with a total biotech crop hectarage of 1.8 million hectares in 2007, almost a 30% increase over the 1.4 million hectares in 2006. Biotech maize, cotton and soybean are grown in South Africa and their area has increased every single year since the first plantings in 1998. The major increase in 2007 was in biotech maize, notably most of it in white maize used for food, which now occupies two-thirds of the total white maize area of 1.7 million hectares. Both small and resource-poor farmers and large farmers grow biotech crops, which have earned their trust and confidence. The Bt cotton grown in KwaZulu Natal region is mainly grown by women subsistence farmers. **Philiswe Mdletshe**, a woman cotton farmer from 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 Rand 38,400 (US$5,730). She reduced insecticide sprayings from ten times a season with non-Bt cotton to twice with Bt cotton and saved 1,000 liters of water. She has continued planting Bt cotton for five successive years. **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 over 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"***, it is Xhosa for ***"It fills our stomachs."*** Mdutshane said ***"For the first time ever they produced enough food to feed themselves."*** **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 2,000 (US$300). Some of the farmers increased their yields by up to 40%. He pointed out that taking 20 farmers, and there were many more, earning an extra income of Rand 2,000 (US$300) totaled Rand 40,000 (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. 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, sponsored by ISAAA, and is engaged in training and human resource development programs with its neighboring African countries. Given South Africa's rich and unique African experience with biotech crops, it can also play an important role as the key country partner on the continent of Africa to facilitate collaboration and cooperate with its counterpart biotech crop countries of China and India in Asia, and Argentina and Brazil in Latin America. The Governments of India, Brazil and South Africa (IBSA) have established a platform for cooperation that includes research collaboration on crop biotechnology. With creative management, IBSA can evolve into an innovative mechanism that can expedite the South-South sharing of biotech crop applications to urgently improve crop productivity in the food insecure nations of Africa. 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 biotech crop 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. South Africa is estimated to have enhanced farm income from biotech maize, soybean and cotton by US$156 million in the period 1998 to 2006, with benefits for 2006 alone estimated at US$67 million.

In 2007, the number of countries planting biotech crops increased to 23 with Poland planting Bt maize for the first time, and bringing the total number of countries planting biotech crops in the EU to 8 out of 27, up from 6 in 2006. Spain continued to be the lead country in Europe planting over 70,000 hectares in 2007, equivalent to a 21% adoption rate and a 40% increase over 2006. Importantly, the collective Bt maize hectarage in the other seven countries (France, Czech Republic, Portugal, Germany, Slovakia, Romania, and Poland) increased over 4-fold from approximately 8,700 hectares in 2006 to approximately 35,700 hectares in 2007, albeit on modest hectarages, and the total Bt maize in the EU exceeded 100,000 hectares for the first time with a year-on-year growth rate of 77%.

It is noteworthy that more than half (55% or 3.6 billion people) of the global population of 6.5 billion live in the 23 countries where biotech crops were grown in 2007 and generated significant and multiple benefits worth US$7 billion globally in 2006. Also, more than half (52% or 776 million hectares) of the 1.5 billion hectares of cropland in the world is in the 23 countries where approved biotech crops were grown in 2007. The 114.3 million hectares of biotech crops in 2007 represents 8% of the 1.5 billion hectares of crop land in the world.

Biotech soybean continued to be the principal biotech crop in 2007, occupying 58.6 million hectares (51% of global biotech area), followed by fast-growing maize (35.2 million hectares at 31%), cotton (15.0 million hectares at 13%) and canola (5.5 million hectares at 5% of global biotech crop area).

From the genesis of commercialization in 1996 to 2007, herbicide tolerance has consistently been the dominant trait. In 2007, herbicide tolerance, deployed in soybean, maize, canola, cotton and alfalfa occupied 63% or 72.2 million hectares of the global biotech 114.3 million hectares. For the first time in 2007, the stacked double and triple traits occupied a larger area (21.8 million hectares, or 19% of global biotech crop area) than insect resistant varieties (20.3 million hectares) at 18%. The stacked trait products were by far the fastest growing trait group between 2006 and 2007 at 66% growth, compared with 7% for insect resistance and 3% for herbicide tolerance.

