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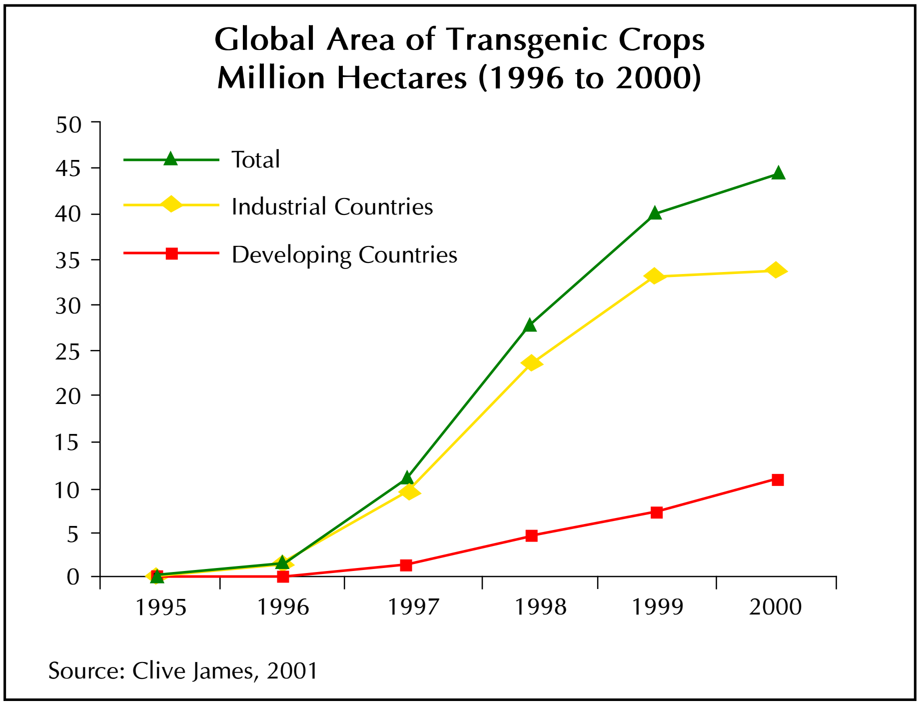
ISAAA Briefs

Global Review of Commercialized Transgenic Crops: 2000

by

Clive James
Chair, ISAAA Board of Directors



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EXECUTIVE SUMMARY

This publication is the fifth in a series of *ISAAA Briefs*, which characterize the global adoption of commercialized transgenic crops. A global database for the first five-year period for GM crops, 1996 to 2000, is presented and 2000 data is analyzed globally, and by country, crop and trait. Data on the global status of transgenic crops are complemented with commentaries on relevant key topics including: the value of the transgenic seed market in the context of the global crop protection and seed markets; status of regulation in Europe; a review of alliances, acquisitions and activities in the biotechnology industry; a review of selected highlights featuring transgenic crops during the last year, and an assessment of the broadening political and institutional support for GM crops globally; an overview of the attributes and economic benefits/advantages associated with transgenic crops and finally some concluding comments about the future.

The critics of biotechnology have always been skeptical about the ability of transgenic crops, more familiarly known as genetically modified (GM) crops, to deliver improved crop varieties that can impact on production and quality of crops at the farm level. The critics have been even more skeptical about the appropriateness of transgenic crops for the developing world, particularly their ability to meet the needs of small resource-poor farmers. It is encouraging to witness that the early promises of crop biotechnology are continuing to meet expectations of large and small farmers in both industrial and developing countries. In 2000, 3.5 million small and large farmers from industrial and developing countries grew and benefited significantly from the 44.2 million hectares of GM crops. As expected, global area planted to transgenic crops started to plateau in 1999 and this has continued in 2000 reflecting the unprecedented high adoption rates to-date; for example, GM soybean in Argentina now occupies more than 90% of the national soybean area and GM cotton more than 70% of the cotton area in the US. Of the total global area (conventional and transgenic) of 271 million hectares planted to soybean, canola, cotton and corn in 2000, 16%, equivalent to 44.2 million hectares, were planted with transgenic varieties. These 44.2 million hectares of transgenic crops grown globally are unprecedented, and equivalent to almost twice the total land area of the United Kingdom (24.4 million hectares). The global area of transgenic crops in 2000, comprised 36% of the 72 million hectares of soybeans planted globally, 16% of the 34 million hectares of cotton, 11% of the 25 million hectares of canola and 7% of the 140 million hectares of corn. Millions of farmers in 15 different industrial and developing countries around the world have made independent decisions after evaluating their first plantings of transgenic crops in 1996. Subsequently, the area of transgenic crops increased by an unprecedented multiple of more than 25-fold – this speaks volumes for the confidence and trust farmers have placed in transgenic crops. In China alone, within a short period of a few years, 3.0 million small resource-poor farmers have embraced *Bt* cotton in 2000 after witnessing at first hand in their own fields, the significant and multiple benefits *Bt* cotton can deliver.

Distribution of GM Crops

Between 1996 and 2000, a cumulative total of fifteen countries, 10 industrial and 5 developing, have contributed to more than a twenty-five fold increase in the global area of transgenic crops from 1.7 million hectares in 1996 to 44.2 million hectares in 2000. The accumulated area of transgenic crops planted in the five-year period 1996 to 2000 totals 125 million hectares, equivalent to more than 300 million acres. In 2000, a total of 13 countries, 8 industrial and 5 developing countries, grew GM crops. Adoption rates for transgenic crops are unprecedented and are the highest for any new technologies by agricultural industry standards. High adoption rates reflect grower satisfaction with the products that offer significant benefits ranging from more convenient and flexible crop management, higher productivity and/or net returns per hectare, and a safer environment through decreased use of conventional pesticides, which collectively contribute to a more sustainable agriculture. The major changes in area and global share of transgenic crops for the respective countries, crops and traits, between 1999 and 2000 were related to the following factors:

- In 2000, the global area of transgenic crops increased by 11%, or 4.3 million hectares, to 44.2 million hectares, from 39.9 million hectares in 1999. Eight transgenic crops were grown commercially in 13 countries in 2000, three of which, Bulgaria, Germany and Uruguay, grew transgenic crops for the first time. Two countries, Portugal and Ukraine, which grew small introductory areas in 1999 did not report transgenic crops in 2000.

- The four principal countries that grew the majority of transgenic crops in 2000 were USA 30.3 million hectares (68% of the global area); Argentina 10.0 million hectares (23%), Canada 3.0 million hectares (7%); China 0.5 million hectares (1%); the balance was grown in South Africa, Australia, Romania, Mexico, Bulgaria, Spain, Germany, France, and Uruguay. The highest growth in transgenic crop area between 1999 and 2000 was reported for Argentina (3.3 million hectares), followed by USA (1.6 million hectares), with China and South Africa with 0.2 and 0.1 million hectares respectively. A decrease of 1 million hectares was estimated for Canada due mainly to less national area planted to canola.

- For the first time in the last five years, growth in area of transgenic crops between 1999 and 2000 in the developing countries exceeded, by more than 5 times, the area growth in transgenic crops in industrial countries (3.6 million hectares versus 0.7 million hectares). Of the 4.3 million hectares global growth in 2000, 3.6 million hectares, equivalent to 84% were in the developing countries.

- In terms of crops, soybean contributed the most to global growth of transgenic crops, equivalent to 4.2 million hectares between 1999 and 2000, followed by cotton with an increase of 1.6 million hectares. GM corn and canola decreased by 0.8 and 0.6 million hectares respectively because of decreases in USA and Canada, which were partly offset by increases in transgenic corn in developing countries.

- There were three noteworthy developments in terms of traits: herbicide tolerance contributed the most (4.6 million hectares) to global growth between 1999 and 2000; the stacked genes of insect resistance and herbicide tolerance in both corn and cotton contributed 0.3 million hectares, with insect resistance decreasing by 0.6 million hectares.

- Of the 4 major transgenic crops grown in 12 countries in 2000, the two principal crops, soybean and corn represented 59% and 23% respectively for a total of 82% of the global transgenic area, with the remaining 18% shared between cotton (12%) and canola (6%).

- In 2000, herbicide tolerant soybean was the most dominant transgenic crop (59% of global transgenic area, compared with 54% in 1999), followed by insect resistant corn (15% compared with 19% in 1999), herbicide tolerant canola (6%), herbicide tolerant corn and herbicide tolerant cotton, both at 5%, *Bt*/herbicide tolerant cotton at 4%, and *Bt* cotton and *Bt*/herbicide tolerant corn both at 3%.

- The combined effect of the above seven factors resulted in a global area of transgenic crops in 2000 that was 4.3 million hectares greater and 11% more than 1999; this is a significant year-on-year increase considering the high percentage of the principal crops already planted to transgenics in 1999.

Value of the GM Crop Seed Market and Industry Developments

The value of the global market for transgenic seed has grown rapidly from $1 million in 1995, to $ 156 million in 1996, $ 858 million in 1997, $ 1,970 million in 1998, $ 2,947 million in 1999 and an estimated $ 3,044 million in 2000.

The pace of biotechnology investments in industry, which is a concern to some, slowed in 2000. One of the features of industry changes was the spinning-off of agbiotech divisions from life science companies with a view to merging with like-divisions from other life science companies to create the necessary critical mass. Most corporations have already undergone substantial restructuring, and completed spin-offs and mergers. Investments in plant genomics continue to grow and are of pivotal importance for future growth. It is critically important that the public sector and international development institutions, in both industrial and developing countries, invest in the new technologies to ensure equitable access and benefits from the enormous potential that transgenic crops offer in terms of increased productivity, more nutritious food and global food security. It is vital that the public sector and the private sector forge partnerships that will allow the comparative advantages of both parties to be optimized to achieve the mutual objective of global food security. The most compelling case for biotechnology is its potential contribution to global food security and the alleviation of poverty and hunger in the Third World.

GM Crop Highlights

Global highlights for transgenic crops during the last year or so are discussed under six topics:

- Status of approvals for commercialization of transgenic crops
- Biosafety
- Food-feed import regulations
- Genome sequencing of rice *Arabidopsis* and *Agrobacterium tumefaciens*
- Sharing of proprietary transgenic technology with developing countries
- Selected highlights re transgenic crops including a summary of the recent set of six papers published by the US National Academy of Sciences that provides reassuring evidence that the widely publicized claim by critics that the Monarch butterfly was being threatened by *Bt* corn, proved to be unfounded.
- Statements and reports by politicians, policy makers, national programs and organizations that reflect a broadening political and institutional support for crop biotechnology and a recognition of its increasingly important contribution to global food security and a more sustainable agriculture.

Attributes and Benefits of GM Crops

The unprecedented rapid adoption of transgenic crops during the five-year period 1996 to 2000 reflects the significant multiple benefits realized by large and small farmers in the 15 industrial and developing countries that have grown transgenic crops commercially. There is a growing body of convincing evidence that clearly demonstrates the improved weed and insect pest control attainable with transgenic herbicide tolerant and insect resistant *Bt* crops, that also benefit from lower input and production costs; GM crops offer significant economic advantages to farmers compared with corresponding conventional crops. The severity of weed and insect pests varies from year to year and hence this will directly impact on pest control costs and economic advantage. Despite the on-going debate on GM crops, particularly in countries of the European Union, millions of large and small farmers in both industrial and developing countries continue to increase their plantings of GM crops because of the significant multiple benefits they offer.

This high adoption rate is a strong vote of confidence in GM crops, reflecting grower satisfaction. Several studies have confirmed that farmers planting herbicide tolerant and insect resistant *Bt* crops are more efficient in managing their weed and insect pests.

More specifically the use of transgenic crops results in:

- more sustainable and resource-efficient crop management practices that require less energy and fuel and conserve natural resources.
- more effective control of insect pests and weeds.
- a reduction in the overall amount of pesticides used in crop production, which impacts positively on biodiversity, protects predators and non target organisms, and the environment.
- less dependency on conventional pesticides that can be a health hazard to producers and consumers; the potential health benefits associated with fewer pesticide poisonings from *Bt* cotton in China is an important finding, with significant implications for other developing countries where small farmers in particular may be at similar risk from heavy and over-use of conventional pesticides.
- *Bt* maize which has reduced levels of the fumonisin mycotoxin in maize grain which provides safer and healthier food and feed products.
- greater operational flexibility in timing of herbicide and insecticide applications.
- conservation of soil moisture, structure, nutrients and control of soil erosion through no or low-tillage practices as well as improved quality of ground and surface water with less pesticide residues.
- improved pest control, lower cost of production and improved yields all contribute to a greater economic advantage to farmers who utilize the technology to develop more sustainable farming systems.

Economic Advantages of GM Crops

There is an increasing body of compelling evidence that transgenic crops are delivering significant economic benefits and case studies are documented in this overview. The "global" economic advantage to farmers deploying herbicide tolerant (HT) soybean, *Bt* cotton, HT canola and *Bt* corn is estimated to be of the order of $ 700 million in 1999, equally shared between developing and industrial countries; of the $710 million, approximately 60 % is derived from HT soybean, 30 % from *Bt* cotton, and 10 % from HT canola. The estimate of $ 710 million is intended to provide an order of magnitude assessment of the direct economic advantage to 2 million small and large farmers who planted 39.9 million hectares of transgenic crops in 1999; in addition to these direct economic advantages that farmers derive from transgenic crops, several studies have confirmed that there are also significant additional indirect benefits to others in society. For crops such as herbicide tolerant soybean, these indirect benefits to consumers globally can be of the same order of magnitude as the direct economic advantage of $ 700 million to farmers in 1999. Thus, the "global" direct and indirect economic advantage associated with the 39.9 million hectares of transgenic crops in 1999 is likely to be of the order of $ 1 billion or more. There is no evidence to support the perception of the critics of biotechnology that the transnational developers of transgenic crops are the sole or major beneficiaries from transgenic crops. On the contrary, studies to-date confirm that not only are farmers significant beneficiaries, but they are usually the major beneficiaries, taking on average from one-third to one-half of the total economic surplus generated by transgenic crops.

Finally, an important finding of the China *Bt* cotton study was that the smallest farmers, those farming less than 1 hectare, gained more than twice as much income per unit of land ($ 400 per hectare) from *Bt* cotton, as the larger farmers ($ 185 per hectare). This finding is important from an equity/distribution viewpoint and is deserving of further investigation for *Bt* cotton and other transgenic crops that offer promise to small resource poor farmers. It also has important implications in relation to the claim often made by critics of transgenic crops that they are inappropriate for small farmers. Indeed, by far the largest benefits reported to-date from the studies reviewed here have been for small farmers who can least afford the loss in yield due to pests, and stand to gain the most from increases in income and suffer less health hazards resulting from fewer applications of conventional insecticide.

The Future

An estimated 3.5 million farmers grew transgenic crops in 2000 and derived multiple benefits that included significant agronomic, environmental, health and economic advantages. In 2001 the number of farmers planting GM crops is expected to grow substantially to 5 million or more. Global area planted to transgenic crops is expected to continue to grow by 10% or more in 2001 despite the unprecedented high percentage of the principal crops already planted to transgenics in the USA, Argentina, Canada and China. In 2001, these top four countries are expected to report a further significant increase in the area of transgenic crops. The other ten countries growing transgenic crops in 2000 are expected to report modest growth in GM crop area, except France and Germany, which will probably continue to grow a small token area of *Bt* maize. South Africa is expected to continue to diversify and expand its portfolio of transgenic crops, with Australia approving and commercializing more traits in cotton. Indonesia will commercialize *Bt* cotton for the first time. India is progressing towards approval of *Bt* cotton which could occur in early 2002. The commercialization of herbicide tolerant soybean in Brazil will be dependent on resolving the outstanding issues between the Ministries of Agriculture, Environment and Justice. The commercialization of GM crops in India and Brazil will represent a watershed for developing countries in that the three most populous countries in Asia – China, India, and Indonesia with 2.5 billion people, as well as the three major economies of Latin America – Argentina, Mexico and Brazil, plus South Africa will then all be commercializing and benefiting from transgenic crops.

The issue that will modulate adoption of specific products in some countries in 2001 will be public acceptance, which drives market demand, regulation and commodity prices. These issues will be the factors that will impact on commercial planting of transgenic crops and consumption of genetically modified derived foods in countries of the European Union. However, progress is expected in the near- to mid-term in the countries of Eastern Europe which have advanced field tests in progress. Several countries in the developing world are expected to proceed with field trials of *Bt* cotton, which has already delivered substantial benefits to both small and large farmers in several countries, notably China where approximately 3 million small farmers derived significant benefits in 2000.

The shift from the current generation of "input" agronomic traits to the next generation of "output" quality traits, is expected to proceed slowly and will be modulated by national regulations and possibly the next round of negotiations at the World Trade Organization (WTO). With the acceptance of the first "quality" products, which will improve the nutritional value of food and feed products, significant value will be added to the GM crop market and it should provide a stimulus to de-commoditize grain and oil seed markets. This shift will not only serve to significantly increase the value of the global transgenic crop market but will also broaden the beneficiary profile from growers to processors and consumers. Food products derived from transgenic crops that are healthier and more nutritious could impact on public acceptance, particularly in Europe.

Significant progress has been made in the first five-year period 1996 to 2000 with an accumulated area of 125 million hectares of transgenic crops planted in 15 industrial and developing countries. As new and novel products with input and output traits will become available for commercialization in the next five years, it is critical that these products be deployed in an integrated strategy in which both conventional and biotechnology applications are applied to attain the challenging goal of global food security. Adoption of such a strategy will allow society to continue to benefit from the vital contributions that both conventional and modern plant breeding offer. Biotechnology can play a critical role in achieving food security in the developing world in countries such as China, which has assigned high priority and a strategic value to biotechnology, and was the first country in the world to commercialize transgenic crops in the early 1990s. The experience of China, where 3.0 million small farmers benefited from planting *Bt* cotton in 2000, Argentina and South Africa should be shared with other countries in the developing world which face the same challenges.

Governments, supported by the global scientific and international development community, must ensure continued safe and effective testing and introduction of transgenic crops and implement regulatory programs that inspire public confidence. Leadership at the international level must be exerted by the international scientific community and development institutions to stimulate discussion and to share knowledge on transgenic crops with society. The public should be well informed and engaged in a dialog about the impact of the technology on the environment, food safety, sustainability and global food security. Societies in food surplus countries must ensure that access to biotechnology is not denied or delayed to developing countries seeking to access the new technologies in their quest for food security. After all, the most compelling case for biotechnology, more specifically transgenic crops, is their potential vital contribution to global food security and the alleviation of hunger in the Third World. In summary, we must ensure that society will continue to benefit from the vital contribution that plant breeding offers, using both conventional and biotechnology tools, because improved crop varieties are, and will continue to be the most cost-effective, environmentally safe, and sustainable way to ensure global food security in the future.

