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EXECUTIVE SUMMARY

BRIEF 41

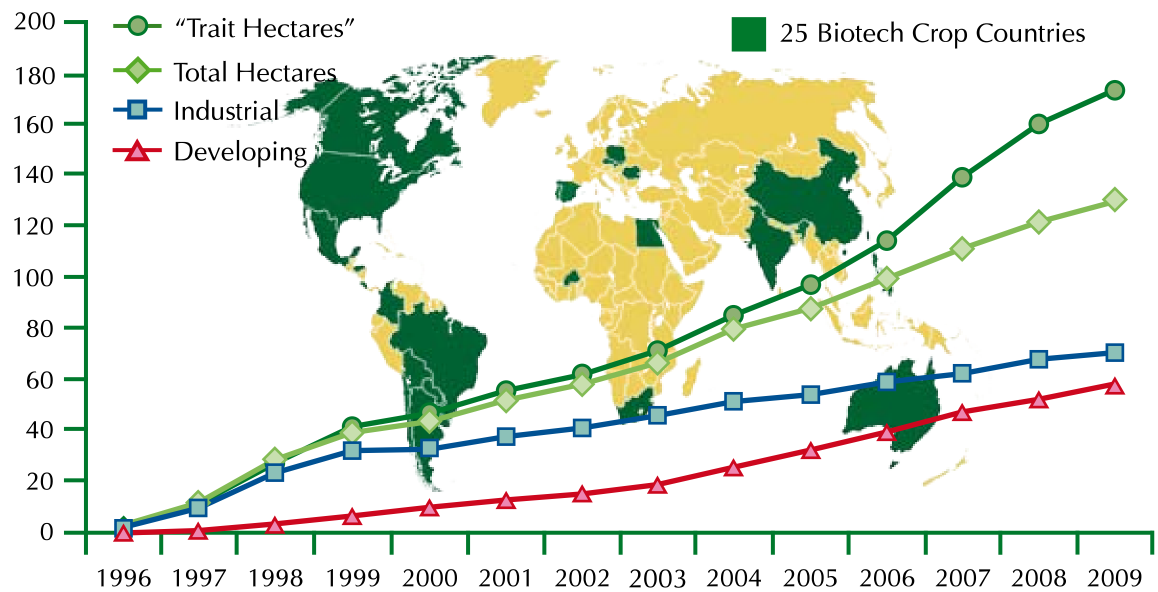
Global Status of Commercialized Biotech/GM Crops: 2009

by

Clive James
Founder and Chair, ISAAA Board of Directors

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

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



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

Source: Clive James, 2009.

No. 41 - 2009

AUTHOR'S NOTE:

Global figures and hectares planted commercially with biotech crops have been rounded off to the nearest 100,000 hectares, using both < and > characters, and hence in some cases this leads to insignificant approximations, and there may be minor variances in some figures, totals, and percentage estimates that do not always add up exactly to 100% because of rounding off. It is also important to note that countries in the Southern Hemisphere plant their crops in the last quarter of the calendar year. The biotech crop areas reported in this publication are planted, not necessarily harvested hectarage in the year stated. Thus, for example, the 2009 information for Argentina, Brazil, Australia, South Africa, and Uruguay is hectares usually planted in the last quarter of 2009 and harvested in the first quarter of 2010 with some countries like the Philippines having more than one season per year. Thus, for countries of the Southern hemisphere, such as Brazil and Argentina the estimates are projections, and thus are always subject to change due to weather, which may increase or decrease actual planted before the end of the planting season when this Brief has to go to press. For Brazil the winter maize crop (safrinha) planted in the last week of December 2009 and more intensively through January and February 2010 is classified as a 2009 crop in this Brief consistent with a policy which uses the first date of planting to determine the crop year. Details of the references listed in the Executive Summary are found in Full Brief 41.

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EXECUTIVE SUMMARY

Global Status of Commercialized Biotech/GM Crops: 2009
The First Fourteen Years, 1996 to 2009

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Global Status of Commercialized Biotech/GM Crops: 2009
The First Fourteen Years, 1996 to 2009

Introduction

This Executive Summary focuses on the 2009 global biotech crop highlights, which are comprehensively discussed in the full version of Brief 41, dedicated to the late Nobel Peace Laureate, Norman Borlaug. An ISAAA tribute to Norm, the First Founding Patron of ISAAA who passed away on 12 September 2009, is also included as a commemorative brochure in Brief 41. Having been awarded the Nobel Peace Prize in 1970 for successfully implementing the green revolution, which saved up to 1 billion people from hunger in the 1960s, Norman Borlaug was the world's most ardent and credible advocate of biotech crops and their vital contribution to the alleviation of poverty, hunger and malnutrition.

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

China approves Bt rice and phytase maize in a landmark decision.

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

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

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

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

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

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

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

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

The challenge of feeding the world in 2050

It is useful to put global food production into context, by tracing the major developments over the last two centuries. Starting at the beginning of the 19th century, when global population was less than 1 billion in 1800, it was relatively easy to increase food production over the next 100 years to feed another 0.6 billion, by simply **increasing the area of land under the plough.** An abundance of new productive land was available and brought into production in the prairies of North America, the pampas of South America, the steppes of Eastern Europe and Russia, and the outback of Australia. In the 20th century (when world population was still only 1.6 billion in 1900), an increase in global food production over the next 100 years was achieved mainly **by increasing crop productivity (yield per hectare)** dramatically, through the green revolution and other agronomic improvements. Fossil fuel was a prerequisite for large-scale mechanization, with tractors replacing horses, and equally important, an increased usage of fossil fuel-based ammonium fertilizers.

At the beginning of the 21st century, with a population of 6.1 billion in 2000 and headed for 9.2 billion by 2050, the challenge of yet again doubling food production in only 50 years has become a daunting task in itself. The situation is further exacerbated because now, we must also **double food production sustainably by 2050** on approximately the same area of arable land (a notable exception is Brazil) **using less resources, particularly, fossil fuel, water and nitrogen**, at a time when we must also mitigate some of the **enormous challenges associated with climate change**. Furthermore, there is the **critical and urgent humanitarian need to alleviate poverty, hunger and malnutrition which is afflicting more than 1 billion people for the first time** in the history of the world. The most promising technological strategy at this time for increasing global food, feed and fiber productivity (kg per hectare) is to combine the best of the old and the best of the new, by **integrating the best of conventional crop technology (adapted germplasm) and the best of crop biotechnology applications including novel traits.** The improved integrated crop products, resulting from this synergy must be incorporated as the **innovative technology component** in a global food, feed and fiber security strategy that must also address other critical issues, including population growth and improved food, feed and fiber distribution systems. Adoption of such a holistic strategy will allow global society to continue to benefit from the vital contribution that both conventional and modern innovative plant breeding offers mankind, at this critical juncture in the history of a world that is desperately struggling with food security as a potential threat to a more peaceful and secure world. **It is striking that Borlaug's acceptance speech for his Nobel Peace Prize, delivered forty years ago, entitled The Green Revolution, Peace and Humanity, focused on basically the same issues.**

More support to Agriculture for "a substantial and sustainable intensification of crop productivity", using both conventional and crop biotechnology applications

ISAAA Brief 41, 2009 is published at a critical juncture when several prestigious international bodies, including the G8, the 2009 FAO Food Summit, the Bill and Melinda Gates Foundation and the Royal Society of London, have all advocated an urgent need for assigning top priority to agriculture, food self-sufficiency and security and the alleviation of hunger, malnutrition and poverty. More specifically, given the pivotal role of crops in food, feed and fiber production, there has been a universal clarion call to utilize both conventional and biotech crop applications to achieve "**a substantial and sustainable intensification of crop productivity" on the 1.5 billion hectares of crop land in use today.** This urgent action has been called for, to avert possible imminent life-threatening consequences for 1.02 billion people, the highest number to ever suffer from the debilitating and destructive effects of poverty, hunger and malnutrition, which is unacceptable in a just society. The situation is exacerbated with **global grain reserves down to a perilous 75 days supply**, compared with a recommended minimum of 100 days, the need to mitigate the multiple challenges associated with climate change, particularly drought that is already in evidence globally, and last, but not least, to protect, at all costs, the natural resource base for future generations in a reasonable state.

Global hectarage planted to biotech crops continued to climb in 2009 – record hectarages for all four major biotech crops – progress on other fronts.

Following the consistent and substantial, economic, environmental and welfare benefits generated from biotech crops over the last fourteen years, millions of large, small and resource-poor farmers in both industrial and developing countries continued to plant more hectares of biotech crops in 2009 than ever before; this testimony to biotech crops from millions of practitioner farmers around the world is the simplest but probably the single most compelling, pragmatic and common-sense measure of the superior performance of biotech crops globally. Despite the severe effects of the 2009 economic recession, record hectarages of all biotech crops were reported in 2009 with the following new highs for the four principal biotech crops. For the first time, more than three-quarters (77%) of the 90 million hectares of soybean grown globally were biotech; for cotton, almost half (49%) of the 33 million hectares were biotech; for maize, over a quarter (26%) of the 158 million hectares grown globally were biotech; and finally for canola, 21% of the 31 million hectares were biotech. In addition to increases in hectares, progress was also made with the number of farmers electing to plant biotech crops globally. Continued substantial progress was achieved in all three biotech crop countries in Africa, where the challenges are greatest. As predicted in previous ISAAA Briefs, developing countries continued to command an increasing share of global plantings, with Brazil clearly exhibiting its potential for becoming the future engine of growth in Latin America. These are very important developments given that biotech crops have already made a modest contribution; more importantly, they have substantial potential to continue to contribute to some of the major challenges facing global society in the future, including: food self-sufficiency and security, more affordable food, sustainability, alleviation of poverty and hunger, and help mitigate some of the challenges associated with climate change and global warming.

134 million hectares of biotech crops in 2009 – fastest adopted crop technology, 80-fold increase from 1996 to 2009, year-to-year growth of 9 million hectares or 7%

Global hectarage of biotech crops continued to grow in 2009 and reached 134 million hectares, (Table 1 and Figure 1) or 180 million "trait or virtual hectares". This translates to an "apparent growth" of 9 million hectares or 7% measured in hectares, whereas the "actual growth", measured in "trait or virtual hectares", was 14 million hectares or 8% year-on-year growth. Measuring in "trait or virtual hectares" is similar to measuring air travel (where there is more than one passenger per plane) more accurately in "passenger miles" rather than "miles". Global growth

Table 1. Global Area of Biotech Crops in 2009: by Country (Million Hectares)

Rank	Country	Area (million hectares)	Biotech Crops
1*	USA*	64.0	Soybean, maize, cotton, canola, squash, papaya, alfalfa, sugarbeet
2*	Brazil*	21.4	Soybean, maize, cotton
3*	Argentina*	21.3	Soybean, maize, cotton
4*	India*	8.4	Cotton
5*	Canada*	8.2	Canola, maize, soybean, sugarbeet
6*	China*	3.7	Cotton, tomato, poplar, papaya, sweet pepper
7*	Paraguay*	2.2	Soybean
8*	South Africa*	2.1	Maize, soybean, cotton
9*	Uruguay*	0.8	Soybean, maize
10*	Bolivia*	0.8	Soybean
11*	Philippines*	0.5	Maize
12*	Australia*	0.2	Cotton, canola
13*	Burkina Faso*	0.1	Cotton
14*	Spain*	0.1	Maize
15*	Mexico*	0.1	Cotton, soybean
16	Chile	<0.1	Maize, soybean, canola
17	Colombia	<0.1	Cotton
18	Honduras	<0.1	Maize
19	Czech Republic	<0.1	Maize
20	Portugal	<0.1	Maize
21	Romania	<0.1	Maize
22	Poland	<0.1	Maize
23	Costa Rica	<0.1	Cotton, soybean
24	Egypt	<0.1	Maize
25	Slovakia	<0.1	Maize

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

Source: Clive James, 2009.