In the first 12 years, the accumulated global biotech crop area for the first time in 2007 exceeded two-thirds of a billion hectares at 690.9 million hectares or 1.7 billion acres, equivalent to approximately 70% of the total land area of the USA or China, or almost 30 times the total land area of the UK. 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. 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.

The most recent survey of the global impact of biotech crops for the period 1996 to 2006, estimates that the global net economic benefits to biotech crop farmers in 2006 was US$7 billion, and US$34 billion (US$16.5 billion for developing countries and US$17.5 billion for industrial countries) for the accumulated benefits during the period 1996 to 2006; these estimates include the very important benefits associated with the double cropping of biotech soybean in Argentina (Brookes and Barfoot, 2008)[2]. The accumulative reduction in pesticides for the period 1996 to 2006 was estimated at 289,000 metric tons of active ingredient, which is equivalent to a 15.5% 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 important and urgent concerns about the environment have implications for biotech crops, which can potentially contribute to a reduction of greenhouse gases and mitigate climate change in three principal ways. First, permanent savings in carbon dioxide emissions through reduced use of fossil-based fuels, associated with fewer insecticide and herbicide sprays; in 2006 this was an estimated saving of 1.2 billion kg of carbon dioxide (CO_2), equivalent to reducing the number of cars on the roads by 0.5 million. Secondly, conservation tillage (need for less or no ploughing with herbicide tolerant biotech crops) for biotech food, feed and fiber crops, led to an additional soil carbon sequestration equivalent in 2006 of 13.6 billion kg of CO_2, or removing 6 million cars off the road. Thus, in 2006 the combined permanent and additional savings through sequestration was equivalent to a saving of 14.8 billion kg of CO_2 or removing 6.5 million cars from the road. Thirdly, in the future, cultivation of a significant additional area of biotech-based energy crops to produce ethanol and biodiesel will, on the one-hand, substitute for fossil fuels and on the other, will recycle and sequester carbon. Recent research indicates that biofuels could result in net savings of 65% in energy resource depletion. Given that energy crops will likely occupy a significant additional crop hectarage in the future, the contribution of biotech-based energy crops to climate change could be significant.

While 23 countries planted commercialized biotech crops in 2007, an additional 29 countries, totaling 52, 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 615 approvals have been granted for 124 events for 23 crops. Thus, biotech crops are accepted for import for food and feed use and for release into the environment in 29 countries, including major food importing countries like Japan, which do not plant biotech crops. Of the 52 countries that have granted approvals for biotech

2 *Brookes, G. and P. Barfoot. 2008. GM Crops: Global Socio-economic and Environmental Impacts 1996-2006, P.G. Economics 2008. In press.*

crops, Japan tops the list followed by USA, Canada, South Korea, Australia, Mexico, the Philippines, New Zealand, the European Union and China. Maize has the most events approved (40) followed by cotton (18), canola (15), and soybean (8). The event that has received regulatory approval in most countries is herbicide tolerant soybean event GTS-40-3-2 with 24 approvals (EU=27 counted as 1 approval only), followed by insect resistant maize (MON810) and herbicide tolerant maize (NK603) both with 18 approvals, and insect resistant cotton (MON531/757/1076) with 16 approvals worldwide.

In 2007, it is estimated that of the 114.3 million hectares of biotech crops grown worldwide, approximately 9% or 11.2 million hectares of biotech crops were used for biofuel production, with over 90% of that hectarage in the USA. It is estimated that in 2007, 7 million hectares of biotech maize was devoted to ethanol production in the USA and approximately 3.4 million hectares of biotech soybean for biodiesel, plus about 10,000 hectares of biotech canola for a USA total of 10.4 million hectares of biotech crops for biofuels. In Brazil, 750,000 hectares of RR® soybean was used to produce biodiesel in 2007 and in Canada approximately 45,000 hectares of biotech canola was used for the production of biodiesel for a total of 11.2 million hectares of biotech crops used globally for biofuel production.