Shortly before this review went to press, two major events of global significance impacted on our continuing ability as a society to alleviate poverty and malnutrition. Following the terrorist attacks in the US on 11 September 2001, the World Bank predicted that poverty would increase with millions more people condemned to poverty in 2002. More specifically, the Bank predicts that global poverty will increase by 10 million more people in 2002. Developing country growth rates could be as low as 2.9% in 2001 compared with 5.5% in 2000. For 2002, lowered growth rates for developing countries in the range of 3.5 - 3.8 percent are projected, compared with the 4.3 percent prediction made before 11 September. Africa is expected to suffer most of the economic damage from the continued economic slowdown of industrial countries with an additional 2 million Africans surviving on less than $1 a day. Africa is judged to be particularly vulnerable because many African nations do not have the means to stabilize their economies when agricultural commodity prices, on which they are dependent, fall. Consequently “farmers, rural laborers, and others tied to agriculture will bear a major portion of the burden.” The Bank recommended that donor countries increase aid, reduce trade barriers for developing countries, and urged the donor community to coordinate its economic reform policies.

The Potential Role of the World Trade Organization (WTO)

The other major global event that will impact more directly on the contribution of transgenic crops to the alleviation of poverty and hunger in the developing countries is the World Trade Organization Meeting held in Doha, Qatar, 9 to 13 November 2001, with 142 members in attendance. It is noteworthy that China, a world leader in transgenic crops, was admitted as a member of WTO on 10 November 2001.

China's membership of WTO has many significant implications for its own future strategy on GM crops, but could also be pivotal for other developing and industrial countries committed to utilizing GM crops to achieve global food, feed and fiber security. Unlike the last WTO meeting in Seattle, this time the world's major trading partners including the US and Europe have had pre-meeting exchanges to discuss a draft of a new trade agreement that addresses trade liberalization in agriculture and textiles which comprise 70% of exports from developing countries; the TRIPS agreement (Trade Related aspects of Intellectual Property rights) is also being reviewed, albeit in the context of public health and pharmaceuticals, but there may be some important implications for agriculture. This represents significant progress which brings hope to many developing countries which have suffered under the terms of the Uruguay round concluded in 1994.

WTO is a key international organization that can ensure that GM crops are accessible to those developing countries that seek to use them to alleviate poverty and hunger and achieve food security. In the new round of trade talks WTO should address the key issues that would facilitate the implementation of the principal recommendation of the well-received 2001 UNDP Human Development Report - to utilize biotechnology and information technology to alleviate poverty in developing countries. More specifically WTO can address several critical issues that impact on developing countries seeking to utilize biotechnology to achieve food security. The most urgent and important issues for WTO to address and remedy are:

- Liberalization of agricultural trade. Abolishing all trade barriers could increase global income by $ 2.8 trillion over the next decade, with well over half of the benefits going to the poor. The World Bank has predicted that global trade liberalization could reduce the 1.3 billion people suffering from poverty today by 300 million to 1.0 billion by 2015. The removal or reduction of trade barriers in agriculture is assigned high priority by the US and developing countries. However, the European and Japanese continue to oppose freer trade in agriculture, particularly export subsidies, and are concerned that environmental issues are not receiving the attention they deserve. Some observers interpret the European position on the environment as an indirect way of re-introducing protection policies for agriculture.

- The establishment of an exemplary advisory body to provide direction and leadership in the implementation of WTO's policy of basing all its decisions, re the use and transfer of transgenic material, on scientific fact and objective evidence – this is in stark contrast to the subjective decision-making of the Biosafety Protocol which requires no scientific justification for invoking the precautionary principle. Applying the precautionary principle to delay or deny access to transgenic crops to developing countries that seek to use them for food security clearly will increase rather than decrease the food security risk to the poor, hungry and malnourished in developing countries. The establishment of an advisory body by the WTO would seem appropriate at this time, particularly to align and rationalize decisions vis-à-vis the contradictions in the Biosafety Protocol re the use and transfer of transgenic material.

- Overseeing implementation of a TRIPS agreement that is equitable to all parties. The current WTO agreement on intellectual property rights (TRIPS) negotiated during the Uruguay round is a key issue and impacts directly on the deployment of transgenic crops in developing countries. The context of the current discussions on TRIPS will be in relation to pharmaceuticals and public health, however, there could be some important implications for agriculture. The US is reluctant to soften the TRIPS requirements but a group of developing countries, including South Africa, Brazil, and India are seeking an exemption to TRIPS for public health initiatives such as the control of AIDS. The renegotiated agreement on TRIPS could have implications for the ease of access, deployment and trading of transgenic crops for developing countries, and the views of China as a new member and a lead country in GM crops could be pivotal.

As this review went to press, the latest and encouraging news from WTO, was that members had reached consensus on the Doha Development Agenda, with Africa in particular welcoming the agreement because of the potential for more open markets for exports. The most difficult issue to resolve was the EU farm subsidies which the EU agreed to phase out, provided that it does not "prejudice the outcome" of the negotiations. However, some developing countries voiced concern that the EU may use environmental restrictions to preclude the importation of GM products. Reaching a consensus on freer trade was very important because it will provide WTO with the necessary solidarity amongst members prior to addressing the outstanding and important issues that need to be resolved in relation to biotechnology, that offers the developing countries a unique opportunity for alleviating poverty and achieving food security.

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APPENDIX

1. INTRODUCTION

Global population exceeded 6 billion in 2000 and United Nations estimates expect it to reach 9.3 billion by 2050, when approximately 90% of the global population will reside in Asia, Africa and Latin America (http://www.unfpa.org).

However what is important to note is that even today 815 million people in the developing countries suffer from malnutrition and 1.3 billion are afflicted by poverty. Transgenic crops, often referred to as genetically modified crops (GM), represent promising technologies that can make a vital contribution to global food, feed and fiber security. During the last five years, 1996 to 2000, global adoption rates for transgenic crops were unprecedented and reflect grower satisfaction with the products that offer significant benefits ranging from more convenient and flexible crop management, higher productivity or net returns/hectare, and a safer environment through decreased use of conventional pesticides, which collectively contribute to a more sustainable agriculture.

Global reviews of transgenic crops have been published by the author as ISAAA *Briefs* annually since 1996. This publication is the fifth by the author in the annual review series, to characterize and monitor the global status of commercialized transgenic crops. The first reviewed transgenic crops planted globally in 1996 (James and Krattiger 1996), the second for 1997 (James 1997), the third for 1998 (James 1998); the fourth for 1999 comprised an early Preview (James 1999) followed by the annual Review for 1999 crops (James 2000a).

The current publication presents the annual global review of transgenic crops for 2000; a Preview (James 2000b) of this publication was published previously. This publication provides the latest information on the global status of commercialized transgenic crops. A detailed global data set on the adoption of commercialized transgenic crops is presented for the year 2000 and the changes that have occurred between 1999 and 2000 are highlighted. The global adoption trends during the last five years from 1996 to 2000 are also illustrated. Given the intensity of the debate on transgenic crops in 1999, particularly the issues in relation to public acceptance, one of the key questions posed at the beginning of 2000 was whether the global area of transgenic crops would continue to increase in 2000; not surprisingly, there was much speculation.

The principal aim of this publication is to:

- provide an overview of the global adoption of transgenic crops in the period 1996 to 2000;
- document detailed information on the global status and distribution of commercial transgenic crops in 2000, by region, country, crop, and trait;
- rank the dominant transgenic crop/trait combinations in 2000;
- summarize and highlight the significant changes between 1999 and 2000;
- review the value of the transgenic seed market from 1995 to 2000 in the

context of the global crop protection and seed market;

- list developments in the crop biotechnology industry, particularly the continuing alliances, acquisitions, and spin-offs in the private sector;

- review selected highlights for transgenic crops including the broadening support for biotechnology;

- provide an overview of attributes and benefits associated with transgenic crops including the economic advantages to farmers at the farm, national and “global” level.

Note that the words maize and corn, rapeseed and canola, as well as transgenic and GM crops, are used synonymously in the text, reflecting the usage of these words in different regions of the world. Global figures and hectares planted commercially with transgenic crops have been rounded off to the nearest 100,000 hectares and in some cases this leads to insignificant approximations, and there may be slight variances in some figures, totals, and percentage estimates. It is also important to note that countries in the Southern Hemisphere plant their crops in the last quarter of the calendar year. The transgenic crop areas reported in this publication are planted, not harvested, hectarage in the year stated. Thus, the 2000 information for Argentina, Australia, South Africa and Uruguay is hectares planted in the last quarter of 2000 and which will be harvested in the first quarter of 2001.

2. OVERVIEW OF GLOBAL STATUS AND DISTRIBUTION OF COMMERCIAL TRANSGENIC CROPS, 1996 TO 2000

Information on the adoption of commercial transgenic crops was provided by many independent sources from both the public and private sectors. Multiple sources of data, as well as additional and independent commercial marketing information, allowed several cross-checks to be conducted, which facilitated a rigorous verification of the estimates. For convenience and ease of interpretation, the data for the global status and distribution of commercial transgenic crops are presented in two complementary formats. Figures are used to best illustrate the changes in global transgenic area between 1996 and 2000. Companion tables provide more detailed corresponding information for 2000 and to illustrate the changes that have occurred between 1999 and 2000.

The estimated global area of transgenic crops for 2000 is 44.2 million hectares or 109.2 million acres (Table 1). It is noteworthy that 2000 is the first year when the global area of transgenic crops has exceeded 100 million acres and almost reached 45 million hectares. To put this global area of transgenic crops into context, 44.2 million hectares is equivalent to almost twice the area of the United Kingdom. The increase in area of transgenic crops between 1999 and 2000 is 11%, equivalent to 4.3 million hectares or 10.6 million acres. This increase of 4.3 million hectares between 1999 and 2000 is about one quarter of the corresponding increase of 12.1 million hectares between 1998 and 1999.

During the five-year period 1996 to 2000, the global area of transgenic crops increased by more than 25-fold, from 1.7 million hectares in 1996 to 44.2 million hectares in 2000 (Figure 1). This high rate of adoption reflects the growing acceptance of transgenic crops by farmers using the technology in both industrial and developing countries. During the five-year period 1996 – 2000 the number of countries growing transgenic crops more than doubled, increasing from 6 in 1996 to 9 in 1998, to 12 countries in 1999 and 13 in 2000.

2.1 Distribution of Transgenic Crops in Industrial and Developing Countries

Figure 2 shows the relative hectarage of transgenic crops in industrial and developing

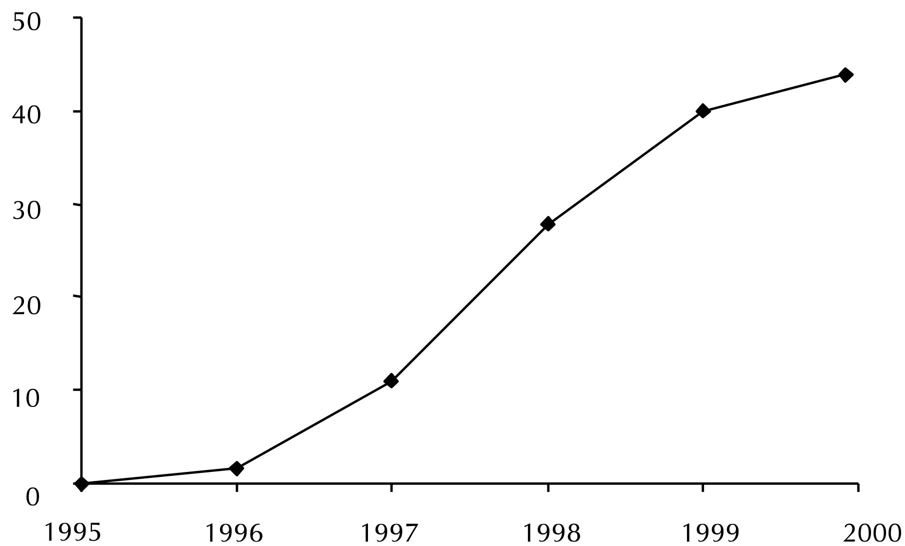
Table 1. Global Area of Transgenic Crops, 1996 to 2000

	Hectares (million)	Acres (million)
1996	1.7	4.3
1997	11.0	27.5
1998	27.8	69.5
1999	39.9	98.6
2000	44.2	109.2

Increase of 11%, 4.3 million hectares or 10.6 million acres between 1999 and 2000.

Source: Clive James, 2000.

Figure 1. Global Area of Transgenic Crops, 1996 to 2000 (million hectares)



Source: Clive James, 2000.

Table 2. Global Area of Transgenic Crops in 1999 and 2000: Industrial and Developing Countries (million hectares)

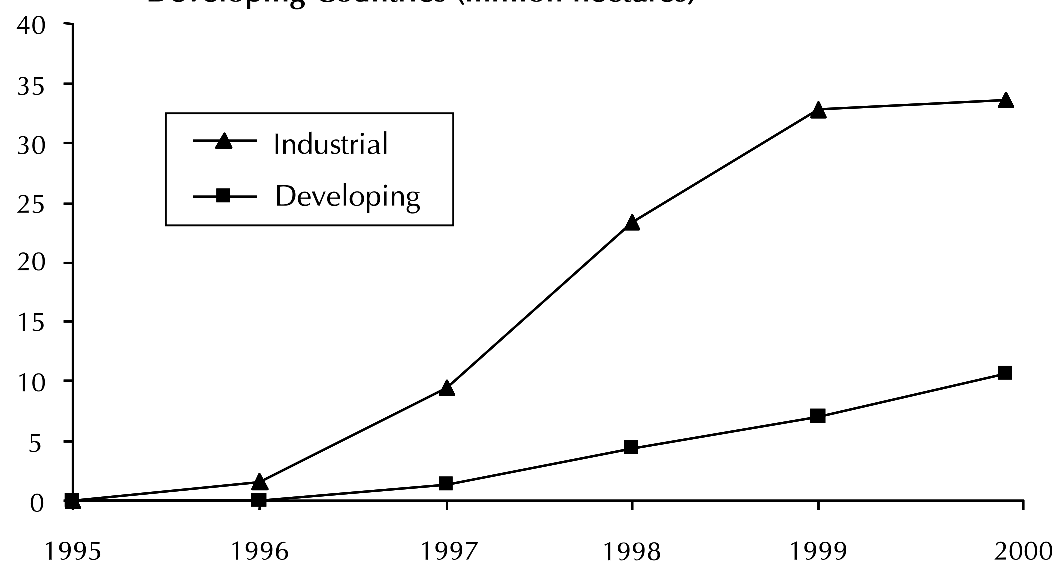
	1999	%	2000	%	+/-	%
Industrial Countries	32.8	82	33.5	76	+ 0.7	+ 2
Developing Countries	7.1	18	10.7	24	+ 3.6	+ 51
Total	**39.9**	**100**	**44.2**	**100**	**+4.3**	**+ 11**

Source: Clive James, 2000.

countries during the period 1996 to 2000. It clearly illustrates that from 1996 to 2000 the substantial share, up to 85% of global transgenic crops, have been grown in industrial countries. However, the proportion of transgenic crops grown in developing countries has increased consistently from 14% in 1997, to 16% in 1998, to 18% in 1999, and 24% in 2000. Thus, in 2000 approximately one quarter (Table 2) of the global transgenic crop area of 44.2 million hectares, equivalent to 10.7 million hectares, was grown in developing countries where growth continued to be strong between 1999 and 2000, in contrast to the expected plateauing that is evident for the industrial countries.

Transgenic crop area is estimated to have increased from 39.9 million hectares in 1999 to 44.2 million hectares in 2000 (Table 2), resulting in a global increase of 4.3 million hectares in 2000, equivalent to 11% growth over 1999. Of this 4.3 million hectares, 3.6 million hectares, equivalent to 84% was in the developing countries – this compares with only 16%, equivalent to 0.7 million hectares in the industrial countries. Thus, the area of transgenic crops in developing countries grew by 51% from 7.1 million hectares in 1999 to 10.7 million in 2000, compared with a 2% growth in industrial countries where hectarage increased from 32.8 million hectares in 1999 to 33.5 million hectares in 2000.

Figure 2. Global Area of Transgenic Crops, 1996 to 2000: Industrial and Developing Countries (million hectares)



Source: Clive James, 2000.

2.2 Distribution of Transgenic Crops, by Country

In 2000, four countries grew 99% of the global transgenic crop area (Table 3). It is noteworthy that they are two industrial countries, USA and Canada, and two developing countries, Argentina and China. Consistent with the pattern since 1996, the USA grew the largest transgenic crop hectarage in 2000. The USA grew 30.3 million hectares, followed by Argentina with 10 million hectares, Canada with 3 million and China 0.5 million hectares. In 2000, transgenic crop hectarage increased in 3 out of these top 4 countries growing commercialized transgenic crops. Increases were reported for the USA, Argentina, and China, with a decrease in area in Canada (Figure 3).

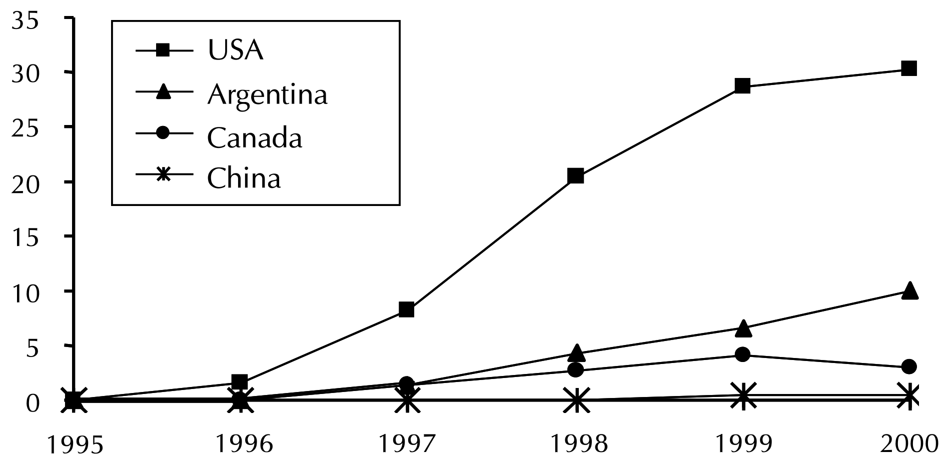
The 13 countries that grew transgenic crops in 2000 are listed in descending order of their transgenic crop areas (Table 3). There are 8 industrial countries and 5 developing countries. In 2000, transgenic crops were grown commercially in all six continents of the world – North America, Latin America, Asia, Oceania, Europe (Eastern and Western), and Africa. Of the top four countries that grew 99% of the global transgenic crop area, the USA grew 68%,

Table 3. Global Area of Transgenic Crops in 1999 and 2000: by Country (million hectares)

Country	1999	%	2000	%	+/-	%
USA	28.7	72	30.3	68	+1.6	+6
Argentina	6.7	17	10.0	23	+3.3	+49
Canada	4.0	10	3.0	7	-1.0	-25
China	0.3	1	0.5	1	+0.2	+66
South Africa	0.1	<1	0.2	<1	+0.1	- -
Australia	0.1	<1	0.2	<1	+<0.1	- -
Romania	<0.1	<1	<0.1	<1	+<0.1	- -
Mexico	<0.1	<1	<0.1	<1	+<0.1	- -
Bulgaria	- -	- -	<0.1	<1	+<0.1	- -
Spain	<0.1	<1	<0.1	<1	-<0.1	- -
Germany	- -	- -	<0.1	<1	-<0.1	- -
France	<0.1	<1	<0.1	<1	-<0.1	- -
Portugal	<0.1	<1	- -	- -	- -	- -
Ukraine	<0.1	<1	- -	- -	- -	- -
Uruguay	- -	- -	<0.1	<1	+<0.1	- -
Total	**39.9**	**100**	**44.2**	**100**	**+4.3**	**+11%**

Source: Clive James, 2000.