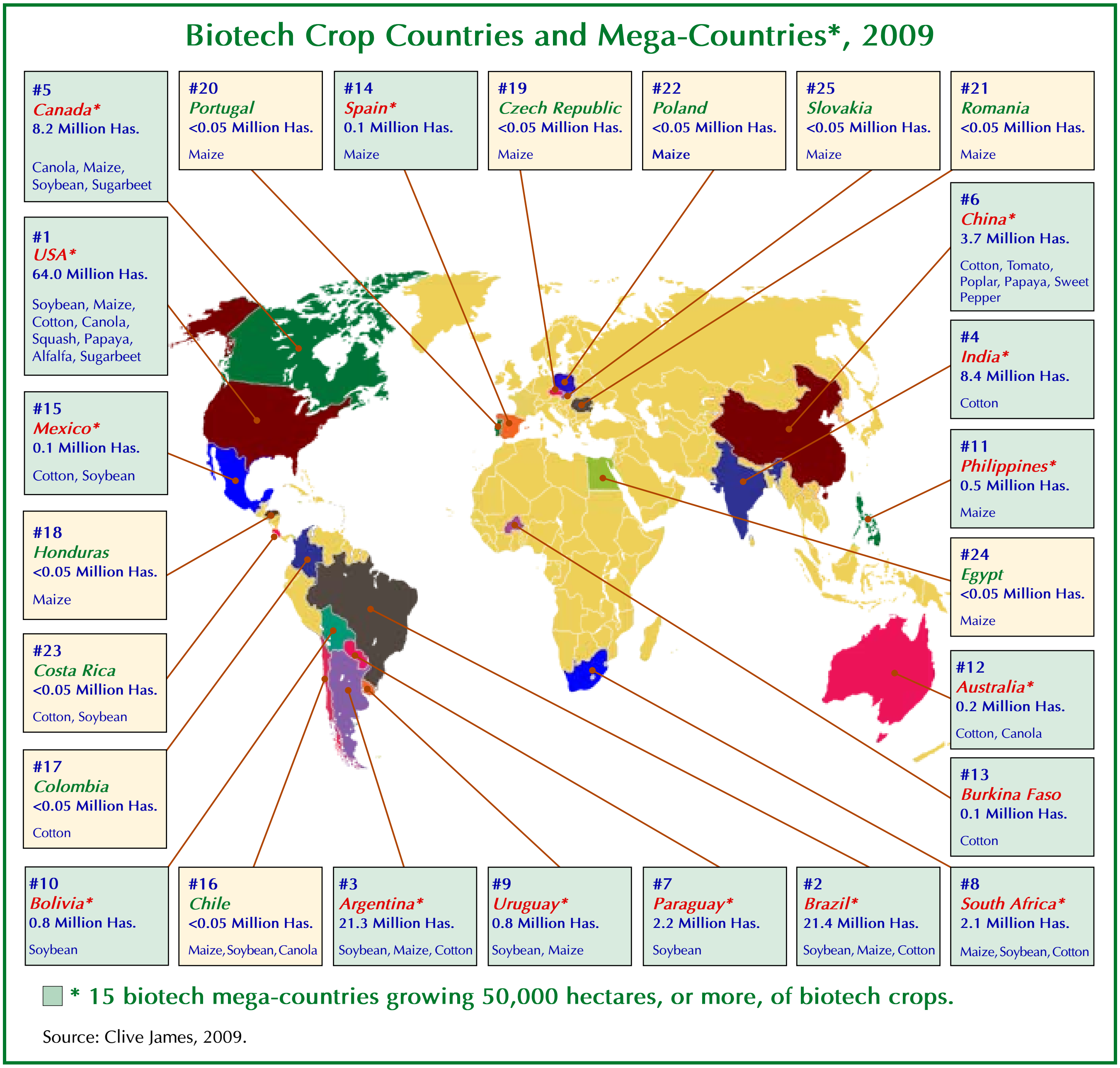


Figure 1. Global Map of Biotech Crop Countries and Mega-Countries in 2009

in "trait or virtual hectares" increased from 166 million "trait or virtual hectares" in 2008 to approximately 180 million "trait or virtual hectares" in 2009. Recent growth over the last few years in the early-adopting countries has come largely 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 of the major biotech crop countries. For example in 2009, an impressive 85% of the 35.2 million hectare national maize crop in the USA was biotech, and remarkably, 75% of it was hybrids with either double or triple stacked traits – only 25% was occupied by hybrids with a single trait. Similarly, biotech cotton occupies up to approximately

90%, or more of the national area of cotton in the USA, Australia and South Africa, with double-stacked traits occupying 75% of all biotech cotton in the USA, 88% in Australia and 75% in South Africa. It is evident that stacked traits have already become a very important feature of biotech crops, and accordingly it is prudent to also measure growth in "trait or virtual hectares" as well as hectares. This unprecedented high growth rate starting from 1.7 million hectares in 1996 to 134 million hectares in 2009 makes biotech crops the fastest adopted crop technology, increasing approximately 80-fold (79) between 1996 and 2009.

Stacked traits planted by 11 countries – 8 of the 11 were developing countries

Stacked products are an important feature of biotech crops and future trend, which meets the multiple needs of farmers and consumers, and these are now increasingly deployed by 11 countries. In descending order of hectarage they were – USA, Argentina, Canada, Philippines, South Africa, Australia, Mexico, Chile, Colombia, Honduras and Cost Rica, (note that 8 of the 11 were developing countries**),** with more countries expected to adopt stacked traits in the future. A total of 28.7 million hectares of stacked biotech crops were planted in 2009 compared with 26.9 million hectares in 2008. In 2009, the USA led the way with 41% of its total 64.0 million hectares of biotech crops stacked. In the Philippines, double stacks with pest resistance and herbicide tolerance in maize were the fastest growing component increasing from 57% of biotech maize in 2008 to 69% in 2009. The new biotech maize, **SmartStax™, will be released in the USA in 2010 with eight different genes coding for a total of three traits, two for pest resistance, (one for above ground pests and the other for underground pests) and herbicide tolerance.** Future stacked crop products are expected to comprise multiple 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 0.7 million to 14.0 million, 90%, or 13.0 million were small and resource-poor farmers in developing countries.

In 2009, the number of farmers benefiting from biotech crops globally in 25 countries reached 14.0 million, an increase of 0.7 million over 2008. Of the global total of 14.0 million beneficiary biotech farmers in 2009, (up from 13.3 million in 2008), over 90% or 13.0 million (up from 12.3 million in 2008) 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 13.0 million small and resource-poor farmers, most were Bt cotton farmers, 7.0 million in China (Bt cotton), 5.6 million in India (Bt cotton), and the balance made up of 250,000 in the Philippines (biotech maize), South Africa (biotech cotton, maize and soybeans often grown by subsistence women farmers) and the other twelve developing countries which grew biotech crops in 2009. **The largest increase in the number of beneficiary farmers in 2009 was in India where, an additional 0.6 million more small farmers planted Bt cotton which now occupies 87% of total cotton, up from 80% in 2008. 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. Initial research in China indicates that up to 10 million more small and resource-poor farmers may be secondary beneficiaries of Bt cotton in China.**

Twenty-five countries planted biotech crops in 2009 – 10 in Central and South America.

In 2009, the number of biotech countries planting biotech crops remained the same as 2008, at 25, with Costa Rica listed for the first time and Germany discontinuing planting of Bt maize at the end of the 2008 season. Costa Rica, like Chile, grows biotech crops exclusively for the seed export market. With the addition of Costa Rica, this brings the total number of countries growing biotech crops in Latin America to an historical figure of 10. The number of countries growing biotech crops has increased steadily from 6 in 1996, the first year of commercialization, to 18 in 2003 and 25 in 2009. Japan initiated commercialization of a biotech blue rose in 2009 – the roses are partially grown in greenhouses, and like biotech carnations in Colombia and Australia are not included in the ISAAA global hectarage of food, feed and fiber biotech crops as defined in the FAO listing of crops.

Biotech crop hectares grew in 2009 even when 2008 percent adoption rates were high.

Global biotech hectares grew in 2009 by a robust 7% or 9 million hectares even though there was limited room for hectare growth in biotech crops in 2009 because:

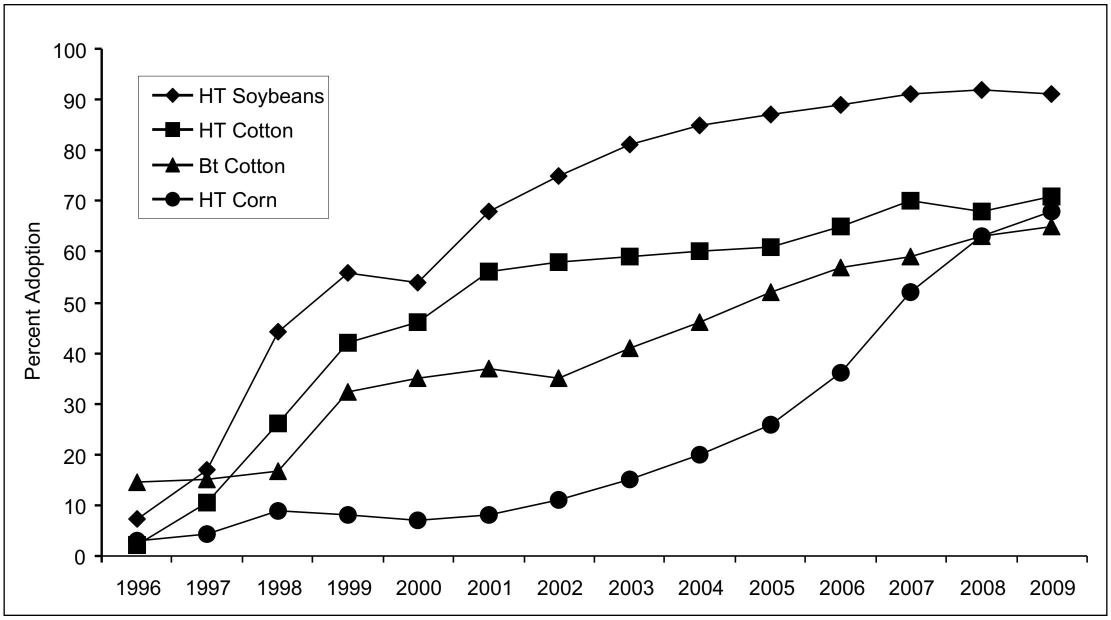
- adoption rates were already 80% or more in the principal biotech crops in most of the major biotech countries;
- there was uncertainty due to extensive droughts and unfavorable climatic conditions;
- an economic crisis, which was the worst since the depression, led to more static or declining total crop plantings; and
- plummeting commodity prices compared with the highs of mid 2008 provided less incentive for farmers to increase total plantings significantly as in previous years.

The percent adoption of biotech crops continued to grow in 2009, even when the 2008 adoptions rates were very high, for example, from 80% to 87% for Bt cotton in India, from 80% to 85% for biotech maize in the USA, and from 86% to 93% for biotech canola in Canada (Figures 2 and 3). For countries, such as China where, consistent with international trends, total crop plantings of cotton declined, the percent adoption remained the same at 68%, but in the case of the USA even when total plantings of cotton were down 4%, percent adoption increased from 86% in 2008 to 88% in 2009. It is notable, that the global area of biotech crops has grown every single year since its first commercialization in 1996, at double digit growth rates consistently for the first twelve years, at 9.4% in 2008, and 7% in 2009 during the economic recession.

Brazil displaced Argentina to become the second largest grower of biotech crops in the world.

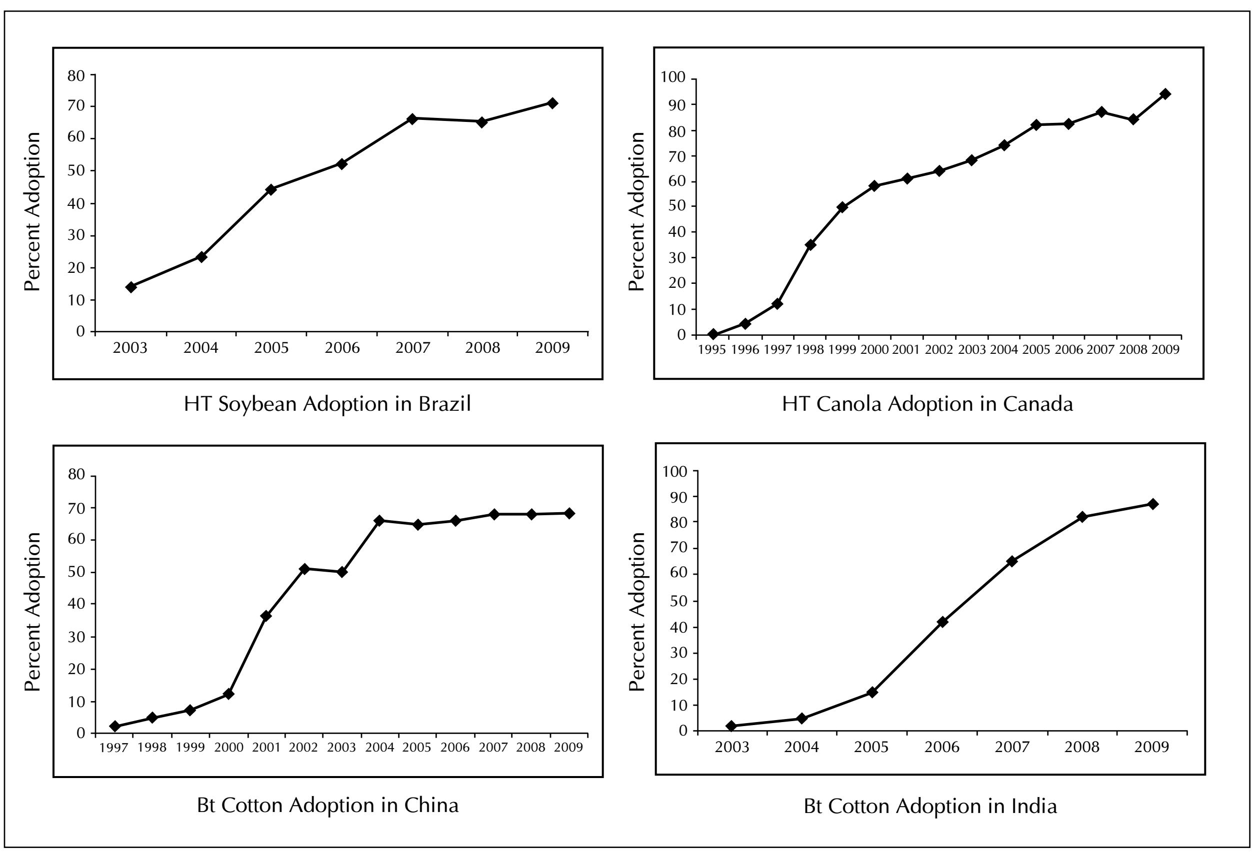
For 2009, biotech crops in Brazil were estimated to occupy 21.4 million hectares, an increase of 5.6 million hectares, the largest increase in any country in the world and equivalent to a 35% increase over 2008. Brazil now plants 16% of all the biotech crops in the world. Of the 21.4 million hectares of biotech crops grown in Brazil in 2009, 16.2 million hectares were planted to RR®soybean for the seventh consecutive year, up from 14.2 million hectares in 2008. The adoption rate was a record 71% versus 65% in 2008 with an estimated 150,000 farmers benefiting from RR®soybeans. In addition in 2009, Brazil planted 5 million hectares of Bt maize for the second time in both the summer and winter (safrinha) seasons. The hectarage of Bt maize increased by 3.7 million hectares, or almost a 400% increase over 2008, and was by far the largest absolute increase for any biotech crop in any country in the world in 2009. The adoption rates were 30% for the summer maize and 53% for the winter maize. Finally, 145,000 hectares of Bt cotton were grown officially for the fourth time in 2009, of which 116,000 hectares were Bt cotton and for the first time 29,000 hectares were HT cotton. Thus in 2009, the collective hectarage of biotech

Figure 2. Percent Adoption of Biotech Crops in the USA, 1996 to 2009.