It is evident that much progress has been made in the first twelve 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. This offers the unique opportunity for the global biotechnology community, from the North and the South, the public and the private sectors, to define in 2008 the contributions that biotech crops can make to the Millennium Development Goals and a more sustainable agriculture in the future – this will give the global biotech crop community seven years to work towards implementing an action plan that can deliver on the goals for 2015. Five goals, described in the following paragraphs, deserve consideration given that there is a high probability that crop biotechnology can deliver on these promises by 2015.

1. ***Increasing global crop productivity to improve food, feed and fiber security in sustainable crop production systems that also conserve biodiversity***
   A significant contribution has already been made in the first 12 (dozen) years of commercialization through deployment of biotech crops more tolerant to the biotic stresses caused by pests, weeds and diseases. This sustainable increase in productivity on the same area of cropland allows biodiversity to be conserved because it will help preclude the need for deforestation and slash and burn agriculture. Increases in productivity of maize for feed, the oil seed crops soybean and canola, and the fiber crop cotton have been significant with gains valued at US$34 billion in the period 1996 to 2006. Initial progress has been made with food crops with white maize in South Africa, ingredients of biotech maize, soybean and canola used commonly in processed foods, biotech papaya and squash consumed in the USA, and papaya in China. Progress with control of abiotic stresses is expected in the near term with drought tolerance available within five years and salt tolerance thereafter. A new family of input and output traits will not only increase yield but provide more nutritious food, such as omega-3 oil and golden rice enriched with pro-vitamin A, expected to be approved by 2012. The most important event in the next five years is the expected approval of biotech rice, the most important food crop in the world, already temporarily released in Iran in 2005. 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 has enormous potential to coincidentally contribute to food security and alleviation of poverty.

2. ***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 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 of the world's poorest people. Biotech cotton has already made a significant contribution to the income of poor farmers in the first decade, 1996 to 2005, and this can be enhanced significantly in the second decade. Biotech maize is already delivering benefits to a modest number of small farmers and holds enormous potential by 2015. Crops such as biotech eggplant, being developed in India, the Philippines, and Bangladesh are expected to be approved in the near term 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.

3. ***Reducing the Environmental Footprint of Agriculture***
   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. 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 has implications in mitigating global warming and the pollution of aquifers and deltas, such as the Mekong, with nitrogen related pollutants. The first biotech maize varieties with drought tolerance are expected to be commercialized by around 2011 and the trait has already been incorporated in several other crops. Drought tolerance is expected to have a major impact on cropping systems worldwide, particularly in developing countries where drought is more prevalent and severe than industrial countries.

4. ***Mitigating Climate Change and Reducing Greenhouse Gases (GHG)***
   Droughts, floods, and temperature changes are predicted to become more prevalent and more severe, and hence there will be a need to expedite improvement of crops that are well adapted to changing climatic conditions. Several biotech crop tools, including diagnostics, genomics, molecular marker-assisted selection (MAS) and biotech crops can be used for 'speeding the breeding' and mitigating 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 moisture, reducing pesticide spraying as well as sequestering CO_2.

5. ***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) 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.