Figure 3. Global Area of Transgenic Crops, 1996 to 2000: by Country (million hectares)



Source: Clive James, 2000.

Argentina 23%, Canada 7% and China 1%. The other 1% was grown in the remaining 9 countries, with South Africa and Australia being the only countries in that group growing more than 100,000 hectares or a quarter million acres of transgenic crops.

In Argentina, a gain of 3.3 million hectares was reported for 2000 as a result of significant growth in transgenic soybean and corn with a modest increase in cotton. In the USA there was an estimated net gain of 1.6 million hectares of transgenic crops in 2000; this came about as a result of an increase in the area of transgenic soybean, cotton and canola, and a decreased area of transgenic corn. For Canada, a net decrease of 1 million hectares was estimated with most of it associated with the decrease in area planted with transgenic canola. For China, the area planted to *Bt* cotton was estimated to have increased by approximately 0.2 million hectares in 2000 to 0.5 million hectares.

A significant increase of up to 100,000 hectares of transgenic crops is reported for South Africa, where the combined area of transgenic corn and cotton is expected to almost double. In Australia, 150,000 hectares of transgenic cotton was planted in 2000, with Mexico reporting a modest area of transgenic cotton. The countries growing transgenic crops in 2000 include two Eastern European countries, Romania growing soybean and potatoes, and Bulgaria growing herbicide tolerant corn. Ukraine, which grew transgenic potatoes in 1999, has not confirmed any transgenic hectarage for 2000. The three European Union countries – Spain, Germany and France – which for the first time grew small areas of *Bt* corn in 1999, grew reduced areas in 2000; Portugal which grew *Bt* corn in 1999 withdrew registration in 2000 and no *Bt* corn was reported for Portugal in 2000. One additional country, Uruguay, reported the commercialization of transgenic crops for the first time in 2000, growing a small area, 3,000 hectares, of herbicide tolerant soybean.

2.3 Distribution of Transgenic Crops, by Crop

The distribution of the global transgenic crop area for the four major crops is illustrated in Figure 4 for the period 1996 to 2000. It clearly shows the dominance of transgenic soybean occupying 58% of the global area of transgenic crops in 2000; all of the transgenic soybean is herbicide tolerant. Transgenic soybean retained its position in 2000 as the transgenic crop occupying the largest area. Globally, transgenic soybean occupied 25.8 million hectares in 2000, with transgenic corn in second place at 10.3 million hectares, transgenic cotton in third place at 5.3 million hectares, and canola at 2.8 million hectares (Table 4).

In 2000, the global hectarage of herbicide tolerant soybean is estimated to have increased by 4.2 million hectares, equivalent to almost a 20% increase. Gains of approximately 2.7 million hectares of transgenic soybean are reported for Argentina and 1.5 million hectares for the USA, with adoption rates estimated at 90% of the 10.2 million hectares of soybeans grown in Argentina, and 54% of the national soybean area of 30.2 million hectares in the USA, in 2000.

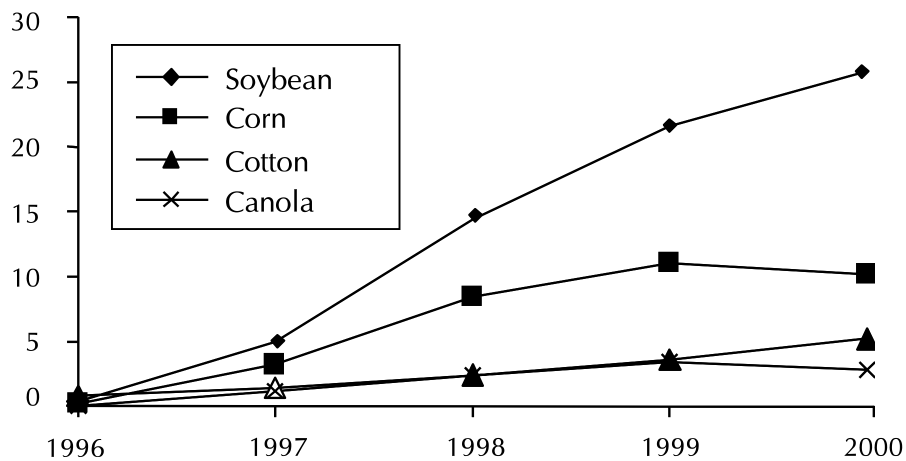
Transgenic corn area in 2000 is estimated to have decreased globally by about 800,000 hectares (Table 4) with the major decrease in the USA and some in Canada. Some observers have identified the principal cause of the

Table 4. Global Area of Transgenic Crops in 1999 and 2000: by Crop (million hectares)

Crop	1999	%	2000	%	+/-	%
Soybean	21.6	54	25.8	58	+4.2	+19
Maize	11.1	28	10.3	23	-0.8	-7
Cotton	3.7	9	5.3	12	+1.6	+43
Canola	3.4	9	2.8	7	-0.6	-18
Potato	<0.1	<1	<0.1	<1	<0.1	- -
Squash	<0.1	<1	<0.1	<1	(- -)	- -
Papaya	<0.1	<1	<0.1	<1	(- -)	- -
Total	**39.9**	**100**	**44.2**	**100**	**+ 4.3**	**+ 11**

Source: Clive James, 2000.

Figure 4. Global Area of Transgenic Crops, 1996 to 2000: by Crop (million hectares)



Source: Clive James, 2000.

decrease in transgenic corn in the USA in 2000 to lower plantings of *Bt* corn by farmers who concluded that the low infestation of European Corn Borer in 1999 may not merit the use of *Bt* corn in 2000, on the basis that infestation would continue to be low. Others have suggested that farmer uncertainty about markets for transgenic corn during the planting season may have led to decreased plantings of transgenic corn in 2000 by a small proportion of farmers. Decreases in transgenic corn in the USA and Canada have been offset by significant increases in transgenic corn in Argentina where adoption rates increased from 5% to 20% of the national corn crop, as well as an increase in transgenic corn in South Africa.

The net decrease in area planted globally with transgenic canola in 2000 is estimated at 600,000 hectares with all of the decrease in Canada, which is offset by a modest increase in transgenic canola in the USA. Canadian observers attribute the decrease in transgenic canola to three factors: firstly, the national canola hectarage decreased by 0.6 million hectares, from 5.5 million in 1999 to 4.9 million hectares in 2000; secondly, herbicide tolerant transgenic canola competed with mutation-derived herbicide tolerant canola varieties which increased in area and occupied 25% of the national acreage in 2000 – this compares with transgenic canola at 50% in 2000; thirdly the low price of canola may have been a disincentive to farmers, who chose to decrease their cost outlays by planting conventional varieties.

In 2000, global area of transgenic cotton is estimated to have increased by 1.6 million hectares, from 3.7 million hectares in 1999 to an estimated 5.3 million hectares in 2000 – this is equivalent to a year-over-year increase of over 40% in the global area of transgenic cotton. The most significant increase was reported for the USA where the percentage of transgenic cotton increased from 55% in 1999 to 72% in 2000. China is reported to have significantly increased its transgenic cotton area to more than 10% of its national cotton area, and modest increases have been reported for Mexico, Australia, Argentina, and South Africa.

2.4 Distribution of Transgenic Crops, by Trait

During the five-year period 1996 to 2000, herbicide tolerance has consistently been the dominant trait with insect resistance being second (Figure 5). In 2000, herbicide tolerance, deployed in soybean, corn and cotton, occupied 74% of the 44.2 million hectares (Table 5), with 8.3 million hectares planted to *Bt* crops equivalent to 19%, and stacked genes for herbicide tolerance and insect resistance deployed in both cotton and corn occupying 7% of the global transgenic area in 2000. It is noteworthy that the area of herbicide tolerant crops has increased between 1999 and 2000 (28.1 to 32.7 million hectares) as well as crops with stacked genes for herbicide tolerance and *Bt* (2.9 million hectares in 1999 to 3.2 million hectares in 2000), whereas the global area of insect resistant crops has decreased from 8.9 million hectares in 1999 to 8.2 million hectares in 2000 (Table 5 and Figure 5). The trend for stacked genes to gain an increasing share of the global transgenic crop market is expected to continue.

2.5 Dominant Transgenic Crops in 2000

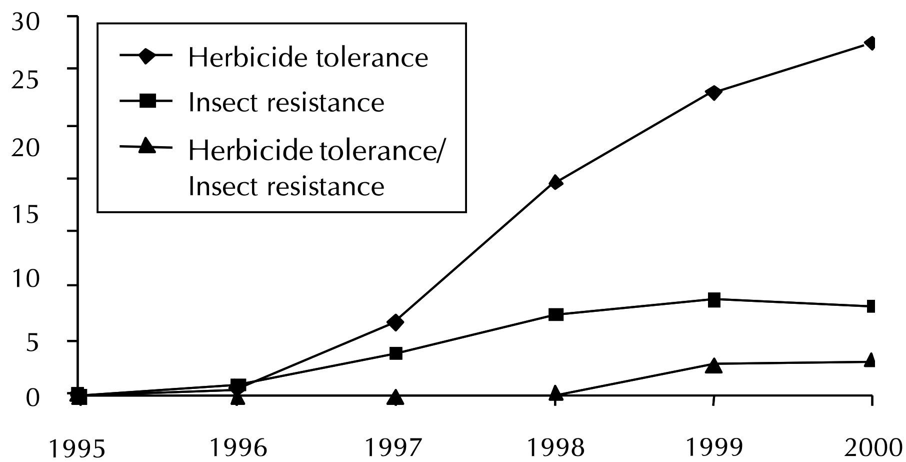
Herbicide tolerant soybean was the most dominant transgenic crop grown commercially in six countries in 2000 – USA, Argentina, Canada, Mexico, Romania, and Uruguay (Table 6). Globally herbicide tolerant soybean occupied 25.8 million hectares, representing 59% of the global transgenic crop area of 44.2 million hectares for all crops. The second most dominant crop was *Bt* maize, which occupied

Table 5. Global Area of Transgenic Crops in 1999 and 2000: by Trait (million hectares)

Trait	1999	%	2000	%	+/-	%
Herbicide tolerance	28.1	71	32.7	74	+4.6	+16
Insect resistance (*Bt*)	8.9	22	8.3	19	-0.6	-7
***Bt*/Herbicide tolerance**	2.9	7	3.2	7	+0.3	+10
Virus resistance/Other	<0.1	<1	<0.1	<1	<0.1	- -
Global Totals	**39.9**	**100**	**44.2**	**100**	**+4.3**	**11**

Source: Clive James, 2000.

Figure 5. Global Area of Transgenic Crops, 1996 to 2000: by Trait (million hectares)



Source: Clive James, 2000.

Table 6. Dominant Transgenic Crops, 2000

Crop	Million Hectares	% Transgenic
Herbicide tolerant Soybean	25.8	59
***Bt* Maize**	6.8	15
Herbicide tolerant Canola	2.8	6
Herbicide tolerant Maize	2.1	5
Herbicide tolerant Cotton	2.1	5
***Bt*/Herbicide tolerant Cotton**	1.7	4
***Bt* Cotton**	1.5	3
***Bt*/Herbicide tolerant Maize**	1.4	3
Total	**44.2**	**100**

Source: Clive James, 2000.

6.8 million hectares, equivalent to 15% of global transgenic area and planted in six countries – USA, Canada, Argentina, South Africa, Spain, and France. The other six transgenic crops listed in Table 6 all occupy <10% of global transgenic crop area and include, in descending order of area: herbicide tolerant canola, occupying 2.8 million hectares (6%); herbicide tolerant maize on 2.1 million hectares (5%); herbicide tolerant cotton on 2.1 million hectares (5%); *Bt*/herbicide tolerant cotton on 1.7 million hectares (4%); *Bt* cotton on 1.5 million hectares (3%); *Bt*/herbicide tolerant maize on 1.4 million hectares (3%).

2.6 Global Adoption of Transgenic Soybean, Maize, Cotton and Canola

One useful way to portray a global perspective of the status of transgenic crops is to characterize the global adoption rates of the four principal crops – soybean, cotton, canola and corn – in which transgenic technology is utilized (Table 7 and Figure 6). The data indicate that in 2000, 36% of the 72 million hectares of soybean planted globally were transgenic. Similarly, 16% of the 34 million hectares of cotton, 11% of the 25 million hectares of canola, and 7% of the 140 million hectares of corn, were transgenic. If the global areas of these four crops are aggregated, the total area is 271 million hectares, of which 16%, equivalent to 44.2 million hectares, is estimated to be transgenic. It is noteworthy that two-thirds of these 271 million hectares are in the developing countries where yields are lower, constraints are greater, and the need for improved production of food, feed, and fiber crops is the greatest.

2.7 Summary of Significant Changes between 1999 and 2000

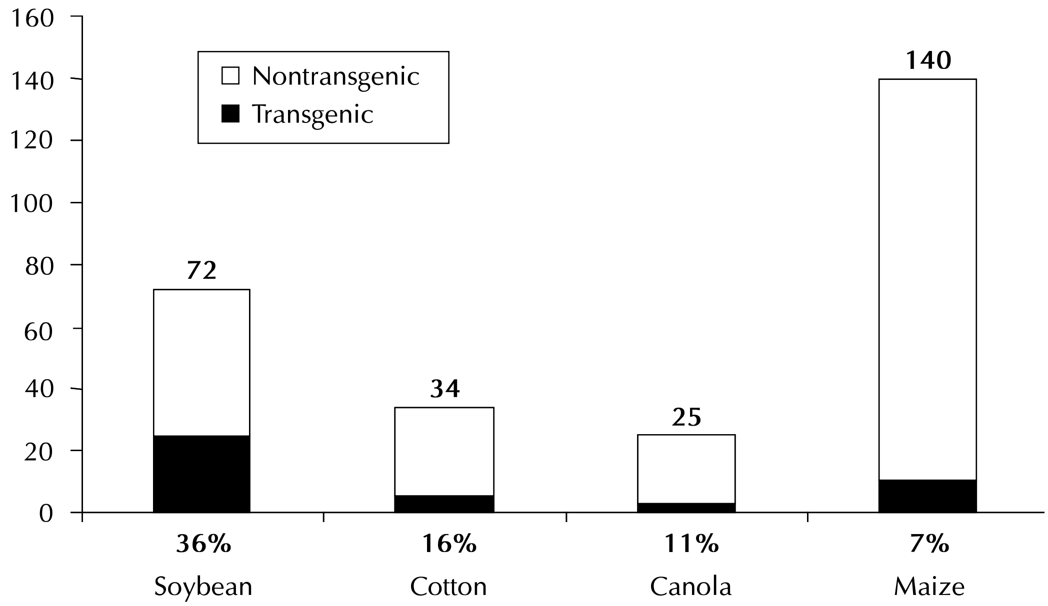
The major changes in area and global share of transgenic crops for the respective

Table 7. Transgenic Crop Area as % of Global Area of Principal Crops, 2000 (million hectares)

Crop	Global Area	Transgenic Crop Area	Transgenic Area as % of Global Area
Soybean	72	25.8	36
Cotton	34	5.3	16
Canola	25	2.8	11
Maize	140	10.3	7
Total	**271**	**44.2**	**16**

Source: Clive James, 2000.

Figure 6. Global Area Adoption Rates (%) for Principal Transgenic Crops, 2000 (million hectares)



Source: Clive James, 2000.

countries, crops, and traits, between 1999 and 2000 were related to the following factors:

- In 2000, the global area of transgenic crops increased by 11%, or 4.3 million hectares, to 44.2 million hectares, from 39.9 million hectares in 1999. Eight transgenic crops were grown commercially in 13 countries in 2000, three of which, Bulgaria, Germany and Uruguay, grew transgenic crops for the first time. Two countries, Portugal and Ukraine, which grew small introductory areas in 1999 did not report transgenic crops in 2000.

- The four principal countries that grew the majority of transgenic crops in 2000 were USA 30.3 million hectares (68% of the global area); Argentina, 10.0 million hectares (23%), Canada 3.0 million hectares (7%); China 0.5 million hectares (1%); the balance was grown in South Africa, Australia, Romania, Mexico, Bulgaria, Spain, Germany, France, and Uruguay. The highest growth in transgenic crop area between 1999 and 2000 was reported for Argentina (3.3 million hectares), followed by USA (1.6 million hectares), and China and South Africa with 0.2 million hectares respectively. A decrease of 1 million hectares was estimated for Canada, mainly due to a decrease in area planted to conventional and transgenic canola.

- For the first time in the last five years growth in area of transgenic crops between 1999 and 2000 in the developing countries exceeded, by more than 5 times, the area growth in transgenic crops in industrial countries (3.6 million hectares versus 0.7 million hectares). Of the 4.3 million hectares global growth in 2000, 3.6 million hectares equivalent to 84%, was in the developing countries.

- In terms of crops, soybean contributed the most to global growth of transgenic crops, equivalent to 4.2 million hectares between 1999 and 2000, followed by cotton with an increase of 1.6 million hectares. Corn and canola decreased by 0.8 and 0.6 million hectares respectively because of decreases in USA and Canada, which were partly offset by increases in transgenic corn in developing countries.

- There were three noteworthy developments in terms of traits; herbicide tolerance contributed the most (4.6 million hectares) to global growth between 1999 and 2000; the stacked genes of insect resistance and herbicide tolerance in both corn and cotton contributed 0.3 million hectares, with insect resistance decreasing by 0.6 million hectares.

- Of the 4 major transgenic crops grown in 12 countries in 2000, the two principal crops of soybean and corn represented 59% and 23% respectively for a total of 82% of the global transgenic area, with the remaining 18% shared between cotton (12%) and canola (6%).