Source: USDA's National Agricultural Statistics Service (NASS), 2009a.

Figure 3. Percent Adoption of Biotech Crops in Brazil, Canada, China, and India



Source: Compiled by Clive James, 2009.

soybean, maize and cotton in Brazil led to a national year-over-year growth of 35% over 2008, equivalent to 5.6 million hectares, the largest for any country in the world, and most importantly resulted in Brazil becoming, for the first time, the number two country in the world in terms of biotech hectarage. The benefits from biotech crops in Brazil for the period 2003 to 2008 was US$2.8 billion, and US$0.7 billion for 2008 alone.

India has 8 years (2002 to 2009) of impressive benefits from Bt cotton – and Bt brinjal (eggplant), India's first biotech food crop, recommended for commercialization.

Remarkably, for the eighth consecutive year, the hectarage, adoption rate and the number of farmers using Bt cotton in India in 2009, all continued to soar to record highs. In 2009, 5.6 million small and marginal resource-poor farmers in India planted and benefited from 8.381 (~8.4) million hectares of Bt cotton, equivalent to 87% of the 9.636 (~9.6) million hectare national cotton crop. Given that the adoption rate was already very high in 2008, when 5 million farmers planted 7.6 million hectares of Bt cotton, equivalent to 80% of the 9.4 million hectare national cotton crop, all the increases in 2009 were robust. The increase from 50,000 hectares in 2002, (when Bt cotton was first commercialized) to 8.4 million hectares in 2009 represents an unprecedented 168-fold increase in eight years. In 2009, for the first time, multiple gene Bt cotton occupied more hectares (57%) than single gene Bt cotton (43%). 2009 was the first year for an indigenous public sector bred Bt cotton variety (*Bikaneri Nerma*) and a hybrid (NHH-44) to be commercialized in India, thus redressing the balance between the role of the private and public sector in biotech crops in India. A new Bt cotton event was approved for commercialization in 2009 (bringing the total to six approved events) featuring a synthetic *cry1C* gene, developed by a private sector Indian company. The deployment of Bt cotton over the last eight years has resulted in India becoming the number one exporter of cotton globally as well as the second largest cotton producer in the world. Bt cotton has literally revolutionized cotton production in India. **In the short span of seven years, 2002 to 2008, Bt cotton has generated economic benefits for farmers valued at US$5.1 billion, halved insecticide requirements, contributed to the doubling of yield and transformed India from a cotton importer to a major exporter**. In 2008 alone, the benefits accruing from Bt cotton in India was an impressive US$1.8 billion. In October 2009, a landmark decision was made by India's Genetic Engineering Approval Committee (GEAC), to recommend the commercial release of Bt Brinjal (Eggplant/Aubergine), which is now pending, subject to final clearance by the government of India. Brinjal is the "King of Vegetables" but requires very heavy applications of insecticide. Bt brinjal is expected to be the first food crop to be commercialized in India, requiring significantly less insecticide and capable of contributing to sustainability and a more affordable food product for consumers and the alleviation of poverty of 1.4 million small, resource-poor farmers who grow brinjal in India. A 2007 IIMA study reported that 70% of the middle class in India accept biotech foods, and furthermore are prepared to pay a premium of up to 20% for superior biotech foods, such as Golden Rice, with enhanced levels of pro-Vitamin A, expected to be available in 2012. India has several other biotech food crops in field trials including biotech Bt rice.

Continued progress in Africa – South Africa, Burkina Faso, and Egypt

Almost 1 billion people live in Africa, which is almost 15% of the world population. It 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. Up until 2008, South Africa was the only country on the continent of Africa to benefit from biotech crops. **The estimated total biotech crop area in South Africa in 2009 was 2.1 million hectares, up significantly from 1.8 million hectares in 2008, equivalent to a year-over-year growth rate of 17%.** Growth in 2009 was mainly attributed to an increase in biotech maize area, accompanied by an increase in biotech soybean with an adoption rate of 85%, and a modest hectarage of biotech cotton with an adoption rate of 98%. The two new African countries, which joined South Africa in 2008, as biotech crop countries, were Burkina Faso and Egypt.

In 2008, for the first time ever, approximately 4,500 Burkina Faso farmers successfully produced 1,600 tonnes of Bt cotton seed on a total of 6,800 farmer fields; the first 8,500 hectares of commercial Bt cotton was planted in the country in 2008. **In 2009, approximately 115,000 hectares of commercial Bt cotton were planted in Burkina Faso. Compared with 2008 when 8,500 hectares were planted, this was an unprecedented 14-fold year-to-year increase, equivalent to 106,500 hectares, making it the fastest percent increase (1,353%) in hectarage of any biotech crop in any country in 2009**. Thus, the adoption rate in Burkina Faso has increased from 2% of 475,000 hectares in 2008 to a substantial 29% of 400,000 hectares in 2009. Enough Bt cotton seed was produced in Burkina Faso in 2009 to plant approximately 380,000 hectares, equivalent to approximately 70% of all cotton in Burkina Faso in 2010, assuming a total planting of 475,000 hectares. It is estimated that Bt cotton can generate an economic benefit of over US$100 million per year for Burkina Faso, based on yield increases of close to 30%, plus at least a 50% reduction in insecticides sprays, from a total of 8 sprays required for conventional cotton, to only 2 to 4 sprays for Bt cotton.

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

Developing countries increase their share of global biotech crop to almost 50% and are expected to continue to significantly increase biotech hectarage in the future.

Consistent with ISAAA projections, in 2009, developing countries continued to increase their share of global biotech crops by planting 61.5 million hectares, close to half (46%) of the global hectarage of 134 million hectares; this compares with 44% in 2008. The five principal developing countries, (with a collective population of 2.8 billion and representing all three continents of the South: Brazil, Argentina, India, China and South Africa, continued to exert strong global leadership, by planting approximately 57 million hectares equivalent to 43% of the global hectarage of 134 million hectares. The “big five” are a formidable force in driving global adoption of biotech crops and enjoy strong political support in their respective countries, which also provide substantial financial support for biotech crops.

It is noteworthy that in 2009, all seven countries that exhibited proportional growth in biotech crop area of 10%, or more, were developing countries. They were in descending order of percentage growth: Burkina Faso (1,353% increase), Brazil (35% growth), Bolivia (33%), Philippines (25%), South Africa (17%), Uruguay (14%) and India (11%). As in the past, the 2009 percentage growth in biotech crop area continued to be significantly stronger in the developing countries (13% and 7 million hectares) than industrial countries (3% and 2 million hectares). Thus, year-on-year growth measured in either absolute hectares or by percent, was significantly higher in developing countries than industrial countries between 2008 and 2009. The strong trend for higher growth in developing countries versus industrial countries is highly likely to continue in the near, mid and long-term, as more countries from the South adopt biotech crops and crops like rice, 90% of which is grown in developing countries, are deployed as new biotech crops.

The five principal developing countries Brazil (21.4 million hectares), Argentina (21.3 million), India (8.4 million), China (3.7 million), and South Africa (2.1 million) collectively represent 56.9 million hectares equivalent to 43% of the global 134 million hectares. The five countries are committed to biotech crops, and it is notable that they span all three continents of the South. Collectively, they represent 1.3 billion people 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 a very important continuing trend with implications for the future adoption and acceptance of biotech crops worldwide. The five countries are reviewed in detail in Brief 41 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 now substantial, even by multinational company standards.

Of the US$51.9 billion additional gain in farmer income generated by biotech crops in the first 13 years of commercialization (1996 to 2008), it is noteworthy that half, US$26.1 billion, was generated in developing countries and the other half, US$25.8 billion in industrial countries (Brookes and Barfoot, 2010, forthcoming).

Status of Bt maize in the European Union in 2009 – six EU countries planted 94,750 hectares in 2009

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

In 2009, of the 27 countries in the European Union, six officially planted Bt maize on a commercial basis. The six EU countries which grew Bt maize in 2009 listed in descending order of Bt maize hectarage were Spain, Czech Republic, Portugal, Romania, Poland and Slovakia**.** Whereas all seven countries growing Bt maize in 2008 reported increases in Bt maize hectares over 2007, year-to-year hectare changes between 2008 and 2009 varied. Of the six EU countries growing Bt maize in 2009, Portugal had a higher hectarage than 2008, Poland had the same hectarage, and Spain had 4% less hectarage but total plantings of maize were also down in 2008 by a similar margin and hence the adoption rate, 22%, was the same in 2008 and 2009. The three other remaining EU countries Czech Republic, Romania and Slovakia reported lower Bt maize hectarages in 2009, albeit based on low absolute hectarages per country of 1,000 to 7,000 hectares.

Adoption by crop

Biotech herbicide tolerant soybean continued to be the principal biotech crop in 2009, occupying 69.2 million hectares or 52% of global biotech area of 134 million hectares, (up from 65.8 million hectares in 2008), followed by biotech maize, 41.7 million hectares at 31% (up from 37.3 million hectares in 2008), biotech cotton 16.1 million hectares at 12%, (up from 15.5 million hectares in 2008) and biotech canola 6.4 million hectares at 5% of the global biotech crop area (up from 5.9 million hectares in 2008).

Adoption by trait

From the first commercialization of biotech crops in 1996, to 2009, herbicide tolerance has consistently been the dominant trait. **In 2009, herbicide tolerance deployed in soybean, maize, canola, cotton, sugarbeet**

and alfalfa occupied 62% or 83.6 million hectares (up from 79 million hectares in 2008) of the global biotech area of 134 million hectares. For the third year running, in 2009, the stacked double and triple traits occupied a larger area, 28.7 million hectares, or 21% of global biotech crop area (up from 26.9 million hectares in 2008) than insect resistant varieties which occupied 21.7 million hectares at 15% (up from 19.1 million hectares in 2008). **The stacked trait products and herbicide tolerant products grew at the same rate of 6% whilst insect resistance grew at 14%.**

RR®sugarbeet achieved a 95% adoption in the USA and Canada in 2009, in only its third year, making it the fastest adopted biotech globally to-date.

In 2009, an estimated 95% of the 485,000 hectares of sugarbeets planted in the United States were devoted to varieties improved through biotechnology (up from 59% in 2008 and a small hectarage in 2007). Canadian growers planted approximately 15,000 hectares of biotech varieties in 2009, representing about 96% of the nation's sugarbeet crop. This makes RR®sugarbeet the fastest adopted commercialized biotech crop globally to-date. In September 2009, a California court ruled that the U.S. Department of Agriculture (USDA) did not adequately study RR®sugarbeet in the USA and ordered the USDA to conduct a more intensive study, which was pending when this Brief went to Press. It should be noted that the court's decision did not question the safety or efficacy of RR®sugarbeets. The very high level of satisfaction and demand by USA and Canadian farmers for RR®sugarbeet launch probably has implications for sugarcane (80% of global sugar production is from cane), for which biotech traits are under development in several countries. Approval for field trials of biotech sugarcane was granted in Australia in October 2009.

Accumulated hectarage of biotech crops 1996 to 2009 reached almost 1 billion hectares.

The top eight countries, each of which grew more than 1 million hectares, in decreasing order of hectarage were: **USA (64.0 million hectares), Brazil (21.4) Argentina (21.3), India (8.4), Canada (8.2), China (3.7), Paraguay (2.2), and South Africa (2.1 million hectares) (Table 1 and Figure 1).** Consistent with the trend for developing countries to play an increasingly important role, it is noteworthy that Brazil with a high 35% growth rate between 2008 and 2009 narrowly displaced Argentina for the second ranking position globally in 2009. **The remaining 17 countries which grew biotech crops in 2009 in decreasing order of hectarage were:** Uruguay, Bolivia, Philippines, Australia, Burkina Faso, Spain, Mexico, Chile, Colombia, Honduras, Czech Republic, Portugal, Romania, Poland, Costa Rica, Egypt, and Slovakia. The growth in 2009 provides a broad and stable foundation for future global growth of biotech crops. The growth rate between **1996 and 2009 was an unprecedented 79-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 85 million individual decisions in 25 countries over a 14-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% in many cases 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.