The Future

The future for biotech crops looks encouraging. The number of biotech crop countries, crops and traits and hectarage are projected to double between 2006 and 2015, the second decade of commercialization; in the developing countries, Burkina Faso and Egypt, and possibly Vietnam are potential candidates for adopting biotech crops in the next one or two years. The lifting of the four-year ban on biotech canola in late November 2007 in the states of Victoria and New South Wales was a very important development for the future of biotech crops in Australia, where drought tolerant wheat is already being field tested. By 2015, the number of farmers adopting biotech crops could increase up to ten fold to 100 million, or more, assuming that only biotech rice will be approved in the near term. Genes conferring a degree of drought tolerance, expected to become available around 2011 will be particularly important for developing countries which suffer more from drought, the most prevalent and important constraint to increased crop productivity worldwide. The second decade of commercialization, 2006-2015, is likely to feature significantly more growth in Asia compared with the first decade, which was the decade of the Americas, where there will be continued vital growth in stacked traits in North America and strong growth in Brazil. The mix of crop traits will become richer with quality traits making their long awaited debut with implications for acceptance, particularly in Europe. Other products, including pharmaceutical products, oral vaccines, and specialty products will also be featured. The use of biotechnology to increase efficiency of first generation food/feed crops and second-generation energy crops for biofuels is likely to have significant impact and present both opportunities and challenges. 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 met. The key role of crop biotechnology 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 reducing poverty and hunger by 50% by 2015. 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 most important message in the recently published 2008 World Bank Development Report "Agriculture for Development" is 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)[3]. The Report offers an important reminder 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 770 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 that poverty today is a rural phenomenon where 50% of the poorest people in the world are resource-poor farmers and another 20%, the rural landless, who are completely dependent on agriculture for their livelihoods. Thus, the majority, 70%, of the world's poorest people are small and resource-poor farmers and the rural landless labor who live and toil on the land. The challenge is to transform this 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 specifically 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 Review. It is encouraging to witness the growing "political will" and conviction of visionary politicians and lead farmers for biotech/GM

3 *World Bank. 2008. The World Development Report, Agriculture for Development. 365 pp, ISBN-13:978-0-8213-807-7 World Bank, Washington DC. USA.*

crops in several of the lead developing countries highlighted in this Review. The challenge for the international community and the lead biotech crop developing countries of India, China, Argentina, Brazil and South Africa, which have already benefited from biotech crops, is to openly share their experience and knowledge with the legion of developing countries that have yet to have first-hand experience with biotech crops. To implement this will require urgent but modest financial support from the philanthropic foundations, the bilateral and multilateral AID organizations and from all the multinationals in the private sector that are benefiting from the US$7 billion biotech crop industry today. Failure to provide this critical support at this time will risk many developing countries missing out on a one-time window of opportunity and become permanently disadvantaged and non-competitive in crop productivity, with all its dire implications for the hope of alleviating poverty. There is no substitution for sharing the collective experience of a "national team of practitioners" who have been involved in a successful national crop biotech program such as Bt cotton in India or China or biotech maize in South Africa or the Philippines. The national team sharing the experience should include all the key resource personnel, including politicians, policy makers, agronomists, biotechnologists, economists and farmers who have been directly engaged with all aspects of biotech crops. Both the pros and the cons must be frankly shared so that there is no need for newcomers to the technology to reinvent the wheel. One key question that must be asked of the team sharing the experience is "how would you implement a crop biotech program differently, the second time around " i.e. what have been the lessons and learning of the first generation of biotech crop adopters that can be shared with second generation adopters so that the latter can gain from the experience.

The most important constraint to biotech crops in most developing countries, that deserves highlighting, is the lack of appropriate cost-effective and responsible regulation systems that incorporate all the lessons of a dozen 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 dozen 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", overriding common sense, and where "the regulatory surgery may be successful but the patient died."

THE GLOBAL VALUE OF THE BIOTECH CROP MARKET

In 2007, the global market value of biotech crops, estimated by Cropnosis, was US$6.9 billion representing 16% of the US$42.2 billion global crop protection market in 2007, and 20% of the ~US$34 billion 2007 global commercial seed market. The US$6.9 billion biotech crop market comprised of US$3.2 billion for biotech maize (equivalent to 47% of global biotech crop market, up from 39% in 2006), US$2.6 billion for biotech soybean (37%, down from 44% in 2006), US$0.9 billion for biotech cotton (13%), and US$0.2 billion for biotech canola (3%). Of the US$6.9 billion biotech crop market, US$5.2 billion (76%) was in the industrial countries and US$1.6 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 eleven-year period, since biotech crops were first commercialized in 1996, is estimated at US$42.4 billion. The global value of the biotech crop market is projected at approximately US$7.5 billion for 2008.

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