- In 2000, herbicide tolerant soybean was the most dominant transgenic crop (59% of global transgenic area, compared with 54% in 1999), followed by insect resistant corn (15% compared with 19% in 1999), herbicide tolerant canola (6%), herbicide tolerant corn and herbicide tolerant cotton, both at 5%, *Bt*/herbicide tolerant cotton at 4%, and *Bt* cotton and *Bt*/Herbicide tolerant corn both at 3%.

The combined effect of the above seven factors resulted in a global area of transgenic crops in 2000 that was 4.3 million hectares greater and 11% more than 1999; this is a significant year-on-year increase considering the high percentage of the principal crops already planted to transgenics in 1999.

3. VALUE OF THE GLOBAL TRANSGENIC SEED MARKET, 1995 TO 2000

The value of the transgenic crop market is based on the sale price of transgenic seed plus any technology fees that apply. The estimates published here are the most recently revised estimates from Wood Mackenzie Agrochemical Services (Wood Mackenzie Agrochemical Services, 2001, Personal communication), which exclude non-genetically modified herbicide tolerant seed.

Global sales of transgenic seed have grown rapidly from 1995 onwards (Table 8). Initial global sales of transgenic seed were estimated at $ 1 million in 1995. Sales increased in value to $ 156 million in 1996, and increased by approximately $ 702 million in 1997 to reach $ 858 million. Sales increased by another $1,112 million between 1997 and 1998 to reach $ 1.97 billion in 1998. Sales continued to increase substantially in 1999 by an additional $ 977 million to reach $2.95 billion in 1999 and in 2000 plateaued at just over $3 billion ($ 3,044 million).

Table 8. Estimated Value of Global Transgenic Seed Market, 1995-2000 ($ millions)

Year	Market value $	Increase $
1995	1	
1996	156	155
1997	858	702
1998	1,970	1,112
1999	2,947	977
2000	3,044	97

Source: Wood Mackenzie Agrochemical Services. 2001 (Personal Communication)

4. VALUE OF TRANSGENIC CROPS IN THE CONTEXT OF THE GLOBAL CROP PROTECTION MARKET

Given that all the traits introduced to-date are crop protection traits, it is useful and appropriate to discuss the value of total sales of transgenic crops as a percentage of the global crop protection market. Wood Mackenzie estimated that transgenic seed in 1998 accounted for 6.3% of the $ 31.25 billion global crop protection market at the ex-distributor market value. Between 1998 and 2000 the value of the transgenic seed market has increased from 6.3% in 1998 to 9.5% in 2000 (Table 9) equivalent to $ 3.044 billion out of a total crop protection market of $ 32 billion. It is noteworthy that the transgenic crops category is the only one of the five categories to show an increase in value between 1999 and 2000 (Table 9); transgenic crops increased by + 3.7%, whilst herbicides decreased by -3.8%, and fungicides by -4.4%.

The distribution of the sale of transgenic seed, based on value, is shown by region and product in Table 10. It is clear that the major market is in North America with its share valued at $ 2.368 billion equivalent to 78% of the global market; the second largest market is in Latin America with $ 542 million equivalent to 18% of the global market, followed by the Far East (developing countries of Asia) at $ 109 million or 4% of global market share. In terms of product, soybean has the major market share at $ 1.674 billion or 55% of the global market followed by maize at $651 million (21%), cotton at $ 479 million (16%) and canola $ 240 million (8%).

The data in Table 11 is a matrix of the transgenic crop market by region and product. It also shows the relative distribution between industrial and developing countries as well as the different types of pesticides. It is noteworthy that the value of the transgenic crop market in North America ($ 2.368 billion) now exceeds

Table 9. Global Crop Protection Market in 2000: by Product (Value in $ millions)

Group	$ millions	% Change from 1999
Herbicides	13,794	-3.8%
Insecticides	8,009	-3.0%
Fungicides	5,801	-4.4%
Plant growth Regulators and Others	1,358	-7.8%
Transgenic Crops	3,044	+3.7%
Total	**32,006**	**-3.2%**

Source: Wood Mackenzie Agrochemical Services, 2001 (Personal Communication)

Table 10. Value of Global Transgenic Crops in 2000: by Crop and Region ($ millions)

Crop	$ millions
Soybean	1,674
Maize	651
Cotton	479
Canola	240
Total	**3,044**
Region	
North America	2,368
Latin America	542
West Europe	2
East Europe	3
Far East	109
Rest of the World	20
Total	**3,044**

Source: Wood Mackenzie Agrochemical Services, 2001 (Personal Communication)

the corresponding market in both fungicides ($724 million) and insecticides ($ 1.582 billion), but is less than half of the herbicide market ($5.766 billion). In fact the value of transgenic crops in North America is already worth 22% of the total crop protection market of $ 32 billion and continues to grow annually – this compares with 11% for Latin America ($ 542 million out of a total of $ 4.980 billion), and 2% for the developing countries of the Far East. It is evident from the data in Table 11 that the value of the transgenic crop market is higher in the industrial countries, $ 2.373 billion equivalent to 78% of the global market, compared with $ 671 million, equivalent to 22%, in the developing countries, over 80% of which is in Latin America and with most of the balance in the Far East.

Of the total crop protection market of $ 20.513 billion in the industrial countries, $ 2.373 billion equivalent to 12% is transgenic crops. The corresponding figures for the developing countries is a total crop protection market of $11.493 billion of which transgenic crops are valued at $ 671 million equivalent to 5%. Whereas, the value of the herbicide market in the industrial countries ($ 9.3 billion) is more than twice that in the developing countries ($4.4 billion), the countries of the South spend more on insecticides ($ 4.1 billion) than the countries in the North. However, the significant difference in herbicide usage between industrial and developing countries is likely to become less marked in the future. Agronomic practices such as zero or low–tillage, availability and cost of labor in developing countries will offer new opportunities for farmers to use herbicide tolerant varieties, that allow improved conservation of moisture and nutrients that collectively contribute to a more sustainable agriculture. Efficient use of water in both rainfed and irrigated agriculture will become increasingly important and herbicide tolerance technology will be seen by farmers to be compatible with changing and emerging new needs.

Of the total global crop protection market of $32 billion about two-thirds is in the industrial countries ($ 20.513 billion) with the other one-third ($ 11.493 billion) in the developing

Table 11. Global Crop Protection Market, 2000: by Region and Product ($ millions)

	Herbicides	Insecticides	Fungicides	Others	Biotech	Total
North America	5,766	1,582	724	415	2,368	10,855
West Europe	2,188	872	1,992	468	2	5,552
East Europe	334	249	140	49	3	775
Japan	1,023	1,185	1,057	96	0	3,361
Industrial Countries	**9,311**	**3,888**	**3,913**	**1,028**	**2,373**	**20,513**
Latin America	2,241	1,164	897	136	542	4,980
Rest of Far East	1,806	1,949	712	130	109	4,706
Rest of World	436	1,008	279	64	20	1,807
Developing Countries	**4,483**	**4,121**	**1,888**	**330**	**671**	**11,493**
Total	**13,794**	**8,009**	**5,801**	**1,358**	**3,044**	**32,006**

Source: Wood Mackenzie Agrochemical Services, 2001 (Personal Communication)

countries (Table 11). The data in Table 12 indicate the global market share of the nine principal countries in crop protection; the balance is assigned to the remaining "Others" category. Of the top nine countries, six are industrial countries (USA, Japan, France, Canada, Germany, and Australia) and three are developing countries (Brazil, China, and Argentina). Expressed as a percentage of the global market, there are five countries with more than 5% of global market share.

The US is by far the biggest crop protection market (30% of the global $ 32 billion market), followed by Japan (11%), Brazil (8%), China (6%), and France (5%). The remaining four countries listed in Table 12 have global market shares of between 2% and 5% of global market share. It is not surprising that the top four countries that grew 99% of the transgenic crops in 2000 (USA, Argentina, Canada, and China) are also in the top ten in the global crop protection market. Collectively the top four countries that grew transgenics in 2000 consumed 44% of the global pesticide market and are already benefiting from reduced and/ or more efficient pesticide usage. Similarly, the four major transgenic crops, soybean, maize, cotton and canola include three out of four of the crops that consume the most pesticides globally (Table 13). Collectively, the four crops consume 36% of global pesticides and are already benefiting from reduced and/or more efficient pesticide usage, particularly in crops such as *Bt* cotton where major reductions are being realized in terms of insecticides and fewer health hazards to farmers. Further reductions and increase in efficiencies in pesticide usage

Table 12. Global Crop Protection Market, in 2000: by country expressed as percentage of total market

Country	% Global Market
USA	30.3
Japan	10.5
Brazil	7.9
China	6.2
France	5.4
Argentina	3.7
Canada	3.6
Germany	3.0
Australia	2.6
Others	26.8
Total	**100**

Source: Wood Mackenzie Agrochemical Services, 2001 (Personal Communication)

Table 13. Global Crop Protection Market, in 2000: by Crop ($ millions)

Total Crop Protection Market by Crop	$ millions
Cereals	4,313
Cotton	2,995
Fruit and Vegetables	8,092
Maize	3,604
Oilseed Rape/Canola	691
Rice	3,109
Soybeans	4,179
Sugar Beet	521
Other Crops	4,502
Total	**32,006**

Source: Wood Mackenzie Agrochemical Services, 2001 (Personal Communication)

can be realized as more insect resistant crops and herbicide tolerant varieties are deployed. Coincidentally these technologies will provide major benefits in terms of more flexible and improved conservation and management practices that farmers value highly and which collectively contribute to more sustainable farming systems.

The significant increase in transgenic crops in the USA and Canada coincided with the first significant decline in 1999 pesticide sales in North America by 10.9% to $ 7.19 billion. Many factors including low commodity prices were also responsible for the decrease but the major factor was the increased area of transgenic crops. In 1999, herbicide revenues in the USA fell by 13.8% to $ 4.75 billion. The principal factor responsible for the decline in herbicide sales was the growth in Round Up Ready and Liberty Link transgenic soybeans, cotton, corn and canola. Insecticide use in 1999 in the US also decreased by 5.3% to $ 1.38 billion due to the adoption of *Bt* corn and cotton (Wood Mackenzie Agrochemical Services 2001, Personal communication).

5. OVERVIEW OF THE COMMERCIAL SEED INDUSTRY

The author estimates that, expressed as a proportion of the global commercial seed market, transgenic seed represents approximately 10% of the estimated $ 30 billion plus global commercial seed market in 2000 (FIS 2001).

Given that seed is the vehicle for incorporating and deploying transgenic traits, it is instructive to characterize the global commercial seed market to gain a sense of the scope, scale and size of the relative sub-segments of the global market classified by country, or seed, or exports. The latest estimate for the global commercial seed market is approximately $30 billion (FIS 2001), with almost 30% of the market in the developing countries. Six of the top ten country markets (Table 14) are in the industrial countries: USA ($ 5.7 billion), Japan ($ 2.5 billion), Commonwealth of Independent States ($ 2 billion), France ($ 1.4 billion), Germany ($ 1.0 billion) and Italy ($ 650 million. The four developing countries in the top ten are China ($ 3 billion), Brazil ($ 1.2 billion), Argentina ($ 930 million) and India ($ 900 million). Of the 13 countries that grew transgenic crops in 2000, nine are in the top twenty countries in terms of seed sales; the four exceptions are South Africa, Romania, Bulgaria and Uruguay.

Considering seed exports worldwide, the global market is valued at approximately $ 3.5 billion, equivalent to about 10% of the global market valued at $ 30 billion (Appendix Table

Table 14. Latest Estimated Values (US $ millions) of the Commercial Markets for Seed and Planting Material for the Top 20 Countries

Country	Internal Commercial Market
USA	5,700
China	3,000
Japan	2,500
CIS	2,000
France	1,370
Brazil	1,200
Germany	1,000
Argentina	930
India	900
Italy	650
United Kingdom	570
Canada	550
Poland	400
Mexico	350
Spain	300
Netherlands	300
Australia	280
Hungary	200
Denmark	200
Sweden	200
Total	**22,600***

* This total represents the sum of the commercial seed markets of the 20 listed countries. The commercial world seed market is assessed at US$ 30 billion.

Source: FIS 2001

1A). Maize is the most important seed export market, valued at $ 530 million annually. The top five crops that have export sales of more than $ 75 million annually are maize ($ 530 million), herbage crops ($ 427 million), potato ($ 400 million), beet ($ 308 million) and wheat ($ 75 million). Breaking down the seed export market by country, out of the top ten countries the top nine are industrial countries with annual exports of seeds valued from $ 799 million to $ 105 million. Given the ongoing debate in Europe re transgenic crops, it is noteworthy that approximately half of the global seed export sales are from European countries. Out of a total global market of $3.5 billion, the USA is ranked # 1 with $ 799 million (Appendix Table 2A), followed by six European countries Netherlands ($ 620 million), France ($ 498 million), Denmark ($190 million), Germany ($ 185 million), Chile ($144 million) Canada ($122 million), Belgium ($ 111 million), Italy ($ 111 million) and Japan ($ 105 million) for a total of $ 2.9 billion. Only one of the top ten countries exporting seeds is a developing country - Chile with annual sales of $ 144 million.

6. STATUS OF REGULATION IN THE EUROPEAN UNION

In the face of the continuing public debate on genetically modified crops in Europe the growing of transgenic crops in countries of the European Union (EU) continues to face bureaucratic/political constraints which contribute to uncertainty and delays that have resulted in a halt to commercial product approvals in the EU. In the year 2000, only one transgenic crop, *Bt* corn, was grown in three countries; Spain grew up to 20,000 hectares, with less than 500 hectares each in Germany and France. The European Commission has recently reviewed its regulations and the following is an overview of the status of the regulation of transgenic crops in Europe (Anonymous 2001a).

6.1 Current Status

Legislation for transgenic crops has applied in the countries of the European Union since the early 1990s. Directive 90/220/EEC is the current legislation that governs environmental release for field-testing and for commercial approval of transgenic crops. A new Directive 2001/18/EC was adopted by the European Parliament and the Council of Ministers in February 2001 and will become effective on 17 October 2002. The current Directive (90/220/EC) is applied on a case by case basis. Products derived from transgenic crops (such as paste from a transgenic tomato) are not covered by Directive 90/220 but by Regulation EC 258/97 which regulates Novel Foods and Food Ingredients.

Under Directive 90/220, the application to commercialize a transgenic crop must be submitted to the designated authority of an EU Member State; the application must include a full risk assessment. If the product does not present a risk to human health or the environment, the Member State advises other Member States of the decision through the Commission. If there are no objections from the other Member States, the initial Member State issues a consent for the marketing of the product which can then be marketed throughout the EU. However, if any objections are raised a decision has to be taken at the Community level which is a complex and lengthy process. This first involves consultation with the Scientific Committees of the Commission, followed by a Commission proposal, which is referred to the Regulatory Committee, composed of representatives of Member States, for voting and subsequent adoption by the Commission. If this process does not result in a decision, the draft Commission decision is referred to the Council of Ministers for adoption or rejection. If the Council does not decide within 3 months, then the Commission may adopt the decision.

To date the Scientific Committee on Plants (SCP) has issued opinions on 17 transgenic crops under Directive 90/220 with only one unfavorable opinion, due to insufficient information for a complete risk assessment – this involved a gene conferring resistance to the antibiotic amikacin. The Scientific Committee on Food (SCF) has issued one favorable opinion for a food of transgenic plant origin – a processed tomato.

6.2 New Requirements under Directive 2001/18

The new Directive 2001/18 that will become effective 17 October 2002 is more stringent and demanding in terms of risk assessment, the decision making process, and the release of transgenic crops into the environment. The Directive requires obligatory consultation with the Commission's Scientific Committees and introduces additional requirements concerning information to the public, labeling, and traceability at all stages of marketing of viable transgenic products. Approvals for the commercialization of transgenic crops will be limited to a maximum of 10 years and require mandatory post-market monitoring during this period.

6.3 Approval of Transgenic Crops and Derived Products

Consents have been issued for fourteen (14) transgenic plant products in the EU (11 of these by a Commission decision) since Directive 90/220 came into force in October 1991. These products are listed in Appendix Table 3A and include the following crops, 4 maize, 4 swede rape, 3 carnations, and one each of soy, tobacco and chicory. However, in two cases, the initial Member State (France) has not implemented the Commission decision. Furthermore, under Directive 90/220, individual Member States can invoke a safeguard clause (Article 16) to temporarily ban EU-consented transgenic plant products in their territory, provided that this is scientifically justified. Five EU countries, Austria, Luxembourg, France, Greece and Germany, are utilizing this clause to prohibit the marketing of eight specific transgenic products at this time. It is noteworthy that the Scientific Committee of Plants at the European Commission has reviewed these eight cases and determined that the ban in place by the five countries is not justified scientifically. As a result of this complex, confusing, and conflicting bureaucratic situation in Europe, farmers in countries of the European Union have actually grown only one transgenic crop. This is *Bt* corn, grown on an estimated 20,000 hectares in Spain in 2000, with less than 500 hectares each in France and Germany.

The European Union has not granted any consent for transgenic crops since October 1998. This moratorium on approvals has resulted in a back-log of a total of 12 applications that have been waiting for approval for up to three years. These 12 applications are listed in Appendix Table 4A and include the following transgenic crops, 4 maize, 3 swede rape, 2 cotton and one each of tomato, fodder beet and chicory.

Ten (10) transgenic crops have been approved for food use in the EU, according to the Novel Food regulation (see Appendix Table 3A for details). Note that there is no EU regulation to authorize processed feeds. There is Community legislation in place covering the use of seed, including both conventional and transgenic seed, and these regulations must be met before seeds can be marketed in the EU and registered in the Community's "Common Catalogue of Varieties of Agricultural Plant Species".

Since 1997 the labeling of certain genetically modified food products has been mandatory in the EU. Council Regulation 1139/38 specifies labeling requirements for foods derived from one transgenic maize and one transgenic soybean variety and this regulation has established the principles for the labeling of other transgenic foods and ingredients. There are no mandatory labeling requirements for food ingredients derived from transgenic crops, which do not contain transgenic DNA or protein. Regulation EC 49/2000 provides for a threshold of up to 1% transgenic food ingredients in conventional foods, provided that appropriate steps have been taken to avoid the presence of transgenic material. Genetically modified seed must be labeled. Whereas there is no specific legislation covering labeling of processed transgenic feed, the general labeling rules under Directive 90/220 apply to feeds, which are viable (grains).

In summary, whereas the European Commission has tried to enact regulations that will facilitate adoption of transgenic crops, and its Scientific Committees have endorsed the safety of many such products, the complexity of the authorization process that requires the concurrence of so many entities (particularly in the Member States), has, with few exceptions, resulted in a failure to authorize products and prevented the cultivation of transgenic crops in EU countries. An exception is Spain, which is facilitating the planting of *Bt* maize. Its farmers are increasingly adopting the crop because of the multiple benefits it offers, and the fact that it does not disadvantage them technologically in their quest to retain international competitiveness in the economic production of maize.