Substitution of first generation products with second generation products with increased yield *per se*

Unlike the first generation RR®soybean which was developed with gene gun technology, RReady2Yield™ soybean was developed with more efficient and precise *Agrobacterium* insertion technology. Genetic mapping of soybean allowed yield enhancing zones of soybean DNA to be identified. In turn, this important achievement in conjunction with advanced insertion and selection technology allowed the RReady2Yield™ gene (MON 89788) to be precisely inserted in one of the high yielding zones. Whereas the yield enhancing genes are not transgenic, (however, products with transgenic genes for higher yield are already in the pipeline), the second generation RReady2Yield™, as a result of the linkage established between yield and glyphosate tolerance, offered significant increases in yield of 7 to 11% over the first generation RR®soybean during the field trial period from 2004 to 2007. Analysis of the yield components responsible for the yield increase in RReady2Yield™ indicates that it is due to more 3-bean pods which in turn increased the number of seeds per plant from 85.8 in RR®soybean to 90.5 in RReady2Yield™. In 2009, RReady2Yield™ varieties of selected maturity classes were commercialized for the first time in a controlled launch in the USA and Canada on approximately 0.5 million hectares, and this hectarage is expected to increase to between 2 to 3 million hectares in 2010. The commercialization of RReady2Yield™ in 2009 is important because it represents the first commercially approved product from a new wave of a whole new class of second generation biotech crop products in the R&D pipeline, from many technology developers, that will also enhance yield *per se* in contrast to the first generation products that, by and large, protected crops from biotic stresses (pests, weeds and diseases).

Economic Impact

Biotech crops can play an important role by contributing to food self-sufficiency/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$51.9 billion during the period 1996 to 2008, 49.6% were due to substantial yield gains, and 50.4% due to a reduction in production costs. In 2008, the total crop production gain globally for the 4 principal biotech crops (soybean, maize, cotton and canola) was 29.6 million metric tons, which would have required 10.5 million additional hectares had biotech crops not been deployed. The 29.6 million metric tons of increased crop production from biotech crops in 2008 comprised 17.1 million tons of maize, 10.1 million tons of soybean, 1.8 million tons of cotton lint and 0.6 million tons of canola. For the period 1996-2008 the production gain was 167.1 million tons, which (at 2008 average yields) would have required 62.6 million additional hectares had biotech crops not been deployed** (Brookes and Barfoot, 2010, 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.

The most recent survey of the global impact of biotech crops for the period 1996 to 2008 (Brookes and Barfoot 2010, forthcoming) estimates that **the global net economic benefits to biotech crop farmers in 2008 alone was US$ 9.2 billion (US$4.7 billion for developing countries and US$4.5 billion for industrial countries). The accumulated benefits during the period 1996 to 2008 was US$51.9 billion with US$26.1 billion for developing and US$25.8 billion for industrial countries.** These estimates include the very important benefits associated with the double cropping of biotech soybean in Argentina.

Reduction in Pesticide Usage

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 2008 was estimated at 356 million kilograms (kgs) of active ingredient (a.i.), a saving of 8.4% in pesticides,** which is equivalent to a 16.1% 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 2008 alone was a reduction of 34.6 million kgs a.i.** (equivalent to a saving of 9.6% in pesticides) and a reduction of 18.2% in EIQ (Brooks and Barfoot, 2010, forthcoming).

Savings in CO_2

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 2008, this was an estimated saving of 1.22 billion kg of carbon dioxide (CO_2), equivalent to reducing the number of cars on the roads by 0.53 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 2008 to 13.2 billion kg of CO_2, or removing 6.41 million cars off the road. **Thus in 2008, the combined permanent and additional savings through sequestration was equivalent to a saving of 14.4 billion kg of CO_2 or removing 6.94 (~7) million cars from the road** (Brookes and Barfoot, 2010, forthcoming).

Food self-sufficiency and food security

During the 2008 price crisis when key food exporting countries, (like Thailand and Vietnam for rice, and Argentina for soybean and maize) blocked food exports, trust in the international rice market by importing developing countries eroded, hence they are now negotiating directly with individual exporting countries; importantly, they are now also engaging in actions that will increase their own productivity and self-sufficiency in the major food staples. For example, the Philippines the world's largest importer of rice, aims to produce 98% of its rice in 2010. India, Malaysia, Honduras, Colombia and Senegal have declared similar strategies to increase self-sufficiency of major food staples. This very important change in strategy (in both donor and developing countries) from food security (enough food for all) to food self-sufficiency (increasing production and productivity per hectare of national food crops) has very important implications for biotech crops. Self-sufficiency and being least dependent on others for food, feed and fiber has long been China's strategy and is consistent with its rational for developing biotech crops to enhance yield. Thus, China's decision to approve the two important staples biotech rice and maize provides a successful working model that other developing countries can emulate. The implications for other developing countries of the approval of biotech rice and maize by China cannot be overestimated and the impact will be multidimensional including; facilitating and expediting the regulatory approval process for biotech crops; opening up new possibilities for creative new South-South cooperation and partnerships, including crop biotechnology transfer possibilities, and public/public and public/private sector partnerships (The Economist, 2009c).

More than half the world's population lived in the 25 countries, with 134 million hectares of biotech crop occupying 9% of the 1.5 billion hectares of all cropland.

More than half (54% or 3.6 billion people) of the 2009 global population of 6.7 billion lived in the 25 countries where biotech crops were grown in 2009 and generated significant and multiple benefits worth US$9.2 billion globally in 2008. 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 2009. **The 134 million hectares of biotech crops in 2009 represent 9% of the 1.5 billion hectares of cropland in the world.**

Consumption of food products derived from biotech crops

Critics of biotech crops have tried to perpetuate the myth that products from biotech crops are not consumed as food, only used as feed or fiber. On the contrary it is estimated that 70% of processed foods sold in the USA and Canada contain approved GM ingredients – thus approximately 300 million people have consumed biotech crop derived products for more than 10 years in North America with not even a suggestion of any problem. Products from biotech crops in the USA include biotech soybean, maize, cotton (oil), canola, papaya and squash. In South Africa, Bt white maize used traditionally for food (yellow maize is used for feed) has been consumed since 2001 and Bt maize now occupies two-thirds of the total white maize hectarage of 1.5 million in 2009. Similarly, products from biotech soybean and cotton (oil) are consumed in South Africa. Finally, China approved biotech papaya which has been consumed since 2006 and in 2009 approved a biotech product of rice which is the most important food crop in the world. In addition, large quantities of biotech crops have been imported in many countries without health incidence.

Twenty-five countries approved biotech crops for planting and 32 for import for a total of 57 countries approving biotech crops or products derived from them.

While **25 c**ountries planted commercialized biotech crops in 2009, an additional **32** countries, totaling **57** have granted regulatory approvals for biotech crops for import for food and feed use and for release into the environment since 1996. A total of **762** approvals have been granted for 155 events[1] for 24 crops. Thus, biotech crops are accepted for import for food and feed use and for release into the environment in 57 countries, including major food importing countries like **Japan, which do not plant biotech crops. Of the 57 countries that have granted approvals for biotech crops, Japan tops the list followed by USA, Canada, South Korea, Mexico, Australia, the Philippines, the European Union, New Zealand and China.** Maize has the most events approved (49) followed by cotton (29)**,** canola (15), potato (10) and soybean (9). The event that has received regulatory approval in most countries is herbicide tolerant soybean event GTS-40-3-2 with 23 approvals (EU=27 counted as 1 approval only), followed by herbicide tolerant maize (NK603) and insect resistant maize (MON810) with 21 approvals each, and insect resistant cotton (MON531/757/1076) with 16 approvals worldwide.

1 An event refers to a unique DNA recombination event that took place in one plant cell, which was then used to generate entire transgenic plants. Every cell that successfully incorporates the gene of interest represents a unique "event". Every plant line derived from a transgenic event is considered a biotech crop. The Event Names correspond to the identifiers commonly used by regulatory authorities and international organizations, such as the Organization for Economic Cooperation and Development (OECD).

National economic growth – potential contribution of biotech crops

In the absence of agricultural growth, national economic growth is not possible in the agricultural-based countries. The 2008 World Bank Development 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. History confirms that technology can make a substantial contribution to crop productivity and to rural economic growth. The best example is hybrid maize in the USA in the 1930s, and the green revolution for rice and wheat in the developing countries, 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, for which the late Norman Borlaug was awarded the Nobel Peace Prize in 1970. Norman Borlaug was the most credible advocate for the new technology of biotech crops and was an enthusiastic patron of ISAAA. Bt cotton already deployed in China generated approximately US$1 billion and US$1.8 billion in India. The Bt rice already approved 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 beneficiaries, 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; furthermore, the potential for the future with crops like Bt rice is enormous.** 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".**

Global value of the biotech seed market alone valued at US$10.5 billion in 2009 with commercial biotech maize, soybean grain and cotton valued at US$130 billion for 2008

In 2009, the global market value of biotech crops, estimated by Cropnosis, was US$10.5 billion, (up from US$9.0 billion in 2008); this represents 20% of the US$52.2 billion global crop protection market in 2009, and 30% of the approximately US$34 billion commercial seed market. The US$10.5 billion biotech crop market comprised US$5.3 billion for biotech maize (equivalent to 50% of global biotech crop market, up from 48% in 2008), US$3.9 billion for biotech soybean (37.2%, same as 2008), US$1.1 billion for biotech cotton (10.5%), and US$0.3 billion for biotech canola (3%). Of the US$10.5 billion biotech crop market, US$8.2 billion (78%) was in the industrial countries and US$2.3 billion (22%) was in the developing countries. The market value of the global biotech crop market is based on the sale price of biotech seed plus any technology fees that apply. The accumulated global value for the twelve year period, since biotech crops were first commercialized in 1996, is estimated at US$62.3 billion. The global value of the biotech crop market is projected at over US$11 billion for 2010. The estimated global farm-scale revenues of the harvested commercial "end product", (the biotech grain and other harvested products) is much greater than the value of the biotech seed alone (US$10.5 billion) – in 2008, the biotech crop harvested products were valued at US$130 billion globally, and projected to increase at up to 10 - 15% annually.

Future Prospects of biotech crops, 2010 to 2015

Crops are the principal source of food, feed and fiber globally, producing approximately 6.5 billion metric tons annually. History confirms that technology can make a substantial contribution to crop productivity,

to rural economic growth, food security and the alleviation of hunger, malnutrition and poverty. From 2010 to 2015, the "Grand Challenge" for global society is to meet the Millennium Development Goals of 2015 and double food, feed and fiber production on less resources (particularly water, fossil fuel and nitrogen) by 2050 through a substantial and sustainable intensification of crop productivity to ensure food self-sufficiency and security, alleviation of hunger, malnutrition and poverty, using both conventional and biotech technologies.

The future adoption of biotech crops from 2010 to 2015, particularly in ISAAA's partner developing countries, will depend on three major factors:

- establishment and effective operation of appropriate, responsible and cost/time-effective regulatory systems;
- strong political will and financial support for the development and adoption of biotech crops that can contribute to a more affordable and secure supply of food, feed and fiber; and
- a continuing and expanding supply of appropriate biotech crops that can meet the priority needs of global society, particularly the developing countries of Asia, Latin America and Africa.

1. Effective and responsible regulatory systems

There is an urgent and critical 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. This is the most important single constraint to the adoption of biotech crops in most developing countries. We must utilize all the knowledge and experience of 14 years of regulation to relieve developing countries of the burden of **unnecessarily cumbersome regulations that are impossible to implement for approval of products which can cost up to US$1 million or more, to deregulate – this is simply beyond the means of most developing countries.** The current regulatory systems were designed almost 15 years ago to meet the initial needs of wealthy industrial countries dealing with a new technology and with access to significant resources for regulation which poor developing countries do not have. With the accumulated knowledge of the last fourteen 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.

2. Political will, financial and scientific support for the development, approval and adoption of biotech crops

In 2008 and 2009, following the unprecedented high prices of food in 2008, (which led to riots in over 30 developing countries and overthrow of Governments in two countries, Haiti and Madagascar), there was a realization by global society of the grave risk to food and public security. As a result, there has been a marked increase in the political will and support for biotech crops in the donor group, the international development and scientific community, and from leaders of developing countries. More generally, there has been a renaissance and recognition of the life sustaining essential role of agriculture by global society, and importantly, its vital role in ensuring a more just and peaceful global society. The following collection of quotes in 2008 and 2009 from world leaders, politicians, policymakers and members of the international scientific community capture the increase in political will and support in 2008 and 2009. The challenge now is for them to practice what they preach, and then preach what they practice.

- In 2008, China committed an additional US$3.5 billion over twelve years to improve crop technology with **Premier Wen Jiabao (Chairman of the State Council/Cabinet of China) expressing China's strong political will for crop biotechnology** 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.***" Later in October 2008 Wen Jiabo (2008) reinforced his support for biotech crops when he stated that, ***"I strongly advocate making great efforts to pursue transgenic engineering. The recent food shortages around the world have further strengthened my belief."*** **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). China's commitment to biotech crops culminated in the landmark decision to issue biosafety certificates for biotech maize and rice on 27 November 2009 (Crop Biotech Update, 2009).

- **The Prime Minister of India Dr. Manmohan Singh**. While inaugurating the 97th Indian Science Congress in Thiruvanthapuran, Kerala on 3 January, 2010, Dr. Manmohan Singh lauded the resounding success of Bt cotton in India and emphasized the need for developments in biotechnology for greatly improving the yield of major crops in India. His speech was of particular significance because the congress is the apex body for science and technology in India and has focused on 'Science and Technology Challenges of the 21st Century-National Perspective'. He said, ***"Developments in biotechnology present us the prospect of greatly improving yields in our major crops by increasing resistance to pests and also to moisture stress. Bt Cotton has been well accepted in the country and has made a great difference to the production of cotton. The technology of genetic modification is also being extended to food crops though this raises legitimate questions of safety. These must be given full weightage, with appropriate regulatory control based on strictly scientific criteria. Subject to these caveats, we should pursue all possible leads that biotechnology provides that might increase our food security as we go through climate related stress"*** (Singh, 2009).