7. ALLIANCES, ACQUISITIONS, SPIN-OFFS AND ACTIVITIES IN THE AGRIBIOTECHNOLOGY INDUSTRY

Spin-offs, alliances, acquisitions, and restructuring were significant features that impacted on the biotechnology industry in 2000. These developments influence directly the level of private sector investments in crop biotechnology and indirectly impact on the future adoption and acceptance of transgenic crops globally. As in the previous years, 2000 witnessed continuing activity in alliances, acquisitions, and spin-offs that contributed to further consolidation of the biotechnology industry. As a result of the large number of alliances, acquisitions and mergers over the last five years, the structure of the private sector involved with biotechnology, seeds, and agricultural chemicals has changed dramatically. However, in 2000, some corporations chose to spin-off their agribiotech component from the pharmaceutical component of the business with a view to merging their agribiotech component with a counterpart agribiotech business from like-minded partner corporations. Restructuring has occurred in all the large transnationals involved in crop biotechnology and this has resulted in a refocusing of resources allocated to crop biotechnology globally. This will directly impact on the rate at which new products will become available and affect lag time before the public can benefit from new products.

This refocusing of resources allocated to crop biotechnology has implications for developing countries, which have an urgent need for improved crops that can produce more and better quality food to combat poverty, hunger and malnutrition. The restructuring that has occurred will impact on our global capacity to increase the quantity and quality of food in a sustainable way. It is highly improbable that the refocusing of allocated resources in the private sector will be offset by an increased allocation of resources by the public sector, which unfortunately is continuing to decrease resources allocated to agriculture in both industrial and developing countries.

Selected highlights of crop biotechnology developments in industry in 2000 are listed in Table 15 to provide the reader with an overview of recent major developments in the private sector. Several of the crop biotechnology highlights in the private sector in 2000 (Table 15) are discussed in more detail elsewhere in this publication, accordingly only a brief reference will be made to these activities in this section. They include StarLink corn discussed in detail in section 8.1.2; Genomics and Genome Sequencing of Rice; *Arabidopsis* and *Agrobacterium*, section 8.4; sharing of proprietary technology by corporations with developing countries in philanthropic projects such as Golden Rice, Golden Mustard and the Positech™ gene marker technology, section 8.5. To facilitate a more coherent and systematic discussion of the activities of the private sector in crop biotechnology in 2000, commentaries are summarized for the following specific areas: sharing information knowledge and technology with the public and with developing countries; new investors in crop biotechnology; acquisitions; alliances; mergers and spin-offs/IPOs; genomics; genetic markers; and finally regulation and marketing.

7.1 Sharing Information, Knowledge and Technology with the Public and with Developing Countries

In response to the continuing debate on transgenic crops and the need to be proactive in informing society by sharing information and knowledge with the lay public about crop biotechnology, industry founded the Council for Biotechnology Information (CBI). CBI was established in the US in 2000 and the founding members were Aventis, BASF, BIO, Dow, DuPont, Monsanto, Novartis, and Zeneca. The initiative aims to share information and knowledge about agricultural biotechnology with the public at large. The program will run for a 3-5 year period. Many companies are putting more resources and effort into engaging the public and investing in initiatives that will respond to the needs of society. In November 2000, Monsanto announced its "New Monsanto Pledge" that commits the company to dialog, transparency, respect, sharing and delivering of benefits and environmental responsibility. Noteworthy is a commitment not to commercialize transgenic crops in the US until full food and feed approval is obtained in the US and Japan, with the option of including Europe later. Monsanto also undertook not to use animal or human genes in transgenic crops, not to develop sterile gene technology, and the company plans to establish an external Biotechnology Advisory Council. Novartis (Syngenta), as well as other companies, has made a commitment to license proprietary technology to subsistence farmers on a royalty-free basis. The further development of 'Golden Rice' for humanitarian purposes, discussed in section 8.5 of this publication, was facilitated as a result of the granting of intellectual property licenses from the following corporations: Bayer, Monsanto, Orynova, Syngenta and Zeneca Mogen. Each company licensed the technology used in the research which led to the 'Golden Rice' invention on a royalty-free basis. In addition several companies including DuPont, Monsanto and Novartis have, in a collaborative mode, posted genomic sequences of rice, *Arabidopsis* and *Agrobacterium* on web sites for sharing with the public sector and the international scientific community. These initiatives are discussed in more detail in section 8.4 of this publication.

7.2 New Investors in Crop Biotechnology

In a strategy mirroring its competitors, BASF announced in March 2000 that it would invest more than 700 million Euros ($ 680 million), for the next 10 years in crop biotechnology, with additional capital to be provided for the acquisition of seed companies. The new subsidiary, BASF Plant Science, will be separate from agrochemicals. In December 2000, BASF Plant Science acquired ExSeed Genetics (US) which has expertise in nutritionally enhanced corn – high oil, protein and amino acid for animal feed as well as starch enhancement in corn grain crops and potatoes.

7.3 Acquisitions

Reflecting the modulation in investments in agricultural biotechnology in 2000, unlike earlier years, there were only a few acquisitions in 2000. Ecogen acquired Mycogen's *Bt* pesticides and a license to some of Mycogen's *Bt* genes. Dow AgroSciences acquired the Brazilian seed company, Empresa Brasileira de Sementes (EBS) which specializes in maize and sorghum. With this latest acquisition Dow AgroSciences' holdings in seeds/biotech in Brazil increases to five acquisitions including EBS, Hibridos Colorado, FT Biogenetica, Hibridos Hata and Dinamillo. Mycogen Seeds, wholly owned by Dow Chemical acquired Cargill's North American seed operations. This makes Dow/Mycogen the third largest maize seed producer in the USA with total seed sales of approximately $300 million in 1999.

7.4 Alliances

The quest to utilize resources in the most effective way required companies to focus on collaboration and the building of alliances as opposed to acquisitions. Accordingly, the forging of alliances was a very active area in crop biotechnology in the private sector in 2000. DuPont and Monsanto agreed that specific DuPont glyphosate products and mixtures can be applied on RR cotton and RR soybeans. Agrinomics, a joint venture of Aventis Crop Science and Agritope, signed a $7.5 million agreement with Vilmorin, Clause and Cie. (France) and the Biotech MAM Plant Genomic Fund of Israel to breed vegetables with improved resistance to bacterial diseases, nematodes, viruses and better tolerance to drought. RhoBio, a joint venture between Aventis and Biogemma, and Entomed agreed to develop insect peptide products for control of fungal and bacterial pathogens. RhoBio will utilize the genes in GM crops. Compared with other active ingredients, it is speculated that resistance to peptides is less likely to develop. Aventis Crop Science, Archer Daniels Midland and SKW Trostberg AG established a $30 million venture capital fund with Burrill & Company to support development of neutraceuticals. Dow Chemical and EPIcyte Pharmaceuticals announced an alliance to develop monoclonal antibodies from plants. Plant-derived antibodies can be produced more cost-effectively and will be used eventually as antibody-based products for the prevention and treatment of infection in animals and in food safety applications. BASF licensed its non-transgenic mutation-bred trait that confers tolerance to the herbicide imidiazolinone (IMI) to Dow AgroSciences/Mycogen for use in maize. The IMI trait was developed by Cyanamid, which was acquired by BASF earlier in 2000. The IMI trait may be incorporated through conventional breeding along with transgenic traits such as *Bt* genes, owned by Mycogen, or in conjunction with a broader based transgenic insect resistance under development by Dow AgroSciences.

7.5 Mergers and Spin-Offs/IPOs

During 2000, several recently formed life science companies that had only completed their last mergers at the beginning of the year were exploring spin-offs of the agricultural/seed activities before the year-end of 2000. The merger between Monsanto and Pharmacia received final approval from the European Commission in March 2000. In May 2000, Monsanto announced an initial public offering (IPO) equivalent to approximately 20% of its stock, with the remaining 80% retained by Pharmacia. In September 2000, Aventis announced that the joint pharmaceutical/ agriculture life sciences approach may not be an appropriate business model with one of the options being to spin off the agricultural business as an IPO. In November, Aventis announced that it would divest its agricultural holding, Aventis Crop Science, before the end of 2001. The merger of Novartis and Zeneca to form Syngenta was cleared by the European Commission in July 2000, and now has its seed activities managed separately.

7.6 Genomics

Genomics continued to be a very active and pivotal area of research and development. The years 2000 and 2001 have been watershed years for genomics with several important genome sequencing projects reaching important milestones. These include completion of the sequencing of the *Arabidopsis thaliana* and *Agrobacterium tumefaciens* as well as a working draft and complete genome of rice. These successes are discussed in section 8.5 of this publication. Genomics attracted significant investments in 2000, and continued to catalyze more alliances than any other area of biotechnology, and stimulated more collaboration between the public and private sectors. Some of the alliances featuring genomics are described below.

Novartis Research Foundation signed a non-exclusive agreement with the genomics company, Novalon Pharmaceutical Corporation. The alliance provides Novartis Foundation with access to Novalon's BioKey genomic assays for herbicides and fungicides. EraGen agreed to provide Novartis with "An Expanded Genetic Information System"(AEGIS) to identify Single Nucleotide Polymorphisms (SNPs) in plants from the same crop species. The identification of SNPs in genes will allow the development of crops with improved traits that contribute to yield and resistance to abiotic and biotic stresses. Zeneca and GeneData AG agreed to collaborate in genomics, more specifically the analysis of data from gene expression arrays to decrease crop losses due to weeds, insects and diseases. Affymetrix developed the GeneChip *Arabidopsis* Gene Array. The GeneChip is capable of analyzing the expression of over 8,000 *Arabidopsis* gene sequences. The *Arabidopsis* Genome Array was co-developed by Affymetrix and Novartis.

The genomics company, Paradigm Genetics, and Monsanto signed a $ 55 million agreement to analyze gene sequencing, bioinformatics and functional genomics data from Monsanto. Monsanto and Rosetta Inpharmatics signed a $ 15 million, 3-year agreement, to develop improved corn, rice and wheat. Rosetta's expertise is in information genomics that analyzes mega-data bases generated from high volume gene expression analyses.

Finally, BASF Plant Science and Omniviz signed a 3-year agreement to analyze genomic data. Metanomics, a subsidiary of BASF, collaborating with Max Planck, invested approximately $ 25 million in a new facility in Berlin to work on plant genome research.

7.7 Genetic Markers

Marker genes allow selection of transgenic cells that can express improved traits. Marker selection systems currently use antibiotic or herbicide resistance marker genes. There has been much debate about antibiotic markers and concern expressed by the critics of biotechnology about their continued use. While antibiotic marker systems do not pose a risk to people, the private sector has devoted resources to develop alternatives to antibiotic resistance marker genes for future transgenic crops. In May 2000 Novartis announced the development of the marker Positech™, which is discussed in more detail in section 8.5.3. Positech™, is a mannose marker and a potential substitute for the more controversial antibiotic and herbicide markers. The marker is being incorporated by Novartis into maize and wheat and should be commercially available in 1 to 2 years. Novartis plans to make Positech™ available free for products used by resource-poor farmers. Rohm & Haas and Agritope agreed to develop a new marker system based on an ecdysone receptor and ligand inducer chemistry that results in a visible pigment in transformed cells. Again this marker is designed to be a substitute for the controversial antibiotic and herbicide markers and can be removed before commercialization.

7.8 Regulation & Marketing

To decrease probability of export from the US of GM corn not approved in the European Union, Pioneer postponed the release of six hybrids with stacked genes for *Bt* and Liberty Link (LL) which have not yet been approved in the countries of the EU. However, the same *Bt* and LL genes have been approved in the EU when incorporated as single genes on their own and these hybrids are being commercialized in the US. Aventis announced that it will introduce Liberty Link (LL) canola in the USA in 2000, when three varieties will be released. Subject to approval, Aventis plans US release of LL cotton in 2003, and LL/*Bt* cotton in 2004/2005.

Table 15. Selected Highlights of Crop Biotechnology Developments in Industry in 2000

Month	Year	Corporations Involved and Nature of Development
January	2000	**Eocene** acquired **Mycogen's** *Bt* pesticides and a license to some of Mycogen's *Bt* genes.
January	2000	**DuPont** and **Monsanto** agree that specific DuPont glyphosate products and mixtures can be applied on RR cotton and RR soybeans.
January	2000	**Agricultural Information Technology (AIT)** agrees to market test GM maize kits developed by **Strategic Diagnostics (SDI**). The kits are for detection of Cry1A (b) in Monsanto's MON810 and Novartis' *Bt* 11 constructs.
January	2000	The genomics company **Novalon Pharmaceutical Corporation** and **Novartis Research Foundation** sign a non-exclusive agreement that provides access to Novalon's BioKey genomic assays for herbicides and fungicides.
February	2000	The genomics company **Paradigm Genetics** and **Monsanto** sign $55 million agreement to analyze gene sequencing, bioinformatics and functional genomics data from Monsanto.
February	2000	**Agrinomics** (joint venture of **Aventis Crop Science and Agritope**) signs $7.5 million agreement with **Vilmorin, Clause and Cie.** (France) and the **Biotech MAM Plant Genomic Fund of Israel** to breed vegetables with improved resistance to bacterial diseases, nematodes, viruses and better tolerance to drought.
March	2000	In a strategy mirroring its competitors, **BASF** is to invest more than 700 million Euros, ($ 680 million) over the next 10 years in crop biotechnology, with additional capital to be provided for the acquisition of seed companies. The new subsidiary, **BASF Plant Science** will be separate from agrochemicals.
March	2000	Merger between **Monsanto** and **Pharmacia** receives final approval from the European Commission.
April	2000	**Monsanto** unveils the first "working draft" of the rice genome and provides arrangements for accessing the information.

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Table 15. Cont'd. **Selected Highlights of Crop Biotechnology Developments in Industry in 2000**

Month	Year	Corporations Involved and Nature of Development
April	2000	**RhoBio** (joint venture between **Aventis and Biogemma**) and **Entomed** agreed to develop insect peptide products for control of fungal and bacterial pathogens. RhoBio will utilize the genes in GM crops. Compared with other active ingredients, it is speculated that resistance to peptides is less likely to develop.
April	2000	**Council for Biotechnology Information (CBI)** was formed in the USA by **Aventis, BASF, BIO, Dow, DuPont, Monsanto, Novartis, and Zeneca** to support a 3-5 year $ 50 million public information campaign to publicize the benefits of agricultural biotechnology.
May	2000	**Monsanto** announces an initial public offering (IPO) equivalent to 19.9% of its stock – the remaining 80.1% of Monsanto stock will be retained by its parent company, **Pharmacia.**
May	2000	**Novartis** announces **Positech™** which is a mannose marker and a potential substitute for the more controversial antibiotic and herbicide markers. The marker is being incorporated by Novartis into maize and wheat and should be commercially available in 1 to 2 years. Novartis plans to make Positech™ available free for products used by resource-poor farmers.
May	2000	**Aventis** introduced **Liberty Link (LL) canola** in the USA with plans to release three varieties. Subject to approval, Aventis plans US release of LL cotton in 2003, and LL/*Bt* cotton in 2004/2005.
June	2000	**BASF Plant Science** and **Omniviz** sign a 3-year agreement to analyze genomic data. BASF Plant Science is a joint venture with **Svalof Weibull** of Scandinavia.
July	2000	Merger of **Novartis** and **Zeneca** to form **Syngenta** cleared by the European Commission.
July	2000	**Aventis Crop Science, Archer Daniels Midland and SKW Trostberg AG** established a $ 30 million venture capital fund with **Burrill & Company** to support development of neutraceuticals.

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Table 15. Cont'd. **Selected Highlights of Crop Biotechnology Developments in Industry in 2000**

Month	Year	Corporations Involved and Nature of Development
August	2000	**Monsanto IPO** is likely to include a smaller (13.7%) than expected percentage (19.9%) of the 255 million shares valued at $ 20 to $ 25/share. Monsanto turnover in 1999 was $ 5.2 billion, increasing by 6% to $3.3 billion in the first six months of 2000.
August	2000	**Dow AgroSciences** acquired the Brazilian seed company, **Empresa Brasileira de Sementes (EBS)** which specializes in maize and sorghum. Dow's holdings in seeds/biotech in Brazil increases to 5 acquisitions including **EBS, Hibridos Colorado, FT Biogenetica, Hibridos Hata and Dinamillo.**
August	2000	**Zeneca** and **GeneData AG** will collaborate in genomics, more specifically the analysis of data from gene expression arrays to decrease crop losses due to weeds, insects and diseases.
August	2000	**Affymetrix** develops **GeneChip Arabidopsis Gene Array**. The GeneChip is capable of analyzing the expression of over 8,000 Arabidopsis gene sequences. The Arabidopsis Genome Array was co-developed by **Affymetrix** and **Novartis.**
September	2000	**Mycogen Seeds,** wholly owned by **Dow Chemical** acquired **Cargill's** North American seed operations. This makes **Dow/Mycogen** the third largest maize seed producer in the USA with total seed sales of approximately $ 300 million in 1999.
September	2000	**Rohm & Haas** and **Agritope** agreed to develop a new marker system based on an **ecdysone receptor** and **ligand inducer chemistry** that results in a visible pigment in transformed cells. The marker will be a substitute for the controversial antibiotic and herbicide markers and can be removed before commercialization.
September	2000	**Aventis** announces that the joint pharmaceutical/agriculture life sciences approach may not be an appropriate business model with one of the options being to spin off the agricultural business as an IPO.
September	2000	**Australia** approves **Monsanto's RR cotton** for commercial production. Bt cotton has been grown commercially in Australia since 1996 and occupies 150,000 hectares in 2000.

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Table 15. Cont'd. **Selected Highlights of Crop Biotechnology Developments in Industry in 2000**

Month	Year	Corporations Involved and Nature of Development
September	2000	**Starlink**, an **Aventis** *Bt* maize product is only approved by the FDA in the US for feed use, and not for food. **Aventis Crop Science** halts the sales of Starlink *Bt* maize seed following detection of Starlink maize in taco shells in the USA. Aventis will fund a USDA program to purchase Starlink maize grown on 128,000 hectares in the USA in 2000, an area equivalent to only less than 1% of US maize area.
September	2000	**Dow Chemical** and **EPIcyte Pharmaceuticals** will develop monoclonal antibodies from plants. Plant-derived antibodies can be produced more cost-effectively and will be used eventually as antibody-based products for the prevention and treatment of infection in animals and in food safety applications.
September	2000	**Metanomics,** a subsidiary of **BASF,** collaborating with M**ax Planck,** invests approximately $ 25 million in a new facility in Berlin to work on plant genome research.
September	2000	**BASF** licenses the non-transgenic mutation-bred trait that confers tolerance to the herbicide imidiazolinone (IMI) to **Dow AgroSciences/Mycogen** for use in maize. The IMI trait was developed by Cyanamid, which was acquired by BASF earlier in 2000. The IMI trait may be incorporated through conventional breeding along with transgenic traits such as Bt genes, owned by Mycogen, or in conjunction with a broader based transgenic insect resistance under development by **Dow AgroSciences.**
November	2000	**Aventis** will divest its agricultural holding, **Aventis Crop Science** before the end of 2001. One option is an IPO called **AgrEva.**
November	2000	**EraGen** will provide **Novartis** with "An Expanded Genetic Information System"**(AEGIS**) to identify Single Nucleotide Polymorphisms (**SNPs**) in plants from the same crop species. The identification of SNPs in genes will allow the development of crops with improved traits that contribute to yield and resistance to abiotic and biotic stresses.

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Table 15. Cont'd. **Selected Highlights of Crop Biotechnology Developments in Industry in 2000**

Month	Year	Corporations Involved and Nature of Development
November	2000	"**New Monsanto Pledge**" commits company to dialogue, transparency, respect, sharing and delivering of benefits and environmental responsibility. Noteworthy is a commitment not to commercialize GM crops in the US until full food and feed approval in the US and Japan, with option of including Europe later. **Monsanto** also undertakes not to use animal or human genes in GM crops, not to develop sterile gene technology and will establish an external **Biotechnology Advisory Council**.
December	2000	**Monsanto**, the **Tata Energy Research Institute (TERI)**, Delhi, India, and **Michigan State University**, USA, will collaborate to develop Golden Mustard, with oil high in beta-carotene (precursor to Vitamin A). The project is being funded by **USAID.**
December	2000	A Presidential decree ratifies a law in Brazil that confers authority on the National Technical Commission on Biosafety (CTNBio) to approve commercialization of GM crops. CTNBio approved **Monsanto's** RR soybean in 1998 but the authority of CTNBio was challenged and approval delayed. Subject to the approval of Congress, this December 2000 decision could lead to commercialization of RR soybeans in Brazil in 2002, and also open up opportunities for *Bt* maize and *Bt* cotton that are also under consideration by CTNBio.
December	2000	To decrease probability of export from US of GM corn not approved in **EU**, **Pioneer** postpones the release of 6 hybrids with stacked genes for *Bt* and LL which have not yet been approved in EU. However the same *Bt* and LL genes have been approved in EU when incorporated as single genes on their own and these hybrids are being commercialized in the US.
December	2000	**BASF Plant Science** acquires **ExSeed Genetics** (US) which has expertise in nutritionally enhanced corn – high oil, protein and amino acid for animal feed as well as starch enhancement in corn grain crops and potatoes.

Source: Compiled by Clive James from various sources, 2000.

In summary, 2000 was a year when the biotechnology industry took a breather after several years of heavy investment, which led to consolidation and the creation of a few large life science companies. The major feature of 2000 was that several of the major companies decided that the life sciences strategy of managing pharmaceuticals and agriculture within the structure of one company may not offer as many advantages as first thought and may not be the best business model for the future. Thus, companies initiated the spinning off of agricultural components and simultaneously looked for opportunities to link up with like-partners in agriculture to create the complementarity and critical mass necessary for cost-effective operation of a company in the global seed market. Alliances were used as a mechanism to cost-effectively strengthen in-house operations with essential external inputs in collaborative mode. Genomics continued to attract new investments and is likely to continue to be pivotal in research and development for the near to mid-term. Initiatives such as Golden Rice offered industry an opportunity to collectively participate as global corporate citizens in a high profile philanthropic project that could contribute more nutritious food for millions of sick and poor people in the developing countries - this reflected well on industry and is one of many opportunities where the private sector, at modest cost, can play a unique role through donating proprietary technology that can contribute to global food security and the alleviation of poverty.

8. SELECTED HIGHLIGHTS FOR TRANSGENIC CROPS

This section reviews some of the highlights for transgenic crops since publication of the last ISAAA Global Review of Transgenic Crops (James 2000a). The literature on transgenic crops has grown logarithmically and hence this brief review of highlights is selective. Items have been selected that are of particular interest to ISAAA's partners in the developing countries of the South, and are discussed under the six following topics:

- Status of approvals for commercialization of transgenic crops
- Biosafety
- Food-feed import regulations
- Genome sequencing
- Sharing of proprietary transgenic technology with developing countries
- Selected highlights re transgenic crops in developing countries
- Documentation of statements and reports by politicians, policy makers, national programs and organizations that reflect a broadening political and institutional support for crop biotechnology and a recognition of its increasingly important contribution to global food security and a more sustainable agriculture.

8. 1 Status of Approvals for Commercialization of Transgenic Crops

8.1.1 EPA approves re-registration for *Bt* cotton and *Bt* corn

In October 2001 the Environmental Protection Agency (EPA) extended registration for *Bt* cotton for five years, and *Bt* corn for seven years. The decision to extend registration for these two products follows nearly two years of extensive scientific review and evaluation of all commercialized *Bt* plant-incorporated protectants (PIPs), consultation with independent scientific experts on key issues, and consideration of public comments.

On October 2, 2001, EPA extended the conditional registration of *Bt* cotton. According to EPA Administrator Stephen Johnson, "There has been extensive public input in the review process, and the outcome is a registration that safeguards important environmental concerns while providing cotton growers with a significant option to meet their pest-control needs." On October 16, 2001, EPA approved re-registration for *Bt* corn and Johnson stated "*Bt* corn has been evaluated thoroughly by EPA, and we are confident that it does not pose risks to human health or the environment... The safeguards incorporated into these registrations will ensure that farmers can continue to use an effective, low-risk pest control alternative, which helps to protect the environment by reducing the amount of conventional pesticides used." More information on EPA's *Bt* cotton and *Bt* corn reassessments is available at (EPA 2001) website: <http://www.epa.gov/pesticides/biopesticides/reds/brad_*Bt*_pip.htm

According to Val Giddings, Biotechnology Industry Organization (BIO) Vice-President for Food and Agriculture, "*Bt* corn is an important tool for food producers that can increase crop yields and protect the environment by reducing the use of conventional pesticides. The EPA's approval of continued use for these products sends a strong signal to the rest of the world that these products are safe and offer significant benefits for growers, consumers and the environment. Of particular importance is the finding that there is no scientific evidence that *Bt* corn impacts Monarch butterflies. We hope this lays to rest this 'urban myth'." The complete BIO statement (BIO, 2001) is available at: http://www.bio.org/newsroom/newsitem.asp?id=2001_1016_01

The National Corn Grower's Association (NCGA) in the US noted that "EPA approval of *Bacillus thuringiensis* (*Bt*) for an additional seven years is a dual win for corn growers." In a NCGA press release, Leon Corzine, a NCGA Biotech working group member and corn grower said the decision was a win for the science-based regulatory system that gives growers access to the technology and that the EPA's Insect Resistance Management (IRM) requirements are based on the initial guidelines NCGA developed with EPA. More information about NCGA and biotechnology (NCGA 2001) is available at their website: http://www.ncga.com

8.1.2 StarLink corn

In September 2000, the presence of a product, StarLink corn, was found in the US in a Kraft food product, Taco Bell tortillas. The event initiated a voluntary recall of all products containing StarLink corn. StarLink corn is a transgenic product of Aventis CropScience and contains the gene protein Cry9C, derived from *Bacillus thuringiensis* that confers resistance against important corn insect pests such as European corn borer. While other varieties of corn have been approved in the US with a *Bt* gene, and grown commercially to confer pest resistance, StarLink corn varieties were the only ones containing Cry9c protein grown commercially. StarLink was grown on only approximately one–half of one percent of all corn acreage in the US in 2000; it was the only *Bt* corn variety approved for use in animal feed without concurrent approval for use in foods for human consumption. While there are no known health risks associated with Starlink there were some questions about its allergenic potential that remained unanswered. The product is no longer offered for sale and the registration for StarLink corn has been withdrawn. Further information can be found on the CAST 2000 website. www.cast-science.org/biotechnology/20000925.htm

The Environmental Protection Agency's Scientific Advisory Panel (SAP) meeting was held in July 2001 to evaluate the latest information available on StarLink corn. The final report reaffirmed previous conclusions of the panel and provides new recommendations. The panel still concluded that there is a "low probability of allergenicity" in the exposed population based on levels of StarLink corn in the US diet. The Panel endorsed EPA's conclusion that the process of wet-milling corn removes almost all of the Cry9C protein from products made by that process. Also, the panel stated that there was not enough information to establish a scientific certainty that exposure would not be harmful to public health and they could not establish a specific tolerance level for Cry9C. Therefore, based on the panel's recommendations, establishing a tolerance for StarLink in human food products was not supported. The SAP also agreed with EPA estimates that StarLink corn will essentially be eliminated from the US corn grain supply by 2002 (EPA 2001b). http://www.epa.gov/oppbppd1/biopesticides/index.htm

Based on the experience with StarLink corn, the following protocol now applies: the USEPA will only grant biotech product registrations if tolerance exemptions for plant incorporated protectants (PIPs) for both food and feed are scientifically supported. It has also been proposed that: USEPA require that testing methods for detection of PIPs, be validated in grain and processed fractions, and be available prior to registration; and that USDA establish laboratories to validate commercially available methods for detecting PIPs in commodity grains intended for both internal trade and export. The PIP rule effective September 2001 clarifies that the DNA of PIPs is exempted from the requirement of tolerance.

8.1.3 New approvals for growing and commercializing transgenic crops

Both the number of countries growing transgenic crops and the number of products approved for commercialization continue to grow, reflecting the confidence and growing trust of national programs, farmers and the public in the new technologies. In 2000 Uruguay introduced herbicide tolerant soybean. In Eastern Europe, Bulgaria grew a transgenic crop, herbicide tolerant corn, for the first time in 2000, becoming the 15th country to grow commercial transgenic crops globally. Indonesia, the third most populous country in Asia planted a commercial transgenic crop for the first time in 2001, deploying 4,000 hectares of *Bt* cotton in South Sulawesi.

It is noteworthy that two of the most populous countries in Asia, China and Indonesia, are already growing *Bt* cotton with the third, India, expected to commercialize the same product early in 2002. It is not insignificant that the combined population of these three countries alone, totals 2.5 billion, over 40% of world population, and that millions of farmers in these countries will gain significant agronomic, economic and environmental/health benefits from adopting *Bt* cotton. In August 2001, Argentina expanded its portfolio of transgenic crops to three by approving the commercial planting of herbicide tolerant cotton by farmers for the growing season 2001/2002. The approved cotton product is tolerant to the broad-spectrum herbicide glyphosate. There are now seven countries growing transgenic cotton in the world and this number is expected to increase significantly over the next five years.

8. 2 Biosafety

8.2.1 Monarch butterflies and *Bt* corn

Premature speculation and extrapolations by critics of biotechnology regarding the work reported two years ago by Losey and co-workers (Losey et al 1999) led to very damaging and much publicized alarming inferences that caterpillars of monarch butterflies were being poisoned and killed by pollen from commercial *Bt* maize planted in the USA (Anonymous 2001b). A recent set of six papers published by the US National Academy of Sciences (Hellmich *et al* 2001, Oberhauser *et a*l 2001, Pleasants *et al* 2001, Sears *et al* 2001, Stanley-Horn *et al* 2001 and Zangerl *et al* 2001) collectively conclude that contrary to the earlier claims, *Bt* maize planted in the USA is not a threat to monarch butterflies feeding on milkweed on which corn pollen is deposited. More specifically, there were five principal findings in the set of six papers supporting the finding that *Bt* corn pollen is not a threat to monarch butterflies. Firstly, with the possible exception of one *Bt* event (which only occupied 2% of *Bt* maize in the USA, and is now being withdrawn from this market for other reasons), commercially grown corn in the US does not pose a significant hazard to monarch caterpillars (Hellmich *et al* 2001). Secondly, it has been shown (Pleasants *et al* 2001) that corn pollen tends to accumulate on the middle leaves of milkweed, whereas monarch caterpillars tend to feed on the upper leaves. Thirdly, this lower density of *Bt* pollen on the upper leaves did not result in any toxicity in caterpillars (Sears *et al* 2001). Fourthly, the current practice of applying broad spectrum insecticides to control insect pests of corn was recognized to have the same potential to affect monarchs as other technologies including transgenic crops (Oberhauser *et al* 2001). Lastly, the destructive effect of broad spectrum insecticides was confirmed by Stanley-Horn *et al* 2001, who showed that the current and widely used corn insecticide, lambda-cyhalothrin, has, unlike *Bt* corn, a damaging effect on monarch butterflies. Collectively, the results from the set of six papers confirm the EPA's original evaluations of the potential risks posed by *Bt* corn to non-target butterflies and moths (Ortman *et al* 2001).

With regard to *Bt* corn impacting on other potential non-target organisms, EPA also had conducted routine risk assessments of ecological toxicity, which included avian species (quail), aquatic species (catfish and daphnia), beneficial insects (honeybee, parasitic wasp, green lacewing, ladybird beetle), soil invertebrates (springtails and earthworms) and mammals (mice) (USEPA 1995, 2000, 2001). These tests provide a basis for assessing potential toxicity to non-target species and indicator organisms, and serve as a basis for developing longer-term studies (Ortman *et al* 2001).

In a parallel development, a group of 22 eminent corn entomologists and ecologists recently wrote a collective letter to the editor of Bioscience (Ortman *et al* 2001) disagreeing with some of the conclusions of an earlier paper (Obrycki 2001) in Bioscience, which was critical of *Bt* corn. The group of scientists noted that the scientific community has rigorously examined the risks and benefits of *Bt* plants more than any other biotechnology application, as is evident from the vast literature, scientific discussions, and numerous public meetings facilitated by the U.S. EPA, the U.S. Department of Agriculture (USDA) and the U.S. Food and Drug Administration (FDA) on this subject.

The 22 scientists reported that "the evidence to date supported the appropriate use of *Bt* corn as one component in the economically and ecologically sound management of lepidopteran pests." The group concluded that the performance of *Bt* corn had validated earlier positive EPA assessments of the technology and stressed that the positive and negative effects of new technologies must be compared to current best practice and cautioned about rejecting technologies simply because they are new. A recently published paper (Shelton and Sears 2001) reflects on the scientific interpretations of the monarch butterfly controversy. The authors conclude that "we believe a retrospective view may be useful for providing insights into the proper roles and responsibilities of scientists, the media and public agencies and the consequences when they go awry."

The lessons to be learnt from the monarch butterfly experience are that inferences about the impact of new technologies at the field level are premature if based on extrapolation from laboratory experiments, and that any such claims should be verified in the field before reaching conclusions. Further, this misleading information can result in long lasting and permanent damage which can delay or preclude the deployment of a useful technology such as *Bt* corn that offers society significant environmental and crop production benefits. *Bt* corn offers significant real benefits to ecosystems and human health, including those from a reduction in use of more broad-spectrum foliar insecticides, (AMA 2000a, APS 2001a, NAS 2000a).

8.2.2 EU launches Round Table on Biotech Safety Research

In October 2001, the European Commission (EC) launched a round table on safety research of GMOs (genetically modified organisms) (EU 2001a). The round table brought together European biosafety researchers and other stakeholders including consumer organizations, national administrations and industry. The round table also aimed to raise the voice of science in the biotech debate by establishing an ongoing discussion forum on research related to benefits and risks of biotech crops. According to the European Commission press release on this initiative, "Research on GM plants and derived products so far developed and marketed, following usual risk assessment procedures, has not shown any new risks to human health or the environment, beyond the usual uncertainties of conventional plant breeding. Indeed, the use of more precise technology and the greater regulatory scrutiny probably make them even safer than conventional plants and foods."

The EC also published a report that reviews the past 15 years of EC-supported biosafety research. The report covers 81 projects conducted from 1985 to 2000 involving over 400 teams from different disciplines (EU 2001a). The release is available at: http://www.europa.eu.int/rapid/start/cgi/guesten.ksh?p_action.gettxt=gt&doc and the complete report at http://europa.eu.int/comm/research/quality-of-life/gmo/index.html

8. 3 Food-Feed Import Regulations

8.3.1 EU Proposals for regulations on labeling and traceability of GM crops and GM food and feeds

In July 2001, the European Commission proposed an important legislative package on genetically modified organisms (GMOs) which would establish a community system to trace and label GMOs and to regulate the placing on the market and labeling of food and feed products derived from GMOs. The new legislation is intended to further strengthen the regulation of GMOs, and processed GM food and GM feed to enhance European consumers' confidence in the technology. The package consists of a proposal for traceability and labeling of GMOs and traceability of products produced from GMOs and a second proposal regulating the authorization and labeling of GM food and feed. It would require the traceability of GMOs throughout the chain from farm to table and the labeling of all food and feed consisting of, containing or produced from a GMO. It will establish a "one door one key" procedure for the authorization of GM products for food and feed use, including their use in the environment. This procedure will consist of a single scientific assessment, carried out by the scientific committees of the European Food Authority. The new system as proposed ensures a tight and stringent regulatory framework on the use of GMOs in Europe by closing existing legal gaps. It meets the requests by Member States governments and consumer organizations and has been drafted in dialogue with all stakeholders and Member States. These proposals are subject to co-decision with the European Parliament and the Council and should enter into force in 2003 at the latest. The labeling provisions in respect of food and feed will be reviewed after two years of operation. Further details (EU 2001b) can be found at the website http://europa.eu.int/comm/press_room/index_en.cfm

Several governments including those of Argentina and the United States and the United Kingdom Foods Standards Agency have raised serious concerns about the Commission's proposals on labeling and traceability, including their enforceability, practicality, cost and their potential impact on international trade.

8.3.2 EU and Japan proposing 1% adventitious presence of GM grain

In August 2001, the Japanese Ministry of Agriculture proposed a 1% threshold for genetically modified ingredients in imported animal feed, providing these have been approved in the exporting country. In the European Commission's legislative proposals, a similar threshold has been proposed for the adventitious presence of genetically modified components in food and feed, provided that the GM product has undergone review by a scientific committee in the EU. For more details see (EU 2001c) and (USDA 2001): http://europa.eu.int/comm/press_room/index_en.cfm; and USDA, 20001) http://www.fas.usda.gov/scriptsw/attacherep/default.asp

8.3.3 Japan – New Regulations

As of August 2001, Japan had approved 37 biotech varieties for food use. New legislation went into effect on April 1, 2001 which made it illegal to import products for food use which contain biotech varieties which are not yet approved in Japan. The Ministry of Agriculture, Forestry and Fisheries (MAFF) is responsible for environmental safety approvals, feed safety approvals and biotech labeling for foods. On April 1, 2001, MAFF established a labeling scheme which requires labeling for biotech food products if the biotech DNA or protein can be scientifically detected in the finished foods. Biotech advisory labels for the 24 products covered under this program are mandatory if the biotech content exceeds 5%.