- India's former **Minister of Finance, Mr. P. Chidambaram**, 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"*** (James, 2008).

- **In September, 2009 India's regulatory body (GEAC) recommended the approval of Bt brinjal (eggplant) for commercialization to the Indian Government**. The significance of this is that Bt brinjal is the first biotech food crop to be recommended for approval in India; final approval by Government was pending at the time that this Brief went to press. Replying to a question "Introduction of Bt brinjal" in the Rajya Sabha (Upper House) of the Parliament of India on 23 Nov 2009, **Minister of State for Environment and Forests Mr. Jairam Ramesh** stated that "***The cumulative results of more than 50 field trials conducted to assess the safety, efficacy and agronomic performance of Bt brinjal demonstrate that Cry1Ac protein in Bt brinjal provides effective protection from the Fruit and Shoot Borer, a major pest in brinjal crop; resulting in enhanced economic benefits to the farmers and traders accrued from higher marketable yield and lower usage of pesticide sprays"*** (Ramesh, 2009).

- Commenting on the approval by GEAC of Bt brinjal in September 2009, **India's Minister of Science and Technology Mr. Prithviraj Chavan** said that "***The main advantage of this technology is that it reduces the use of chemical pest control, making this technology safe for the environment***

as well as human consumption." He further stressed that ***"I am sure that the development of Bt brinjal, the first biotech vegetable crop is appropriate and timely***". He went on to say that "***Bt crops have been grown around the world since 1996 without any reported adverse health implications***" (Chavan, P. 2009).

- **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).

- **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."***

- **G8 members in a Joint Statement on Global Food Security endorsed at La'Aquila, Italy, July 19, 2009**, agreed to provide US$20 billion over the next three years "***to help farmers in the poorest nations improve food production and help the poor feed themselves."*** The hallmark of the decision was the new emphasis on increasing food productivity, and "self-sufficiency", as opposed to food security (they are not mutually exclusive) captured in the adage "**give a man a fish and feed him for a day – teach a man to fish and feed him for a lifetime."** The G8 said ***"We remain deeply concerned about global food security, the impact of the global financial and economic crisis and last year's spike in food prices on the countries least able to respond to increased hunger and poverty. While the prices of food commodities have decreased since their peak of 2008, they remain high in historical terms and volatile…There is an urgent need for decisive action to free humankind from hunger and poverty. Food security, nutrition and sustainable agriculture must remain a priority issue on the political agenda, to be addressed through a cross-cutting and inclusive approach, involving all relevant stakeholders, at global, regional and national level. Effective food security actions must be coupled with adaptation and mitigation measures in relation to climate change, sustainable management of water, land, soil and other natural resources, including the protection of biodiversity"*** (G8, 2009)**.**

- **Nobel Peace Laureate Norman Borlaug.** The Nobel Peace Prize Committee of 1970 concluded that ***"Borlaug, more than any other single person of this age, he has helped to provide bread for a hungry world. We have made this choice in the hope that providing bread will also give the world peace… He has helped to create a new food situation in the world and who has turned pessimism into optimism in the dramatic race between population explosion and our production of food."*** Norman Borlaug was the world's most credible advocate of biotech/GM crops and their contribution to global food security and alleviation of hunger and poverty. He opined that "***Over the past decade, we have been witnessing the success of plant biotechnology. This technology is helping farmers throughout the world produce higher yield, while reducing pesticide use and soil erosion. The benefits and safety of biotechnology has been proven over the past decade in countries with more than half of the world's population. What we need is courage by the leaders of those countries where***

farmers still have no choice but to use older and less effective methods. The Green Revolution and now plant biotechnology are helping meet the growing demand for food production, while preserving our environment for future generations (James, 2008). Before his passing in September 2009, Norman Borlaug, called for a second "Green Revolution", in response to the Food Security Act of 2009 introduced by Sen. Richard Lugar and Sen. Robert Casey. ***"The Green Revolution hasn't been won yet,"*** said Borlaug. ***"Developing nations need the help of agricultural scientists, researchers, administrators and others in finding ways to feed ever-growing populations... The forgotten world is made up primarily of the developing nations, where most of the people, comprising more than 50 percent of the total world population, live in poverty, with hunger as a constant companion… The Food Security Act of 2009 can lead the way in starting a second Green Revolution by helping improve agriculture and food security in developing countries"*** (Borlaug, 2009).

- **Bill Gates in his keynote address during the World Food Prize Symposium** on Oct. 15, 2009 in Des Moines, Iowa **endorsed the use of biotech crops:**
  "***In some of our grants, we include transgenic approaches because we believe they can help address farmers' challenges faster and more efficiently than conventional breeding alone… It's the responsibility of governments, farmers, and citizens – informed by excellent science – to choose the best and safest way to help feed their countries… We have the tools. We know what needs to be done. We can be the generation that sees Dr. Borlaug's dream fulfilled – a world free of hunger"*** (Gates, 2009).

- **FAO.** During the High Level Forum on October 12, 2009, Director-General Jacques Diouf declared that: ***"Agriculture will have no choice but to be more productive,"*** noting that increases would need to come mostly from yield growth and improved cropping intensity rather than from farming more land. He noted that ***"while organic agriculture contributes to hunger and poverty reduction and should be promoted, it cannot by itself feed the rapidly growing population"*** (Diouf, 2009).

- **World Summit on Food Security**. Support to Biotechnology was one of the strategies in the Declaration signed by the heads of states and governments during the World Summit on Food Security, 6-18 November 2009, Rome Italy. ***"We recognize that increasing agricultural productivity is the main means to meet the increasing demand for food given the constraints on expanding land and water used for food production. We will seek to mobilize the resources needed to increase productivity, including the review, approval and adoption of biotechnology and other new technologies and innovations that are safe, effective and environmentally sustainable."*** This statement is one of the strategies that will address Principle 3 of the Declaration: Strive for a comprehensive twin-track approach to food security that consists of: 1) direct action to immediately tackle hunger for the most vulnerable and 2) medium and long-term sustainable agricultural, food security, nutrition and rural development programs to eliminate the root causes of hunger and poverty, including through the progressive realization of the right to adequate food (World Summit on Food Security, 2009).

- **Hilary Benn, Secretary of State, Environment Food and Rural Affairs (DEFRA)** UK, proposed that GM crops may offer a solution to climate change and population growth. He said "***We saw last year when the oil price went up and there was a drought in Australia, which had an impact on the price of bread here in the UK, just how interdependent all these things are... We have to feed another two and a half to three billion mouths over the next 40 to 50 years, so I want British agriculture to produce as much food as possible."*** Mr. Benn told Radio 4 Today Program that farmers would decide what to grow "***But it was important to investigate new techniques to discover the "facts" about them. If GM can make a contribution then we have a choice as a society and as a world about whether to make use of that technology, and an increasing number of countries are growing GM products… Because one thing is certain – with a growing population, the world is going to need a lot of farmers and a lot of agricultural production in the years ahead. Some GM crops could be more drought-resistant and used without pesticides to combat the expected rise in insects associated with rising temperatures"*** (Waugh, 2009). **Dr. Robert Watson,** Chief Scientific Advisor to the UK's Department of Environment, Food and Rural Affairs (DEFRA) and Secretariat Director of the controversial IAASTD Report, said that "***GM crops have a role to play in prevention of mass starvation across the world caused by a combination of climate change and rapid population growth"*** (Shields, R. 2009). The UK Government's Food 2030 study, published in early January 2010, concluded that Britain must embrace GM crops or face serious food shortages in the future. The Report has had unusually strong support from Government, ministers, leading scientists and is consistent with the recommendations of the recent substantive report from the UK's prestigious Royal Society, referenced in the following paragraph. Speaking at the Oxford Farming Conference, after the publication of the Food 2030 Report, Professor John Beddington, the UK's Chief Scientist said, ***"GM and nanotechnology should be part of modern agriculture... – We need a greener revolution, improving production and efficiency through the food chain within environmental and other constraints. Techniques and technologies from many disciplines ranging from biotechnology and engineering to newer fields such as nanotechnology will be needed"*** (Gray, 2009).

- **The Royal Society of London,** UK. In a very substantive report, published in October 2009, and entitled "***Reaping the Benefits – Science and the sustainable intensification of agriculture", The Royal Society***, the UK's most prestigious scientific academy, recommended publicly funded research of GM crop technologies in an effort to achieve sustainable intensification of agriculture. The report recommended that ***"Due to the scale of the challenge (on food security), no technology should be ruled out, and different strategies may need to be employed in different regions and circumstances."*** The report concludes that the application of both conventional and biotech applications would allow northern Europe to become one of the '***major bread baskets of the world'***. The UK Government's Chief Scientist, Dr. John Beddington has endorsed biotech crops for the UK. In addition, the UK Food Standards Agency (FSA) is due to initiate a dialogue to explore GM crops with consumers. The UK Government policy on biotech crops, established in 2004, states that "***There is no scientific case for a blanket ban on the cultivation of GM crop in the UK, but that proposed uses of GM need to be assessed on a case by case basis"*** (Hills, 2009).

- **Pontifical Council for Justice and Peace.** Members of the Pontifical Council for Justice and Peace supported biotechnology to alleviate poverty and hunger in Africa. In a Forum "For a Green Revolution in Africa" conducted in Rome in September 24, 2009, Archbishop Giampaolo Crepaldi, former secretary of the Pontifical Council for Justice and Peace, said that ***"Underdevelopment and hunger in Africa are due in large part to outdated and inadequate agricultural methods, new technologies that can stimulate and sustain African farmers must be made available, including seeds that have been improved by techniques that intervene in their genetic makeup."*** Father Gonzalo Miranda, professor of bioethics at the Pontifical Regina Apostolorum University, which sponsored the symposium, said that, ***"If the data shows that biotechnology can offer great advantages in the development of Africa, it is a moral obligation to permit these countries to do their own experimentation"*** (African Forum on Biotechnology, 2009).

3. Will global adoption of biotech crops, by country, number of farmers, and hectarage all double by 2015, and will there be an expanding supply of appropriate biotech crops to meet the priority needs?

Given the impressive progress with biotech crop adoption, already achieved by 2009, and the promising future prospects between now and 2015, there is cautious optimism that the ISAAA 2005 prediction that the number of biotech countries, biotech crop farmers and biotech hectarage would be double between 2006 and 2015 (from 20 to 40 countries, 10 to 20 million farmers and 100 to 200 million hectares) is achievable.

Firstly, between 2010 and 2015, 15 or more new 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, ten 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; biotech potatoes have 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.

Secondly, the number of biotech crop farmers is likely to reach, and may even exceed, the projected 20 million biotech crop farmers by 2015, (already 14 million in 2009), assuming that the following high probability events will materialize: deployment by China, in 2 or 3 years from now, of biotech rice (110 million rice households in China alone) and biotech maize (100 million maize households in China alone) with the possibility that other Asian countries will follow suit following commercialization by China of the most important food and feed crops in the world; optimization of Bt cotton in India and introduction of Bt brinjal in India, Philippines and Bangladesh; significant expansion of biotech soybean, maize and cotton in Brazil: expansion of Bt cotton in Burkina Faso and Bt maize in Egypt, with possible additional deployment by other Africa countries; adoption of Golden Rice by the Philippines, and Bangladesh followed by India and then Indonesia and Vietnam before 2015; addition of new biotech countries like Pakistan, with many small farmers, contributing to the global total expected to reach 20 million or more by 2015.

Thirdly, the comparative advantage of biotech crops to produce more affordable and better quality food to ensure a safe and secure supply of food, feed and fiber globally augurs well for a possible doubling of hectarage to 200 million hectares of biotech crops by 2015. There is considerable potential for increasing the biotech adoption hectarage of the four current large hectarage of biotech crops (maize, soybean, cotton, and canola), as well as new biotech crops and traits such as Bt rice, Golden Rice, biotech sugarcane and biotech potatoes that are likely to be introduced before 2015. The four current principal biotech crops collectively occupied 134 million hectares in 2009 out of a total potential hectarage of 312 million hectares; this leaves over 175 million hectares for potential adoption with biotech crops, which is a significant potential area in itself. Taking the maize crop as an example, only approximately one-quarter of the global 158 million hectare crop has benefited from biotech crops to-date, leaving three-quarters equivalent to almost 120 million hectares as potential for biotech crops in the future. Whilst the USA, the largest grower of maize in the world, already has biotech maize planted on 85% of its 35 million hectares, China, the second largest grower of maize in the world has just approved its first biotech maize, opening up a potential 30 million hectares for phytase maize as well as other traits. The third largest maize grower in the world, Brazil with 13 million hectares, has already expedited the planting of a record 5 million hectares of biotech maize in 2009, in only its second season of commercialization, and is likely to increase its hectarage significantly in 2010. Both the fourth (India, 8 million hectares) and fifth (Mexico, 7 million hectares) largest growers of maize in the world have biotech maize field trials underway in 2009 with a view to assessing benefits which are likely to be significant. In Asia, generally, only half a million hectares were planted with biotech maize (only the Philippines) out of a total of 50 million hectares. Similarly, in Africa less than 2 million hectares out of a total of 28 million hectares (only South Africa and Egypt plant Bt maize) are benefiting from Bt maize. Even in South America, a region with high adoption rates for biotech crops, only 7 million hectares out of a total of 20 million hectares are currently benefiting from biotech maize. It is evident from this global overview of maize that even with the current portfolio of traits, there is significant potential for substantially increasing the global adoption of biotech maize in the short medium and long term.