8. 4 Genome Sequencing

8.4.1 Rice

Three billion people are dependent on rice as their major staple; by 2020 this figure will increase to 4 billion people, more than half the world population. The challenge of ensuring food security through increased rice production can be greatly accelerated and facilitated by biotechnology, particularly through genomics, which is pivotal to improving the understanding and application of rice genetics in crop improvement programs using tools of both transgenic and molecular breeding. Because of the relatedness of the rice genome to those of the other cereal grasses, it is also expected that research and improvement in corn, wheat, sorghum, millets, etc., will also benefit enormously. This will allow crop improvement programs to develop varieties that are more nutritious and more productive. It will also allow the development of more effective and durable means of protecting crops against diseases and pests.

In April 2000, Monsanto announced that the rice genome sequence had been decoded to the level of a "working draft," providing basic information on the structure and location of almost all the genes in rice. This was the first time a crop genome was characterized at this level and should lead to a better understanding of rice genetics and to an acceleration in the development of improved and higher yielding rice varieties. The sequencing project was undertaken by Dr. Leroy Hood of the University of Washington Seattle under contract to Monsanto.

Monsanto has generously made its rice genome sequence data and the supporting materials and files available to the International Rice Genome Sequencing Project (IRGSP) - an 11 member public sector global consortium led by the Japanese Ministry of Agriculture, Forestry, and Fisheries. Based on the availability of the Monsanto data, the Japanese Rice Genome Project has taken on the sequencing of three additional rice chromosomes. The IRGSP has announced an important acceleration of the project overall and now expects to complete at least a Phase II coverage of the whole rice genome by the end of 2002. Large amounts of the Monsanto sequences, combined with new sequences from IRGSP members, have now been deposited in the public databases by IRGSP members. In support of the acceleration of the project, Monsanto has continued to supply its updated results to the IRGSP.

Monsanto has made its rice genome sequence data broadly available to public researchers around the world. In June 2000, the www.rice-research.org Internet web site was launched, through which Monsanto shares its draft sequence of the rice genome with public researchers. More than 700 researchers have registered to access Monsanto's draft rice genome data via this site. A number of research reports have already been published by scientists using the Monsanto data and these scientists have deposited the relevant sequences in public databases as part of their publications. In October 2000, Monsanto announced the release of another important set of rice genome sequence data that can be used to identify genetic traits in rice. These new data, consisting of approximately 6,700 sequence files derived from draft genome sequence, and known as Simple Sequence Repeats (SSRs), are expected to be used to expand knowledge of rice genetics and to accelerate breeding research in rice around the world. The data file (Monsanto 2000) has been posted on Monsanto's external rice genome sequence web site (www.rice-research.org). These SSR data may be downloaded easily from the rice-research.org database or from GenBank.

In January 2001, the Torrey Mesa Research Institute (TMRI), the genomics research center of Syngenta, announced that it had completed the Rice Genome Map in collaboration with Myriad Genetics Inc. This is the first crop plant genome of significance to be completed at this level of detailed information. In addition to finding the DNA sequence of virtually every gene, TMRI has undertaken an analysis of gene expression and of rice proteins. Because rice is a model for other cereals, the knowledge from this genome map will lead to opportunities for other improved staples. As well as the DNA sequence, the new information includes the regulatory DNA sequences controlling gene activity and the location of most of the genes. A more detailed analysis of gene activity and function and the resulting proteins is underway. Thus, the initiative has not only identified the genes, but their functions and how they work. Syngenta is making the information available to the public sector through collaborative agreements with academia. For the developing world, where rice is a vital crop, Syngenta is working with local research institutes to explore how this information can best be used to support improvement programs to benefit subsistence farmers.

Syngenta's generous policy is to provide such information and technology for use in products for subsistence farmers, without royalties or technology fees. Syngenta has supported the public release of rice genome sequence information. Over 100,000 sequences from its program with the Clemson University Genome Institute (CUGI) have been posted on the CUGI website.

8.4.2 *Arabidopsis*

Arabidopsis thaliana is an important model plant for genomic research. It is the first plant genome to be completely sequenced and opens the way for characterizing gene functions and for establishing rapid systematic methods to identify genes for crop improvement. The *Arabidopsis* genome sequence has been completed after years of research and collaboration globally. An article in Nature highlights this key milestone and other plant genome sequencing efforts (Institute for Genomic Research 2000). A special issue of Plant Physiology is solely devoted to *Arabidopsis*. Six articles in the issue review "Resources and Opportunities" for *Arabidopsis* genome research. http://www.plantphysiol.org/content/vol124/issue4/

8.4.3 *Agrobacterium tumefaciens*

The genome sequence for *Agrobacterium tumefaciens*, a bacterium that can naturally transfer DNA to plant cells, has been released by two groups of scientists working in public and private sector collaborative projects. One group is comprised of researchers from Hiram College, OH, the University of Richmond, VA, and Monsanto. A second group (with partial funding from the National Science Foundation) is made up of researchers at the University of Washington School of Medicine, MO, the University of Campinas, Brazil, and DuPont. The Monsanto/U. Richmond/Hiram College group (Genomes Group 2001) made their genome available at the National Center for Biotechnology Information (NCBI) at the US National Institutes of Health (http://www.ncbi.nlm.nih.gov/PMGifs/Genomes/micr.html). The U. Washington/U. Campinas/DuPont group made their sequence available at www.agrobacterium.org. The two groups are now coordinating journal publications and a comparison of the independently derived sequences.

8. 5 Sharing of Proprietary Transgenic Technology with Developing Countries

There are many collaborative projects among national and international public research institutions and companies through which biotechnology applications and knowledge developed in the private sector are being donated or shared on a royalty-free or humanitarian basis for the benefit of developing countries. These projects have been developed during the last decade and details can be found in various publications (James 2001, MSU 2001, and ADB 2001). As a part of the New Monsanto Pledge launched in November 2000, Monsanto has committed to share its knowledge and technology with public institutions, not for profit groups and local industry around the world, to benefit farmers in the developing world, to help improve food security and protect the environment (www.monsanto.com). The Monsanto Technical Cooperation program includes half-dozen collaborative agricultural biotechnology research projects around the world.

The Syngenta Foundation for Sustainable Agriculture (Syngenta Foundation 2001) was launched in October 2001. The new Foundation supports research projects on sustainable food security in the poorest regions of the world. The Foundation is currently promoting three projects in Sub-Saharan Africa with focus on food supplies grown by small farmers. Professor Klaus M. Leisinger, Acting Director of the Foundation, views the aim of the foundation-sponsored work as developing and supporting existing efforts, enabling people to eventually carry out such initiatives on their own (www.syngenta.com). In addition Syngenta Seeds supports several biotechnology projects in which proprietary technology has been donated to several organizations for the use of subsistence farmers in developing countries.

Several specific examples of biotechnology transfer projects featuring donation of proprietary technology that have been developed during the last year or so are listed below.

8.5.1 'Golden Rice'

Vitamin A is an important nutrient and essential for good health, particularly in children. Vitamin A deficiency (VAD) can cause irreversible blindness and death, mainly in children. In Southeast Asia it is estimated that five million children develop symptoms that can lead to blindness every year. VAD can be equally important in some areas of Africa, Latin America and the Caribbean. Globally, around 500,000 children become irreversibly blind as a result of VAD annually. According to UNICEF, an estimated 124 million children worldwide suffer from Vitamin A Deficiency. Improved Vitamin A nutrition could prevent approximately 1 to 2 million deaths annually among children aged 1-4 years, and an additional 0.25 to 0.5 million deaths during later childhood.

'Golden Rice' is a transgenic rice containing beta-carotene and other carotenoids, precursors of Vitamin A, and is one potential solution to VAD. Alternative VAD alleviation strategies include improved diet, through the intake of green vegetables and animal products, or the use of vitamin pills. The inventors of 'Golden Rice' are Professor Ingo Potrykus of the Institute for Plant Sciences, Swiss Federal Institute of Technology (ETH), Zurich, Switzerland, and Professor Peter Beyer of the Centre for Applied Biosciences, University of Freiburg, Germany. The 'Golden Rice' technology was developed with funding from the Rockefeller Foundation (1991-2002), the Swiss Federal Institute of Technology (1993-1996), the European Union under a

European Community Biotech Programme (1996-2000) and the Swiss Federal Office for Education and Science (1996-2000). In 2000, the inventors explored ways in which golden rice could be donated for humanitarian purposes to alleviate poverty in countries of the Third World.

The further development of 'Golden Rice' for humanitarian purposes is being facilitated as a result of the granting of intellectual property licenses from the following corporations, listed in alphabetical order, Bayer, Monsanto, Orynova, Syngenta and Zeneca Mogen. Each company licensed free-of-charge technology used in the research, which led to the 'Golden Rice' invention. Subject to further research, initially in the developing countries of Asia, as well as the granting of local regulatory clearances, 'Golden Rice' can then be made available free-of-charge for humanitarian uses in any developing nation.

In January 2001 samples of 'Golden Rice', were provided to the International Rice Research Institute (IRRI) in Los Baños, Philippines. IRRI scientists have begun research, which is part of an international program to investigate the safety and utility of 'Golden Rice' in combating Vitamin A Deficiency (VAD). IRRI will conduct necessary research and testing using local varieties to explore the feasibility of eventually providing the world's millions of poor rice farmers and consumers with a more nutritious product in terms of vitamin A. In order to further expedite the introduction of 'Golden Rice' to developing countries, a 'Humanitarian Board' has been established, comprised of a number of public and private sector organizations. The Humanitarian Board has four principal aims: to support the inventors in making 'Golden Rice' freely available to those that need it, consistent with the highest standards of safety assessment; to ensure the proper investigation of 'Golden Rice' as one potential solution to Vitamin A Deficiency; to support individual developing countries and their national research institutes as they assess their interest in 'Golden Rice'; and to facilitate information sharing between 'Golden Rice' projects in different parts of the world. This is an excellent example of public-private sector collaboration. It should be encouraged and extended to provide developing countries with access to patented biotechnology applications that can provide more nutritious food to alleviate life-threatening diseases that afflict the poor and their children in countries of the Third World.

8.5.2 'Golden Mustard'

In December 2000, a collaborative project was launched between the not-for-profit Tata Energy Research Institute (TERI) in India, Monsanto and Michigan State University (MSU) to develop a 'golden mustard' that will yield cooking oil high in beta-carotene (pro-vitamin A). It is estimated that more than 18 percent of the children in India suffer some level of vitamin A deficiency. The World Health Organization estimates that approximately 250 million people suffer significant illnesses, including vision impairment, inability to absorb proteins and nutrients, and reduced immune function because of vitamin A deficiency. The project has potential to help hundreds of thousands of children suffering from vitamin A deficiencies, particularly in northern and eastern India, where mustard oil is commonly used for food preparation and cooking. Monsanto has been working since the mid-1990s to enhance the carotenoid levels of oilseed crops with a focus on the accumulation of beta carotene in the seed of canola/oilseed rape. Therefore, researchers have been able to achieve concentrations of beta-carotene in oil from crushed canola seed greater than currently available in any other oil or vegetable (Shewmaker et al 1999). In March 1999, Monsanto announced it would share this technology at no cost, and simultaneously joined a public and private sector partnership with the U.S. Agency for International Development (USAID) and the Global Vitamin A Alliance. In addition to technical and financial support from Monsanto, USAID is also funding the effort through a grant to MSU's Agricultural Biotechnology Support Project.

It is hoped that technology used to develop golden rice and golden mustard oil might one day be extended to other crops such as maize, a staple food in many African countries where vitamin A deficiency is also prevalent. Collectively, projects such as these can put biotechnology to work to improve the nutritional quality of staple foods grown and consumed by the poorest households. More information can be obtained from the Tata Energy Research Institute's (TERI 2001) home page at: http://www.teriin.org

8.5.3 Positech™ - A new marker system, based on mannose

Marker genes allow selection of cells that can express improved traits. Marker selection systems currently use antibiotic or herbicide resistance marker genes and a chemical to eliminate unwanted cells. Much has been written about antibiotic markers and concern expressed by the critics of biotechnology about their continued use. Whereas antibiotic marker systems do not create a risk to farmers or consumers, such systems are often confused with antibiotic use in healthcare. In May 2000 Novartis, now Syngenta, announced the development of Positech™, a new marker system. Positech™ provides a selection system based on a marker gene that enables plant cells to use a simple sugar (mannose) to grow and form new plants. Positech™ is an alternative to antibiotic resistance genes as markers in future transgenic crops. Novartis made a commitment to phase out the use of antibiotic resistance marker genes wherever possible. Positech™ has been used successfully in cassava. Novartis has indicated that Positech™ will be provided free for use in products for subsistence farmers provided that appropriate regulations are in place to confirm user and consumer safety and protect local environments for crops modified using Positech™.

8.6 Selected Highlights in Transgenic Crops in Developing Countries

8.6.1 China – Bumper cotton production expected in 2001 following widespread adoption of *Bt* cotton and favorable weather

USDA claims that cotton yields in China have been increasing due to widespread adoption of insect-resistant transgenic *Bt* cotton varieties. High adoption of high yielding *Bt* cotton and favorable warm weather are expected to push China's cotton yields to an estimated 23 million bales in 2001. This forecast by the US Department of Agriculture (USDA) suggests that this might result in the largest cotton yield in ten years in China. The expected production for 2001/02 is forecast to be as high as 2.7 million bales more than last year's harvest.

8.6.2 South Africa reaffirms its commitment to biotechnology

South Africa is the only country on the continent of Africa to commercialize transgenic crops. It currently grows *Bt* cotton, which is of particular importance to small farmers in the Makhatini Flats of KwaZulu Natal Province, yellow *Bt* corn for feed, and plans to add white *Bt* corn for food to its selection of transgenic crops in 2001. The South African government has reaffirmed its commitment to biotechnology in agriculture and medicine. The South African Department of Arts, Culture, Science and Technology (DACST) have published a biotechnology strategy document. The director-general of DACST, Dr Rob Adam, emphasized the important contribution that biotechnology can make to food security and environmental sustainability. The project manager of the South African National Seed Organization, Dr. Wynand van der Walt, also stressed the importance of biotechnology to South African agriculture and indicated that the country needs to capitalize from the recent advances in genomics.

South Africa's recently published draft policy for biotechnology allocates R45 million (US$ 4.5 million) for the overall biotechnology strategy and R182 million ($ 18.2 million) for biotechnology research. The draft policy has the support of the Farmers Union which views the strategy as an important step for ensuring that biotechnology in South Africa meets the economic, political, and social needs and conditions of the nation.

The draft policy states that biotechnology will improve access to and affordability of food and provide sufficient nutrition at affordable costs, create jobs in manufacturing, and protect and enrich the environment. The draft strategy which has the support of the country's Department of Agriculture, provides for the mandatory labeling of GM food and products, including specifications with regard to the composition, mode of storage, levels of allergens and toxins, and guidelines regarding human and animal genes. AfricaBio is an organization that focuses on biotech applications of food, feed and fiber; and it seeks to provide information and guidance in all aspects of crop biotechnology. AfricaBio collaborates with ISAAA in the dissemination of knowledge on crop biotechnology. (AfricaBio 2001a. www.africabio.com).

In the 1999-2000 season, small farmers planting *Bt* cotton in the Makhatini Flats reported yield increases of 40%, a gross margin advantage of 35% equal to 249 Rand /ha (US$ 25) and a decrease in pesticide cost of 46 Rand/ha, equivalent to 36% less than farmers planting conventional cotton (Ismael et al 2001).

8.6.3 Nigeria assigns high priority to ag-biotech

Nigeria is the most populous country in Africa with a population of 120 million. Increased food production, to meet the needs of its fast growing population, has been assigned a high priority. Nigeria is seeking to become a key player and leader among developing countries in biotechnology in the next decade. The government's cabinet has recently approved a biotechnology policy and a strategy for implementation. The proposed program assigns a very high priority to food, agriculture, the environment, and health related areas.

Nigeria has established a National Biotechnology Development Agency (NBDA), which will provide the support and organizing capability for national and international networking, co-ordination, awareness creation, R&D management and linkages with the private sector. The Nigerian government has allocated NBDA a budget of $ 263 million per year for three years to support biotechnology development programs with a special focus on agriculture. Nigeria has a cooperative arrangement with Rutgers University New Jersey, USA, to develop a collaborative program in biotechnology.

The President of Nigeria, Olusegun Obasanjo, has made a personal commitment to biotechnology and has stated that "the acquisition of biotechnology capability in the country is now crucial to Nigeria's advancement toward food self-sufficiency and the eradication of diseases." (AfricaBio 2001b). www.africabio.com/biolines/9.html. Nigeria is seeking to build an international collaborative network to achieve its goals in biotechnology during the next decade. The Nigerian Minister of Agriculture, Mr. Hassan Adamu, recently stated "To deny desperate, hungry people the means to control their futures by presuming to know what is best for them is not only paternalistic but morally wrong."

8.6.4 Indian Seed Bill addresses emerging issues in biotechnology with prospects of commercializing *Bt* cotton in the near-term

India's Plant Variety Protection and Farmers Rights Bill (Jayaraman 2001) was approved by the Indian parliament in August, 2001. The bill has received the full support of farmers, public sector plant breeders, biotechnology companies and NGOs because it has been successful in integrating and meeting the diverse needs of the various parties involved. Dr M.S Swaminathan, the father of the Green

Revolution in India and recipient of the first World Food Prize, recognized the uniqueness of the bill and noted that "Farmers and breeders are allies in the struggle for sustainable food security and hence their rights should be mutually reinforcing and not antagonistic. The bill retains this important feature."

More importantly from a biotechnology perspective, the bill meets the need of plant breeders seeking to produce and commercialize seed varieties through a "fast track" approval system for transgenic crops. Plant breeders have an obligation to demonstrate that the germplasm has been lawfully acquired and that the new variety "does not contain any gene or gene sequence involving terminator technology." On the controversial issue of farmers' rights, the bill provides protection for India's 50 million farmers, by recognizing their right to save and sell seeds produced on their farms. A National Gene Fund will be established and funded from royalties paid by breeders for the use of farmers' plant varieties and land races. The National Gene Fund will be used to compensate farmers for crop failure and other related needs in the rural areas. The article (Jayaraman 2001) notes that the new bill fulfills India's World Trade Organization obligation to provide plant variety protection to breeders and provides a useful model for other developing countries to peruse.

In June 2001 India's Genetic Engineering Approval Committee requested that Mahyco, the developer of *Bt* cotton in India, conduct more large scale field trials before *Bt* cotton is considered for approval. Mahyco has completed the trials and is currently preparing additional data and information for submission and consideration of the Committee before year-end. Some observers expect that commercialization of *Bt* cotton in India will be approved by early 2002.