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 the first generation biotech crops, a significant increase in yield and production was realized by protecting crops from losses caused by pests, weeds, and diseases. However, the second generation biotech crops will offer farmers additional new incentives for further increasing yield per se. RReady2Yield™ soybean, launched in 2009, was the first of many such second-generation products that enhance yield. Quality traits like Golden Rice, omega-3 soybeans, high lysine maize are also likely to become available providing a much richer mix of traits for deployment in conjunction with a growing number of input traits. There will be several new traits, and combinations thereof, as well as 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. A partial selection of a few examples of the key new biotech crops/traits likely to become available in the near term are presented in the following paragraphs

China approves biotech rice and maize

In November 2009, China completed its approval of a troika of key biotech crops – fiber (Bt cotton already approved in 1997), feed (phytase maize) and food (Bt rice). The ISAAA 2008 Brief, predicted ***"a new wave of adoption of biotech crops….providing a seamless interface with the first wave of adoption, resulting in continued and broad-based strong growth in global hectarage."*** This prediction started to become reality on 27 November 2009, when China's Ministry of Agriculture (MOA) granted three biosafety certificates (Crop Biotech Update, 2009). Two certificates were issued for biotech rice, one for a rice restorer line (Bt Huahui-1) and the other for a hybrid rice line (Bt Shanyou Shanyou-63), both of which expressed *cry1Ab/cry1Ac* genes and developed at Huazhong Agricultural University. The approval of Bt rice is extremely important because rice is the most important food crop in the world that feeds half of humanity and is also the most important food crop of the poor. The third certificate was for biotech phytase maize, and this is also very important because maize is the most important feed crop in the world. The phytase maize was developed by the Chinese Academy of Agricultural Sciences (CAAS) and licensed to Origin Agritech Limited after 7 years of study at CAAS. **The three certificates of approval have momentous positive implications for biotech crops in China, Asia and the whole world.** It is important to note that the MOA conducted a very careful due diligence study, prior to issuing the three certificates for full commercialization which is expected in about 2 to 3 years, pending completion of the standard registration field trials which applies to all new conventional and biotech crops. It is noteworthy that China has now completed approval of a troika of the key biotech crops in an appropriate chronology – first was FIBER (cotton), followed by FEED (maize) and FOOD (rice). The potential benefits of these 3 crops for China are enormous and summarized below.

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

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

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

The above advantages of the proprietary Bt cotton, Bt rice and phytase maize, (importantly, all nationally-developed by Chinese public sector institutions) also offer similar benefits to other developing countries, particularly in Asia, (but also elsewhere in the world) which have very similar crop production constraints. Asia grows and consumes 90% of the production from the world's 150 million hectares of rice, and Bt rice can have enormous impact in Asia. Bt rice can not only contribute to increase productivity but can also make a substantive contribution to the alleviation of poverty for poor small farmers who represent 50% of the world's poor – there are approximately 250 million poor rice households globally – assuming four per family there are potentially up to 1 billion poor people that could benefit directly from Bt rice in Asia. Similarly, there are up to 50 million hectares of maize in Asia that could benefit from biotech maize, with 100 million poor maize households with 400 million people in China alone. China's exertion of global leadership in approving biotech rice and maize will likely result in a positive influence on acceptance and speed of adoption of biotech food and feed crops in Asia, and more generally globally, particularly in developing countries. The approval and deployment by China of the most important food and feed crops in the world, provides the country with new powerful tools to maintain self-sufficiency in rice and achieve self-sufficiency in maize. China can serve as a model for other developing countries, particularly in Asia, which could have substantive implications for:

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

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

SmartStax™

A novel biotech maize product called, "SmartStax™", gained registration from the U.S. Environmental Protection Agency (EPA) and regulatory authorization from the Canadian Food Inspection Agency (CFIA) in July 2009 (PRNewswire, 2009). SmartStax™, resulted from a cross licensing agreement and research and development collaboration, signed in 2007, between the Monsanto Company and Dow AgroSciences. SmartStax™, a multiple-trait product based on a total of 8 genes, is the most advanced stacked biotech crop approved to-date, and is designed to provide the most comprehensive insect pest control in maize (both above and below ground) plus herbicide tolerance for weed control.

SmartStax™ is a 4-way stack of approved products of the following events: MON 89034 x TC1507 x MON 88017 x DAS-59122-7.

1) MON 89034 expresses two complementary proteins Cry2Ab and Cry1A.105 for lepidopteran control;

2) TC1507 expresses Cry1F for lepidopteran control and BAR for glufosinate tolerance;

3) MON 88017 expresses Cry3Bb1 for corn rootworm control and CP4 for glyphosate tolerance;

4) DAS-59122-7 expresses a binary protein Cry34/35Ab1 for corn rootworm control and BAR for glufosinate tolerance.

Thus in total, there are 8 genes (*cry2Ab, cry1A.105, cry1F, cry3Bb1, cry34, cry35Ab1, cp4,* and *bar*) that code for the following three traits: above-ground insect control, below-ground insect control, and herbicide tolerance. For the convenience of the reader, the following paragraph provides details of the commercial products used in the development of SmartStax.

- **Above-ground insect control** of corn earworm, European corn borer, southwestern corn borer, sugarcane borer, fall armyworm, western bean cutworm and black cutworm is provided with Dow AgroSciences' HERCULEX®I Insect Protection technology and Monsanto's VT PRO™, a second-generation, two-gene lepidopteran control product contained in Genuity™ Triple PRO™.

- **Below-ground insect control** of Western, Northern and Mexican corn rootworms with the integration of Monsanto's YieldGard VT Rootworm/RR2 technology with Dow AgroSciences' HERCULEX® RW Insect Protection technology.

- **Broad spectrum weed and grass control** with the combination of Monsanto's Roundup Ready®2 technology with Bayer CropScience's Liberty Link® herbicide tolerance.

It is documented that SmartStax™ protects against the broadest spectrum of insect pests with the most consistent level of control available to-date. The multiple mechanisms of insect resistance deployed in SmartStax™ significantly reduce the likelihood of insect resistance developing, thus making it possible for regulators to approve a significant reduction in the refuge requirement. Thus, the increase in durability of insect resistance allowed EPA and CFIA to reduce the farm refuge requirement for SmartStax™ from 20 to 5% in the U.S. Corn Belt and Canada, and from 50 to 20% of the U.S. Cotton Belt. The 5% refuge will in itself allow farmers to increase whole-farm maize yield by 5 to 10%. Thus, farmers will benefit from increased productivity due to both improved pest protection and a reduced refuge.

At the time of manuscript preparation plans were on track to launch the product in the USA and Canada next year, 2010, on approximately 1 to 1.5 plus million hectares – this would make it the biggest launch ever in terms of the first year commercial hectarage of a biotech crop. Work is also underway with regulatory agencies in key countries to have import approvals for SmartStax™ in place prior to the 2010 North American planting season to support commercialization for the 2010 crop season.

Bt brinjal (eggplant) in India

Brinjal is the "King of Vegetables" in India. It constitutes a major ingredient in vegetable diets and is preferred by vegetarians for many preparations. India is the second largest producer of brinjal in the world, after China. A total of 1.4 million small, marginal and resource-poor farmers grow brinjal on 550,000 hectares annually in India. Brinjal is an important cash crop for poor farmers, which provides a stable income from market sales for most of the year. However, brinjal is prone to attack by many insect-pests and diseases that cause significant losses of up to 60 to 70% in commercial plantings. Accordingly, brinjal cultivation requires very heavy applications of insecticide. Bt brinjal, which was developed jointly by public and private sector institutions in India, is expected to reduce insecticides sprays up to 80% to control fruit and shoot borer, which translates into a 42% reduction in total pesticides normally used in controlling all insect-pests of brinjal. Bt brinjal offers a significant increase in marketable yield by 33% over the non-Bt counterparts and 45% over the national check hybrid. As a result, brinjal farmers in India are expected to reap a significant net benefit of US$1,539 per hectare over non-Bt counterparts, and US$1,895 per hectare over the national check, including a net saving on the mean cost of sprays (based on Economic Threshold Levels) of US$115 per hectare. At the national level Bt Brinjal would contribute a net benefit of US$411 million per annum to vegetable producers.

Bt brinjal has been generously donated by its developer Mahyco, to public sector institutions in India, Bangladesh and the Philippines for use in open-pollinated varieties of brinjal in order to meet the specific needs of small resource-poor farmers in these three countries. Currently, 8 Bt brinjal hybrids and 10 Bt brinjal open pollinated varieties (OPVs) have been awaiting commercial approval in India.

Bt brinjal has been tested rigorously by regulatory agencies in India since 2000. In October 2009, a landmark decision was made by India's Genetic Engineering Approval Committee (GEAC), to recommend the commercial release of Bt Brinjal, which is now pending, subject to final clearance by the government of India.

Golden Rice

Among cereals, rice has the highest energy and food yield but lacks essential amino acids and vitamins needed for normal body functions. It lacks beta carotene, the precursor of Vitamin A needed for sight and cell differentiation, in embryonic development in mammals, and in functioning of the immune system and of body mucosal membranes. Vitamin A deficiency (VAD) is a nutritional problem in the developing world afflicting 127 million people and 25% of pre-school children. Currently around 250,000 to 500,000 become blind annually, 67% of whom die within a month, or around 6,000 deaths of children a day, equivalent to 2.2 million per year. This is morally unacceptable when there is a potential remedy available that could be administered today – this is a moral dilemma. Vitamin A supplementation in developing countries is conducted by the FAO, but it is expensive (costing around US$500 million a year), not sustainable, and it cannot reach remote areas. Around 3 billion people (approximately half of the global population) are dependent on rice for their caloric intake, and many cannot afford other foods containing Vitamin A or supplements. Golden Rice offers a practical biotech crop remedy that provides cost-effective and efficient protection against VAD.

In 1984, Dr. Peter Jennings, a rice breeder at IRRI, conceived the Golden Rice initiative because he wanted to alleviate Vitamin A deficiency in rice consuming populations. The Rockefeller Foundation funded a research program at approximately US$1.0 million over 8 years conducted by Prof. Ingo Potrykus and Dr. Peter Beyer. With Rockefeller Foundation support, Potrykus and Beyer elucidated the pathway, the possible genes and conducted the rice transformation to develop the first genetically modified rice that produced beta carotene. The project was a public/private partnership involving the companies Bayer, Mogen, Monsanto, Novartis and Zeneca, as well as an anonymous Japanese company; the companies donated the necessary technology licenses in the early stages of the project. In 2000, the first Golden Rice, in Taipei 309 (japonica) background was developed which contained two transgenes from daffodil and one from a bacterium. The beta carotene content was low at 1.6 to 1.8 μg/g, but it proved the functionality of the genes in rice. With the bacterial gene and a change in the promoter of one gene from daffodil, a javanica variety Cocodrie was developed by Syngenta that contained 6 to 8 μg/g beta carotene. This line was designated Golden Rice 1 and was donated by Syngenta in 2004 to the Golden Rice Humanitarian Board. The Board oversees the direction of the Golden Rice research and the deployment of the lines in the network that includes the International Rice Research Institute (IRRI) and Philippine Rice Research Institute (PhilRice) in the Philippines; Cuu Long Delta Rice Research Institute in Vietnam; Department of Biotechnology India, Directorate of Rice Research, Indian Agricultural Research Institute, University of Delhi, Tamil Nadu Agricultural University, Agricultural University Patnagar, University of Agricultural Sciences Bangalore; Bangladesh Rice Research Institute in Bangladesh; Huazhong Agricultural University, Chinese Academy of Sciences, Yunnan Academy of Agricultural Sciences in China; Agency for Agricultural Research & Development in Indonesia; and Albert-Ludwigs University, Freiburg in Germany (http://www.goldenrice.org).

In 2005, Golden Rice 2 was developed by Syngenta – Kaybonnet (javanica rice) – a variety which contained maize and bacterial transgenes that produced up to 36.7 μg/g beta carotene – more than a four-fold increase compared with Golden Rice 1. The Golden Rice 2 lines were donated by the developer to the Humanitarian Board. In 2005, the Bill and Melinda Gates Foundation provided funding for a collaborative project on "Engineering rice for high beta-carotene, Vitamin E, protein, enhanced iron and zinc bioavailability" to Dr. Peter Beyer of Albert Ludwigs University, Freiburg, Germany. The collaborators include, PhilRice, IRRI, Michigan State University, Baylor College of Medicine, Cuu Long Delta Rice Research Institute, and the Chinese University of Hongkong. Golden Rice 1 which was initially distributed to the Golden Rice network countries, was replaced by Golden Rice 2 in March 2009.

Up to six events of Golden Rice 2 were developed in the background of the American long grain rice Kaybonnet variety (Paine, 2005). A defining step was the selection of one single event for regulatory approval and commercialization. The event selected was GR2G with a single copy insert which produced up to 25 µg/g of beta carotene – as much as 3-4 times more beta carotene compared to GR1 event (8 µg/g). The event was selected based on several criteria, that collectively would allow the beta-carotene requirements of 1-3 year old children eating 100 g of Golden Rice to be met (Barry, 2009; Virk & Barry, 2009). The next step was to identify target countries where the GR2G event would be introgressed into the most promising and popular rice varieties in VAD prone areas. Philippines, India. Bangladesh, Vietnam, and Indonesia were identified as the countries where the GR2G would be the only event to move forward through regulatory approvals and eventually released (Zeigler, 2009). It is expected that Golden Rice will be released in the Philippines and Bangladesh as early as 2012, followed by India, Indonesia and Vietnam. The choice of varieties to be introgressed with GR2G event in the respective countries was based on their popularity and acceptability in regions deficient in Vitamin A. These popular varieties undergoing introgression with GR2G are being developed by the respective national rice research institutions in close collaboration with the International Rice Research Institute (IRRI) under the supervision of the Golden Rice Humanitarian Board. The GR2G varieties in three of the countries with the most advanced products are listed below.

In the Philippines one popular rice variety, PSB Rc-82 is being modified with the GR2G event by the Philippine Rice Research Institute (PhilRice). The variety PSB Rc-82 is estimated to occupy about 13% of the rice in both wet and dry season croppings which is equivalent to about 0.5 million hectares of the total rice hectarage of 4.2 million hectares grown in the Philippines annually.

In Bangladesh the GR2G event is being introgressed into one variety – it is the single most important Boro rice variety **BR-29** in Bangladesh and the introgression is being conducted by the Bangladesh Rice Research Institute (BRRI). BR-29 occupies 2.8 million hectares, equivalent to 28%, of the 10 million hectares of rice in Bangladesh.

In India 3 popular varieties, Swarna, MTU-1010 and ADT-43 are undergoing modification with GR2G: Swarna is a variety that is very popular in Bihar, Eastern Uttar Pradesh, West Bengal, Orissa and Andhra Pradesh and grown by small farmers on an estimated 3 million hectares. The Indian Agricultural Research Institute (IARI) is breeding the GR2G Swarna variety. MTU-1010, also known as Cotton Dora Sannalu, is a very popular variety in Andhra Pradesh and adjoining areas and grown on an estimated 0.8 million hectares. The Directorate of Rice Research (DRR), Hyderabad is breeding the GR2-MTU-1010 variety.

Projecting an adoption scenario at this early stage, prior to approval and the expected first release in 2012, is difficult because the adoption is likely to take place on a step-by-step basis in different regions within each of the three countries, possibly initiating in the Philippines followed by Bangladesh and India. What maybe useful to project at this early stage is the maximum potential area in each of the three countries that could be planted with the Golden Rice varieties currently being developed. In the Philippines, the maximum potential is approximately 0.5 million hectares based on the current hectares occupied by PSB Rc-82. Similarly, in Bangladesh the maximum potential is approximately 2.8 million hectares based on the current hectares occupied by BR-29. For India, the maximum potential is approximately 4.0 million hectares based on the current hectares occupied by Swarna (3 million hectares), MTU-1010 (0.8 million hectares) and ADT-43 (0.2 million hectares). Thus, collectively for the three countries, the Philippines, Bangladesh and India, there is an estimated maximum potential area of up to 7.0 to 7.5 million hectares that could be occupied by Golden Rice varieties starting in 2012. This projection is not intended to be an accurate estimate but to provide the reader with a sense of the order of magnitude of hectares that could be planted with Golden Rice from 2012 onwards, subject to timely approval. *Ex-ante* economic impact analyses projected that Golden Rice consumption could add from US$4 to US$18 billion annually to the GDP of Asian countries over the long term (UNICEF, 2007).

The Golden Rice project is unique in many ways in that it has brought together a diversity of institutions and individuals of like mind, who share the common goal of preventing the death and misery of millions of children and adults (estimated at 127 million) suffering from VAD worldwide, mainly in Asia. The project enjoys the support of the donor and international development communities, the public and the private sectors and the commitment of governments in Asia which have put in place the necessary policy and technology support to remedy a human carnage caused by VAD that kills 6,000 helpless children a day (Barry, 2009).

Whereas VAD is estimated to affect 33% of individuals in South East Asia, corresponding figures for iron deficiency (anemia) is 57% and 71% for zinc deficiency. Rice germplasm with the GR2G event is now being crossed with rice lines having a high content of zinc and iron to pyramid the three benefits. Work is also underway at PhilRice in the Philippines to pyramid 3 traits: GR2G and resistance to the important diseases caused by the Tungro virus and bacterial leaf blight of rice.

Drought Tolerance – Drought tolerant maize expected to be deployed in the USA in 2012 and in Sub-Saharan Africa in 2017 – Global Drought Overview for 2009

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. 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.

The encouraging news is that drought tolerant biotech/GM maize, the most advanced of the drought tolerant crops under development, is expected to be launched commercially in the USA in 2012 – see the special supplement on Drought Tolerance in Maize: An Emerging Reality published in ISAAA Brief 39 (James, 2008). Drought is particularly important in Africa where in 2003 the World Food Program spent US$0.57 billion on food emergency supplies due to drought. The uncertainty associated with drought prevents the execution of best management practices for stabilizing yield which are essential if benefits are to be derived from necessary crop inputs. Notably, a private/public sector partnership called WEMA (Water Efficient Maize program for Africa) is making progress (Oikeh, 2009). The WEMA project is coordinated by AATF and involves Monsanto, (which donated the technology), the Gates Foundation, the Howard Buffet Foundation (funding), CIMMYT, and selected African national programs including Mozambique, Kenya, South Africa, Tanzania, and Uganda. WEMA hopes to release the first royalty-free biotech drought tolerant maize by 2017 in Sub-Saharan Africa where the need for drought tolerance is greatest and where 650 million people are dependent on maize. Under moderate drought the expected benefits from WEMA include yield increases of the order of 20 to 35%, equivalent to 12 million tons of maize which can feed 14 to 21 million people during a drought year. The first field trial with biotech drought tolerant maize was planted in South Africa in November 2009 and the first conventional drought maize is expected in 3 to 4 years around 2013. The challenges in the WEMA project include: establishment of operational and effective regulatory bodies in the national programs; production and distribution of high quality hybrid seed and supply of adequate credit for small farmers (Oikeh, 2009).

The increasing frequency and severity of droughts globally over the last few years, have led some to conclude that climatic change-generated droughts are already in evidence and that drought resulted in a significant decrease in food, feed and fiber production globally in 2009. The following is a an overview of the impact of drought around the world in 2009, by Eric de Carbonnel (2009) and augmented with information from other sources. He concludes that the principal countries that produce two-thirds of the world's agricultural output are also, by and large, the same countries that suffered significantly from drought in 2009.

Africa

Countries in the horn of Africa were hard hit by drought resulting in widespread famine in Kenya where 10 million people faced starvation in 2009. Neighboring countries including Tanzania, Burundi, Ethiopia and Uganda face similar situations. South Africa was projecting that harvests would be the lowest for 30 years. Other countries in Sub- Saharan Africa reporting drought in 2009 included Malawi, Zambia, Swaziland, Somalia, Zimbabwe, Angola, Mozambique, and Tunisia in North Africa.

China

The drought which started in November 2008 in north and northeastern China (where rainfall was 50 to 90% less than normal) was the worse in 50 years and affected over 10 million hectares of cropland including half of the wheat crop in the eight following provinces, which are the major wheat producing provinces in China: Henan (the largest crop production province in China), Anhui (>50% of crops damaged), Shanxi, Jinagsu (20% of wheat lost), Hebei, Shaanxii, and Shandong which had 73% less rain than last year. To avert disaster, the Government of China allocated US$12.7 billion to cushion the impact of drought, which directly affected over 4 million people in the rural areas of these eight provinces alone. The areas hard-hit by the drought were China's main grain production areas, which produce approximately 18% of the world's grain (equivalent to about 500 million tons per annum). It is noteworthy that China's Government has set a goal to produce 540 million tons of grain domestically by 2020 (Xinhua, 2009a) – this will be a formidable challenge if droughts become more frequent and severe and water tables continue to drop. In July 2009, the drought area in China expanded rapidly into the inner Mongolia Autonomous Region, the Xinjanag Uyugur Autonomous Region, Jilin, Shanxi and Liaoning (Xinhua, 2009b). It was reported that almost 7 million people utilizing more than one-third of a million vehicles, were physically involved in fighting the drought, which affected both potable and irrigation water supplies in the worst-hit areas. Later in 2009, the devastation caused by the drought in the north and northeast was exacerbated by the severe flooding that resulted from Typhoon Morakot in south China in August 2009 – extremes of drought followed by floods may represent the new challenges that climate change and global warming will bring.

Australia

The country has suffered severely from droughts since 2004, with 2006 and 2007 being the worst two years of drought ever since records began 117 years ago – it is estimated that over 40% of the country's agriculture is still suffering from the devastating droughts of 2006/07. The droughts were so severe at its worse that major rivers like the Murray River actually stopped flowing.

USA

In 2009, the state of Texas in the USA had the worst drought in 50 years. Losses due to the drought were estimated at US$3.5 billion in Texas' US$20 billion agriculture sector (The Economist, 2009d). The 2009 drought was the worst since 1917 and it was estimated that 88% of the state suffered from abnormally dry conditions and that 18% suffered from the most severe state of drought. The governor of Texas declared a disaster for much of the state – to exacerbate matters, droughts increase the probability of devastating wild fires. In June and July temperatures in Austin, Texas hit triple-digit levels for more than half of the time – 39 days out of a total of 61 days. In California in 2009, the drought was also the worse since records began with thousands of hectares of row crops fallowed. Run-off from the snow in the high Sierras, which feeds the reservoirs, was only 49% of normal. Other states in the USA suffering from drought included Florida, Georgia, North Carolina and South Carolina. The weather in 2009, including both droughts and floods, is thought to have been significantly influenced by El Niño (warm and wet) and La Niña (cool and dry). La Niña, associated with cooler waters in the Pacific exacerbated the drought problems in the USA, resulting in dryer weather in the southern states of the USA and elsewhere in the Americas.

South America

In Argentina, the worst drought in 50 years resulted in significant decrease in grain production especially the state of Cordoba. Brazil, which is the second biggest exporter of soybeans in the world, also suffered some damage due to drought. Several other countries in South America suffered from drought in 2009 including Mexico, Paraguay, Uruguay, Bolivia and Chile where La Niña has prevented the rain clouds from penetrating into Chile and South America.

Middle East and Central Asia

Countries in these regions also reported drought, which decreased yields, with wheat production down by about 20%. The supply of water in reservoirs in the two regions is at low levels and there is also concern that smaller harvests will result in limited supply of farmer-saved seed for the next cropping season. Some of the countries in this region are also wracked by political instability and war, which seriously exacerbates the ability of the countries to deal with devastating droughts. Countries reporting drought in the two regions in 2009 included, Iraq, Syria, Afghanistan, Jordan, the Palestinian Territories, Lebanon, Israel, Bangladesh, Myanmar, Tajikistan, Turkmenistan, Thailand, Nepal, Pakistan, Turkey, Kyrgyzstan, Cyprus and Iran.

Europe

Europe was the only principal crop production region globally to have suffered relatively little drought in 2009 although countries like Spain and Portugal have experienced significant droughts in recent years.

The extent of drought globally in 2009 does not auger well for the future if the droughts associated with climate change and global warming are going to result, as predicted, in more frequent and more severe droughts which will have more impact in developing than industrial countries. It is evident that under such circumstances,when drought will become even more important, that the value of biotech-based drought tolerance will be paramount.

Nitrogen Use Efficiency (NUE)

Nitrogen and water were pre-requisite external inputs for the unprecedented success of the green revolution of the 1960s in both wheat and rice. Agriculture uses 70% of all the fresh water in the world and there is an urgent need to address the increasingly short supply of water globally, as water tables in high population countries like China drop precipitously. There is an equally important and urgent need to increase nitrogen use efficiency in order to decrease dependency on fossil fuel-based nitrogen fertilizers and also to reduce greenhouse gas emissions and pollution of water sources with leaked nitrogen products. It is estimated that today, approximately half of the nitrogen atoms in a human body is derived from fossil fuel-based ammonia (Ridley, 2009). The annual global cost of nitrogen fertilizers is approximately US$100 billion. It is estimated that up to two-thirds of the nitrogen fertilizer applied by farmers globally is lost though run-offs, leaching and gasification. In turn, the leaked nitrogen products result in extensive algal blooms which suffocate other life forms in "dead zones" in estuaries and deltas worldwide, including the Mississippi estuary in the USA and the enormous Mekong delta in South East Asia. Nitrogen products in soil are also lost when they convert to a nitrous oxide gas which is 300 times worse for global warming than carbon dioxide. Whereas changes in agronomic practices can reduce nitrogen requirements by half without penalizing yield, encouraging progress is also being witnessed in biotech crops with enhanced nitrogen use efficiency. Some of these more advanced biotech crop products, expected to be available in about 5 years or more, may offer increases of up to 30% in nitrogen efficiency, whilst initial results for some experimental products suggest that even increases of up to 50% may be eventually feasible (Ridley, 2009). Biotech crops have already delivered significant benefits in terms of increased yield and decreased pesticides, and nitrogen efficient biotech crops offer further benefits in about 5 years, or more, from now. The Economist recently declared that "**Genetically modified crops are proving to be an unmitigated environmental miracle.**" Ridley (2009) opined that the organic movement would probably scoff at NUE technology and recommend that synthetic fertilizer be replaced with manure and legumes. However, he notes that this would require a quintupling of the global cattle population from 1.2 billion to 7 to 8 billion (Smil, 2004) and questioned where this gigantic global cattle herd would graze.

Biotech Wheat – A reality in the near-term?

In a recent article by Jeffrey L Fox (2009), he posed the question "Whatever Happened to GM Wheat?" Around mid-year 2009, several coincidental developments heralded the possible return of biotech wheat, which has been out in the cold for five years, after Monsanto discontinued its RR® wheat program in 2004 due to lack of grower and consumer support. There are five principal developments that changed the mood for biotech wheat. First, nine major wheat organizations (US, Canadian and Australian) pledged, "***to work toward the goal of synchronized commercialization of biotech traits in our wheat crops.***" Second, 75% of US wheat growers now approve of biotech wheat (National Association of Wheat Growers, Washington, DC, 2009). Third, Monsanto acquired the wheat operations of WestBred in 2009 indicating its intent to reengage in biotech wheat, starting with conventional and MAS applications with biotech wheat as a longer-term goal (Monsanto, 2009a). Fourth, Bayer CropScience announced a GM-wheat development alliance with CSIRO Australia to bring "solutions" to wheat growers as early as 2015 (Bayer CropScience, 2009). Fifth, and final, on review of wheat biotech activities in China some observers concluded that China could be the first to commercialize biotech wheat, possibly in 5 years time (Fox, 2009).

Over the last decade or so, it is evident that wheat has suffered a decline in hectarage as a result of decreased competitiveness in productivity, compared with maize and soybean, which have benefited from biotechnology. Maize productivity for instance has exceeded an annual 1.6% increase, the minimum necessary to double food production by 2050, whereas wheat has consistently failed to meet this target which has led to production shortfalls.

Who are the leaders in biotech wheat? The Chinese Academy of Agricultural Sciences (CAAS) has probably the biggest investment worldwide in biotech wheat. CAAS is developing biotech wheat with a range of traits including resistance to yellow mosaic virus, head scab, powdery mildew, insect resistance, as well as drought and salinity tolerance, improved grain quality, plus herbicide tolerance. In 2008, the Chinese government is reported to have allocated more support to biotech wheat than any other biotech crop, with commercialization expected possibly in 5 years (Shiping, 2008; Stone, 2008). Resistance to yellow mosaic virus is the most advanced and maybe the first biotech wheat product in about five years' time. The CAAS investment is not the only effort in biotech wheat in China. In Henan Agricultural University, a group of 40 researchers are developing biotech wheat that is tolerant to sprouting, which currently results in a significant 20% loss in production. Field trials are in their third year, and some optimistic observers believe that sprouting-tolerant wheat could be commercialized as early as 2 to 3 years from now (Fox, 2009). India is also assigning priority to biotech wheat with plant breeders at the national Indian Agricultural Research Institute in New Delhi developing several biotech wheat lines tolerant to drought and resistant to disease. MAHYCO, India's largest indigenous seed company, already markets several varieties of conventional hybrid wheat, and has had extensive experience in successfully developing hybrid Bt cotton in India. Drought tolerance in wheat, although very challenging, is clearly emerging as the major trait of interest to both the public and private sector involved in R& D on biotech wheat.

In the industrial countries, both the USA and Australia are active. USDA invests about US$40 million annually in 125 programs focusing on improved grain quality, drought tolerance and disease resistance-a few projects are at the field-trial stage. USDA also has a US-China collaborative project on wheat with CAAS, which focuses more on conventional and marker-assisted breeding. Australia is also a leader in biotech wheat, and CSIRO and Bayer CropScience have a joint project for the "development of wheat lines with improved yield potential and stress tolerance, whereas another focuses on wheat lines with improved utilization of phosphorus. This collaboration is expected to generate commercial varieties by 2015" (Fox, 2009). The Australian Gene Technology Regulator has already approved CSIRO to conduct field trials on 16 GM-wheat lines with altered grain composition between July 2009 and June 2012 (OGTR, 2009). The Victorian Department of Primary Industries, in partnership with La Trobe University has an alliance with Dow AgroSciences to develop drought tolerant biotech wheats, which are already in their second year of field-testing with promising results. Optimistically the GM wheat could be ready in 5 to 10 years (Department of Primary Industries, 2009). Syngenta, which had an advanced project on *Fusarium*-resistant wheat assigned it to a "hold" status about 5 years ago, and this could now be a candidate for reconsideration with the renewed interest in biotech wheat. Syngenta through its Foundation for Sustainable Agriculture, recently linked with CIMMYT to focus on stem rust, using marker-assisted breeding, to develop stem rust resistant varieties of wheat (Syngenta, 2009). In July 2009, Monsanto announced a comprehensive plan for its wheat business beginning with conventional and marker-assisted breeding, (with biotech wheat as a longer term goal) to boost wheat yields with traits conferring drought and disease resistance as well as higher efficiency use of nitrogen fertilizer. Monsanto expects that it will be 8 to 10 years before the first biotech wheat is introduced. In the short term the emphasis will not be on herbicide tolerant biotech wheat but on "multi traits across multiple types of wheat," and to "take genes from corn and bring them into wheat". Monsanto is investing in human capital through its US$10 million Beachall-Borlaug Fellowship program on wheat and rice, managed by Texas A&M, to support young scholars specifically for the public sector (Monsanto, 2009b).

It is noteworthy that both China and India, consume all their wheat production and are predominantly reliant on wheat imports. In contrast to the international trade disputes between North America and Europe over biotech crops, biotech wheat in China and India would be exclusively for the domestic markets. Regulators in these countries will likely have much less concern about international trade, with more of an incentive to assign priorities for meeting urgent national food security needs; the same would apply to countries importing rice and maize.

During the past several years, the issues that drove the dynamics of the discussion on biotech wheat during 2003 and 2004 have changed markedly. "The wheat industry has come full circle and unified its support for going forward with a biotech strategy," said Allan Skogen, a North Dakota wheat grower, who also chairs Growers for Biotechnology. "***There is no doubt that we can increase production if given these biotech tools*. *The key focus for growers is drought tolerance***," he adds. "***Water is the issue, and the limiting factor for wheat***" (Fox, 2009).

Other Crops and Traits

Several other medium hectarage crops are expected to be approved before 2015. A partial listing of candidate products include: potatoes with pest and/or disease resistance and modified quality for industrial use; sugarcane with quality and agronomic traits; disease resistant bananas; and virus-resistant beans. Some biotech orphan crops are also expected to become available. For example, Bt brinjal will probably become available as the first biotech food crop in India in 2010 (subject to government endorsement) 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 very 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, in 40 countries.

Biofuels

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 both the first and second generation biofuel technologies 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.

Growth by region, globally

The second decade of commercialization, 2006-2015, is likely to feature significantly more growth in Asia and Africa compared with the first decade 1996 to 2005, 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.

Responsible management of biotech crops

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 and implementation of best practices are a must , particularly by the countries of the South, which will increasingly become the major new deployers of biotech crops in the second decade of commercialization of biotech crops, 2006 to 2015. The hectarage of biotech crops in developing countries is expected to exceed that of industrial countries before 2015.

The Grand Challenge

In a provocative article entitled ***"If words were food nobody would be hungry"*** (The Economist, 2009b), the case is made that the international donor and development communities are now reversing a 30 year decline of funding and support to agriculture, following the food price crisis of 2008. It quotes Bill Gates' reassuring statement to agriculturists at the October 2009 World Food Prize that, ***"the world's attention is back on your cause,"*** which he is generously supporting. During the same address, Gates endorsed the use of biotech crops in conjunction with conventional technology in the fight against hunger and in our quest for food sufficiency and food security. There was a similar call for utilizing both conventional and crop biotechnology at the November 2009 Food Summit in Rome, the first since 2002, seven years ago. The high commodity prices of 2008, which sparked riots in over thirty countries and the overthrow of two governments in Haiti and Madagascar, galvanized the world's attention and focused on the simple truth that daily bread at affordable prices is an essential need for every man, woman and child, irrespective of creed, color and race – survival is, by far, our most important instinct. As always it is the poor that get hurt, and the year 2008 was no exception, it was the poor, not the rich, who went hungry because when food prices doubled, the poor could only afford half the food they ate before the crisis. Moreover, unlike the rich who spend up to 20% of their income on food, the poor spend 70 to 80% of their hard earned income on food. It is of great concern that many observers believe that another similar food price crisis to 2008 is in the offing in the near term if remedial actions are not taken by both development donors and governments of food insecure developing countries. In 1974 at the first Food Summit in Rome, Henry Kissinger declared that in 10 years, not a single child would go to bed hungry – 35 years later at the 2009 Food Summit in Rome, and despite MDG promises to cut hunger in half by 2015 it was declared that for the first time ever more than 1 billion people (1.02 billion) would go to bed hungry (World Food Program, UN 2009). The World Bank estimates that the number of people living on less than US$1.25 per day will increase by 89 million between 2008 and 2010 and for those on US$2.00 a day by 120 million.

Whereas the pledge of US$20 billion from the G8 for agriculture in July 2009 is significant, and the new emphasis on self-sufficiency, in addition to food security, is welcome, it is important to ensure that this US$20 billion is new and not recycled contributions, and to recognize that it will only fund an estimated three years (at US$7 billion per year) of the activities that will be required for protecting agriculture from climate change. Nevertheless, credit should be given to several key organizations for substantially increasing their contribution to agriculture: the World bank increased its contribution by 50% to US$6 billion in 2009, the US Congress is being requested by the President Obama administration to double its budget for agriculture in USAID to US$1 billion in 2010; institutionally a new "High Level Task Force" on agriculture has been working with the UN Secretary General's Office and renowned Economist Jeffrey Sachs is advocating a global mega fund in support of agriculture, similar to the Mega Fund for HIV/AIDS. However, it is policy and technology initiatives at the national program level in developing countries, not in the donor community, that is more important and encouraging. African nations are starting to deliver on the 2003 promises of spending 10% of budgets on agriculture. Many countries are subsidizing inputs of seeds and fertilizers with Malawi used as an example where an investment of 4.2% of GDP resulted in a trebling of maize yield in four years, transforming the country from a significant importer (40% of its needs) of food in 2005 to a significant exporter (50% of its production) in 2009. Malawi is one of the lead countries in Africa committed to enhancing maize yields further, as already successfully done in South Africa, through adopting biotech crops such as Bt maize now effectively deployed in 15 countries around the world – white maize is the staple food for 300 million people in Sub-Saharan Africa.

When several major food producing countries blocked food exports during the 2008 food price crisis, some rich food deficit countries assigned high priority to acquisition of arable land in foreign countries. In the last few years, several countries which anticipate food shortages in their own countries in the future, have been acquiring arable land in other countries in order to have access to an additional secure and independent supply of food. For example, the six member states of the Gulf Cooperation Council, which collectively import food valued at US$10 billon annually, are pursuing a strategy to create a new "bread basket in Africa". The African countries involved include Mozambique, Senegal, Sudan, Tanzania and Ethiopia. The Ethiopian Central Statistics Agency reports that 13.3 million small Ethiopian farmers are developing up to 1 million hectares of new land for foreign investors (The Economist, 2009a). Critics view this acquisition as "land grabbing" attempts in countries which are themselves food insecure and poverty stricken, and where there are also concerns about environmental degradation of marginal land brought into production.

The 2008 World Bank Development Report emphasized that, ***"Agriculture is a vital development tool for achieving the Millennium Development Goals that calls for halving by 2015 the share of people suffering from extreme poverty and hunger"*** (World Bank, 2008). The Report noted that three out of every four people in developing countries live in rural areas and most of them depend directly or indirectly on agriculture for their livelihoods. **It recognizes that overcoming abject poverty cannot be achieved in Sub-Saharan Africa without a revolution in agricultural productivity for the millions of suffering subsistence farmers in Africa, most of them women.** However, it also draws attention to the fact that Asia's fast growing economies, where most of the wealth of the developing world is being created, are also home to 600 million rural people (compared with the 800 million total population of Sub-Saharan Africa) living in extreme poverty, and that rural poverty in Asia will remain life-threatening for millions of rural poor for decades to come. It is a stark fact of life that poverty today is a rural phenomenon where 70%, of the world's poorest people are small and resource-poor farmers and the rural landless labor that live and toil on the land. The Grand Challenge is "to transform a problem into an opportunity" by transforming the concentration of poverty in agriculture into an opportunity for alleviating poverty by sharing with resource-poor farmers the knowledge and experience of those from industrial and developing countries which have successfully employed biotech crops to increase crop productivity, and in turn, income. The World Bank Report recognizes that the revolution in biotechnology and information offer unique opportunities to use agriculture to promote development, but cautions that there is a risk that fast-moving crop biotechnology can easily be missed by developing countries if the political will and international assistance support is not forthcoming, particularly for the more controversial application of biotech/GM crops which is the focus of this ISAAA Brief. The **Grand Challenge** is to optimize the use of crop biotechnology in conjunction with conventional technology, to double food production, with less resources, in a sustainable manner by 2015.

The Epilogue and Norman Borlaug's legacy

Two events stand out in 2009 – first the passing of a personal and noble friend, Nobel Peace Laureate Norman Borlaug on 12 September 2009 – second the approval by the Government of China, on 27 November 2009, of biotech rice and biotech maize. Rice is the most important food crop in the world and provides food for 3 billion people or almost half of humanity; importantly it is also the most important food crop of the poor of the world. Maize is the most important feed crop in the world that provides feed for China's 500 million swine herd (equivalent to 50% of the global swine herd) and its 13 billion chickens, ducks and other poultry. China's exertion of leadership in approving the first major biotech food crop, rice, and its determination to elect to use technology, both conventional and biotech crops, to achieve food self–sufficiency, is a momentous development and deserves to be emulated by other developing countries in Asia, Africa and Latin America – the potential implications in terms of a world that is more secure, prosperous, just and peaceful is enormous.

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

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

He cared, more than others thought wise
He dreamed, more than others thought real
He risked, more than others thought safe
And he expected, and normally achieved
What others thought impossible

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