8.6.5 China – draft sequence of the super hybrid rice genome nearing completion

Researchers at the Chinese Academy of Sciences (CAS) are nearing completion of a draft sequence of the "super hybrid rice" genome, developed by Dr Yuan Longping. The sequencing work by CAS researchers was facilitated and accelerated as a result of the experience with the human genome project. The work was initiated in May 2000 and is expected to be completed by the end of 2001. The draft sequence of the "super hybrid rice" genome will complement rice sequencing information that has already been made available by Monsanto and Syngenta and work underway by the public sector IRGSP led by Japan. The sequencing initiative hopes to identify the genes involved with reproduction, pest resistance and yield in the super hybrid rice. This work will also benefit crop improvement specialists working with other crops such as maize and wheat. CAS plans to publish the results and place the final hybrid rice genome map in the public domain when the work has been completed.

8.6.6 Philippines develops its own transgenic rice, resistant to bacterial-blight, ready for field testing

The Philippines joins a group of developing countries that include China, Mexico, Cuba, Argentina, South Africa, Thailand and Malaysia, that have developed their own transgenic crops to the stage where they are ready for field testing. This is a very important achievement, with technology and policy implications for the adoption of transgenic crops as well as a clear indication of the capability and sustainability of national programs in crop biotechnology.

Researchers at the Philippine Rice Research Institute (PhilRice) have developed and greenhouse-tested a transgenic rice in cooperation with researchers of the International Rice Research Institute (IRRI). The transgenic rice, IR72, incorporates the Xa-21 gene and has been carefully checked in greenhouse inoculation tests in which it proved to be resistant to nine types of the bacterial blight disease organism. The plans are to test the new transgenic rice in two trial sites in Laguna and Nueva Ecija. The field trials will commence as soon as the requirements of the National Committee on Biosafety of the Philippines are met and approval confirmed. The Philippines has already successfully tested *Bt* corn varieties in field trials in the Philippines.

8.6.7 Brazil - status of approval for transgenic soybean

The Brazilian biosafety regulatory system was established in 1995 with the creation of a Biosafety Law and establishment of a national technical biosafety committee, CTNBio. Under a "Presidential Decree" linked to the Biosafety Law, a Committee was created (CTNBio) with authority to develop regulations to deal with all technical aspects of genetically modified organisms. CTNBio was given the authority/oversight to regulate experiments with GM plants at laboratory and field level and provide a 'final conclusive technical opinion' on the environmental and food safety of GM plants and food derived from GM crops. In 1998 CTNBio delivered its first positive 'final conclusive technical opinion' on the environmental and food safety of a transgenic soybean tolerant to the herbicide glyphosate. For commercial clearance of transgenic products, Brazilian law requires approval from other Government ministers, the Ministers of Agriculture, Health and Environment. The latter may require an environmental impact study before making a judgment on approval of the product. CTNBio's 'final conclusive technical opinion' on glyphosate tolerant soybean did not request such a study. This resulted in lawsuits/injunctions by non-governmental organizations opposed to plant biotechnology and a constitutional debate and an impasse on commercialization of biotech crops, which is still not resolved. A "Provisionary Law" was signed by the President of Brazil and four Cabinet Ministers in December 2000. This law, modified the biosafety requirements and established the authority of CTNBio while recognizing the oversights and authority of the Ministers of Agriculture, Environment, and Health. To date, commercial approval of glyphosate tolerant soybean in Brazil is still pending, awaiting decisions from Government authorities re the need for the impact study and the status of the approval of herbicide tolerant soybean for commercialization.

8.6.8 Indonesia successfully commercializes *Bt* cotton - its first trangenic crop

Indonesian Minister of Agriculture, Bungaran Sarigih, confirmed that the government's first experience with commercial transgenic crops had been successful. The introductory commercial plantings of *Bt* cotton occupied 4,000 hectares of commercial *Bt* cotton fields in Sulawesi, and resulted in superior yields that produced 2.2 tons per hectare in contrast to only 1.4 tons per hectare for the Kanesia cotton normally planted in Sulawesi. The Minister stated that the Government will now proceed with the planting of genetically modified (GM) cotton in South Sulawesi. "We promise to issue a new ministerial decree to continue the cultivation of transgenic cotton in seven regencies in South Sulawesi as long as it is not harmful to the environment," he said. The new decree will not set a limit on the acreage to be planted to GM cotton. Current production of cotton in Indonesia supplies less than one percent of total domestic requirements and Indonesia imports 500,000 tons of cotton every year.

Indonesia joins the USA, China, Australia, Mexico, Argentina and South Africa in growing *Bt* cotton commercially. Area planted to *Bt* cotton globally has increased consistently every year since its introduction in 1996. In 2001 it is expected that up to 20% of the 34 million hectares of world cotton will be planted to transgenic cotton varieties, a proportion of which will carry a gene for insect resistance, another portion a gene for herbicide tolerance and a final portion that will carry two "stacked genes" – a gene for insect resistance and also a gene for herbicide tolerance. An analysis of existing data on transgenic cotton varieties has found no evidence to indicate that genetically engineered cotton had any effect on fiber quality.

8.6.9 Kenya – First field trials of a transgenic crop - virus resistant sweet potato

For millions of people in the developing countries of East Africa and other regions, sweet potatoes are a major part of the diet because they are nutritious and easy to grow. Equally important is that they can also be conveniently stored underground for an extended length of time. Sweet potatoes are a reliable source of food, even in dry seasons. However, attacks by pests and diseases can reduce yields significantly. One of the important diseases in East Africa is caused by the feathery mottle virus. Starting in 1991, following extensive research and development, a partnership was facilitated by ISAAA, and USAID (working with Michigan State University's Ag Biotech Support Project, ABSP), between researchers from the Kenyan Agricultural Research Institute (KARI) and Monsanto in the United States. The objective was to develop varieties of sweet potatoes resistant to the feathery mottle virus. A royalty-free license from Monsanto provides the technology free of charge to KARI. ISAAA, which has a center in Kenya, was instrumental in assisting Kenyan authorities to develop biosafety regulations that allow the safe and efficient field testing of transgenic crops, in harmony with international standards. In early 2000, Kenya conducted its first field trials of a transgenic crop - virus resistant sweet potato. This is a watershed for a country like Kenya which has assigned high priority to biotechnology and exerts leadership in the region by playing a leading and model role in East Africa for transgenic crops. An important new development in the project is that the Agricultural Research Center (ARC) in Roodeplaat, South Africa, has also joined the project to work on developing virus-resistant South African varieties.

8.7 Broadening Political and Institutional Support for Crop Biotechnology

8.7.1 APEC Leaders support the use of biotechnology to increase food production

At the October 2001 APEC meeting in Shanghai, China, APEC Leaders confirmed their "support for the development of biotechnology to help feed growing populations and its safe use based on sound science. Biotechnology can help developing economies increase crop yields, while using fewer pesticides and less water than conventional methods." (US Dept. of State 2001) http://usinfo.state.gov/topical/global/biotech/01102101.htm.

APEC released the following statement (APEC 2001): "Noting that sustainable growth in the APEC region also requires the ability to feed a growing and increasingly prosperous population, leaders call for accelerated implementation of the APEC Food System initiative. Recognizing the benefits of biotechnology in improving productivity, increasing nutrition, and reducing the environmental impact of agricultural production, we reaffirm the importance of safe introduction and use of biotechnology products based on sound science. We also welcome the initiative to hold a policy-level dialogue on agricultural biotechnology and call for more related capacity building activities." http://www.apec-china.org.cn/APEC2001/20011021/927933.htm

APEC Leaders endorsed a U.S. proposal to establish a new High-Level Biotechnology Policy Dialogue. Most APEC economies are developing domestic regulatory, trade, and scientific policies to address the emerging field of agricultural biotechnology. The dialogue will allow policy-makers to exchange views and pursue cooperative activities on a wide range of issues relating to biotechnology development, regulations governing new products, implications for trade, and effective communications strategies. APEC officials plan to hold the first session of the Biotechnology Dialogue in Mexico City in February 2002. The United States believes that the High-Level Policy Dialogue will help officials harness this new technology and capitalize on its benefits. The dialogue will also facilitate the discussion of those issues in other international forums. The APEC Leaders' Declaration calls for more capacity building activities to help member economies develop agricultural biotechnology.

8.7.2 The President of the USA, President George W. Bush, advocates biotechnology in address to World Bank

In a July 2001 speech delivered to the World Bank (White House 2001), President Bush stated, "The world also needs to begin realizing the enormous potential of biotechnology to help end hunger." President Bush also referenced the UNDP Human Development Report and, "the need to move forward based on sound science, to bring these benefits to 800 million people, including 300 million children, who still suffer from hunger and malnutrition." http://www.whitehouse.gov

8.7.3 The President of the Republic of Kenya seeks cooperation in biotechnology

In August 2000, the President of the Republic of Kenya, President Moi urged President Clinton of the USA for cooperation in agricultural biotechnology.

8.7.4 UNDP Human Development Report for 2001 highlights the use and potential benefits of biotechnology

Of all the reports from international agencies that have assessed the potential benefits of biotechnology to developing countries, this UNDP Report has had the highest impact in influencing opinion re the critically important contribution that technology offers society. The UNDP "Human Development Report 2001 - Making New Technologies Work for Human Development" (UNDP 2001) provides a thoughtful and professional analysis of the potential of biotechnology and information and communications technology (ICT) for developing countries. The report highlights the critically important point that, biotechnology, and information and communications technology can make major contributions to reducing world poverty. UNDP Administrator Mark Malloch Brown states, "Ignoring technological breakthroughs in medicine, agriculture and information will mean missing opportunities to transform the lives of poor people." Key issues addressed in the report include:

- Managing the risks of technological change
- Potential for biotech crops and foods to help developing countries

- Potential for crops improved using biotechnology to produce higher yielding crops, and other enhancements such as drought tolerance and pest tolerance

- Potential of crops enhanced using biotechnology to improve farming practices in the developing world

- Potential of biotechnology to improve food security in Africa, Asia, and Latin America.

The report also urges greater public investment in research and development to ensure that biotechnology can meet the agricultural needs of the world's poor, calls for more research into the long-term impacts of GMOs and advocates labeling genetically modified products.

Summaries on key topic areas include

- New technologies key to reducing world poverty

- Although controversial GMOs could be breakthrough technology for developing countries

- Some developing countries become hi-tech leaders while others fall far behind

- The report calls for R&D, differential pricing and IPR support to help developing countries bridge the technology divide

- "Brain drain" costs developing countries billions.

8.7.5 Joint Report on Transgenic Plants and World Agriculture by seven Academies of Science representing the North and the South

In July 2000, the joint report (National Academy of Sciences 2000) of the seven Academies of Science was prepared under the auspices of the Royal Society of London, the U.S. National Academy of Sciences, the Brazilian Academy of Sciences, the Chinese Academy of Sciences, the Indian National Science Academy, the Mexican Academy of Sciences and the Third World Academy of Sciences.

The report is a very important statement on biotechnology and GM crops from the international scientific community, in that it represents five Academies of Science from the South and two from the North. The following verbatim summary captures the main thrust of the statement from the seven Academies:
"It is essential that we improve food production and distribution in order to feed and free from hunger a growing world population, while reducing environmental impacts and providing productive employment in low-income areas. This will require a proper and responsible utilization of scientific discoveries and new technologies. The developers and overseers of GM technology applied to plants and microorganisms should make sure that their efforts address such needs.

Foods can be produced through the use of GM technology that are more nutritious, stable in storage, and in principle health promoting – bringing benefits to consumers in both industrialized and developing nations.

New public sector efforts are required for creating transgenic crops that benefit poor farmers in developing nations and improve their access to food through employment-intensive production of staples such as maize, rice, wheat, cassava, yams, sorghum, plantains and sweet potatoes. Cooperative efforts between the private and public sectors are needed to develop new transgenic crops that benefit consumers, especially in the developing world.

Concerted, organized efforts must be undertaken to investigate the potential environmental effects - both positive and negative – of GM technologies in their specific applications. These must be assessed against the background of effects from conventional agricultural technologies that are currently in use.

Public health regulatory systems need to be put in place in every country to identify and monitor any potential adverse human health effects of transgenic plants, as for any other new variety.

Private corporations and research institutions should make arrangements to share GM technology, now held under strict patents and licensing agreements, with responsible scientists for use for hunger alleviation and to enhance food security in developing countries. In addition, special exemptions should be given to the world's poor farmers to protect them from inappropriate restrictions in propagating their crops" (National Academy of Sciences, 2000).

8.7.6 European Commission releases report on the status of biotechnology and developing countries

The 2001 report of the European Commission, "Towards a Strategic Vision of Life Sciences and Biotechnology: Consultation Document", reports that life sciences and biotechnology have entered a stage of exponential growth, opening up a vast potential to move economics in Europe and globally towards more sustainable development and improved quality of life. The report (European Commission 2001) goes on to point out that Europe cannot afford to miss the opportunity that new sciences and technology offer if Europe wants to become a leading knowledge-based economy. In the 32 page report are a number of topic areas including the potential impacts of life sciences and biotechnology, a section on innovation and competitiveness as well as sections on ethics, research, views of the public, regulation, international collaboration and policy development. http://europa.eu.int/comm/biotechnology/pdf/doc_en.pdf

8.7.7 New Zealand Royal Commission Report on Biotechnology

The New Zealand Royal Commission released their recommendations on biotechnology to the Cabinet in August 2001. The Commission was an independent review panel set up to report to the government on the options available to New Zealand to deal with genetic modification, and to advise on appropriate changes to government policy, regulatory legislation, public institutions, and the future direction of biotechnology and associated research. The full report of the Royal Commission on Genetic Modification (New Zealand Royal Commission on Biotechnology 2001) is available at http://www.gmcommission.govt.nz

The Commission concluded that "it (GM) holds exciting promise, not only for conquering diseases, eliminating pests and contributing to the knowledge economy, but for enhancing the international competitiveness of the primary industries so important to our country's economic well-being." The major conclusion drawn by the Commission was that New Zealand should keep options open and encourage the co-existence of all forms of agriculture. The Commission did report satisfaction with the basic regulatory framework carried out by key institutions including the Environmental Risk Management Authority (ERMA) and the Australia New Zealand Food Authority (ANZFA).

The leaders of the country's eight universities have voiced their full support for the findings of the Commission. Professor James McWha, chair of the New Zealand Vice-Chancellors Committee noted that "universities back the Commission's rigor and reasoned analysis of the complex scientific, cultural, and ethical considerations involved." He also warned the government not to be influenced by some interest groups that were distorting the issues involved with genetic modification by the dissemination of misinformation. "This country has considerable expertise in the biological sciences and the scientists involved are frustrated by the fallacies now being propounded by some GM opponents. Responsible leadership should not be influenced by argument based on emotion rather than fact ... Above all else, it needs to be remembered that the Royal Commission on GM heard the best information available and based its findings on the views of the entire community."

The Royal Society, New Zealand's science academy, also counseled Prime Minister Helen Clark's government to allow field trials of GM animals and plants to continue. "Field trials are an essential element in risk and benefit assessment," the scientists counseled the Prime Minister. Royal Society Chief Executive Steve Thompson indicated that scientists believed that New Zealand had to take a leadership role in dealing with GM technologies. The society had "grave concerns" that opponents of the technology circulating misleading material were now undermining the work of the Royal Commission. "Many of our members with expertise in the biological sciences feel very frustrated at seeing these emotive distortions and untruths circulated," noted Thompson, who indicated that the Academy was independent from Government. The group represented at least 15,000 scientists and other researchers across a wide range of fields, and had a role in providing independent policy advice on science issues. The Chief Executive of the Royal Society urged members of parliament "to give the highest possible weight to the Royal Commission's findings in coming to your Government's decision regarding genetic modification policy and legislation."

Finance Minister Michael Cullen has warned of economic decline if New Zealand adopts too cautious an approach to genetic engineering. He said deciding whether and to what extent New Zealand embraced biotechnology would probably be "the single most important strategic policy decision that governments will make in the next 20 years."

8.7.8 American Medical Association supports biotechnology for food production

The AMA released an executive summary, "Genetically Modified Crops and Foods", in support of biotechnology. The AMA statements were recommended by the Council of Scientific Affairs and adopted as AMA Policy at the 2000 Interim AMA Meeting. The AMA recommendations were based on 11 reports issued over the past two years by various scientific and government bodies, scientific references related to the safety, regulation, and environmental impact of transgenic crops and food, and information obtained from scientific and regulatory web sites. According to the results AMA released, "More than 40 transgenic crop varieties have been cleared through the federal review process with enhanced agronomic and/or nutritional characteristics or one or more features of pest protection (insect and viruses) and tolerance to herbicides. Crops and foods produced using recombinant DNA techniques have been available for fewer than 10 years and no long-term effects have been detected to date. These foods are substantially equivalent to their conventional counterparts." The original statement (AMA 2000b) can be found at http://www.ama-assn.org/ama/pub/article/2036-3604.html.

The American Medical Association held a media briefing in New York on October 4, 2001 to promote food biotechnology. Biotech experts presented the benefits and potential of biotechnology in a number of areas including: designer crops benefit humans and environment; genetic enhancement guards against food allergies; plant-based vaccines show promise against infectious diseases; world without hunger may be within reach; new study shows that biotechnology offers significant benefits to diverse crops. Summaries of these presentations (AMA 2001) can be accessed at http://www.ama-assn.org/ama/pub/article/4197-5322.html

8.7.9 International Fund for Agricultural Development (IFAD) states that biotechnology could alleviate poverty

The 2001 Rural Poverty Report of IFAD makes a strong case that effective use of biotechnology could be essential to the alleviation of rural poverty in developing countries (IFAD 2001).

8.7.10 Asian Development Bank Report on Biotechnology recommends increased investment in biotechnology

The Asian Development Bank Report on Biotechnology (ADB 2001) recognizes that during the next 25 years Asia will face a serious challenge on how to reduce poverty and achieve food security. The report states that modern biotechnology brings new possibilities for achieving the sustainable increases in agricultural productivity that will be necessary to meet the projected demand for food by Asia's growing population. It notes that biotechnology has the potential to increase agricultural production and improve processing. Using modern biotechnology, new high yielding varieties can be developed much more quickly with greater precision compared with conventional breeding methods.

The major conclusion of the ADB Report is that funding agencies, including ADB, would be wise to continue and increase their investments in the safe applications of biotechnology, as one means to achieving poverty reduction and food security in Asia over the next 25 years. More specifically, the report recommends that ADB should assist its member countries in: "policy and priority setting to enhance investments in the safe application of biotechnology; increase dialogue to identify potential benefits and opportunities in the use of different biotechnologies to address specific targets; strengthen risk assessment and management capabilities through systematic capacity building, facilitate access to proprietary technologies and encourage greater private and public sector cooperation in the development and delivery of new products at affordable prices for the poor; and support a strategic R&D agenda and associated human resources development in Asia to generate new knowledge in biotechnology and disseminate the results for the public good."

The full report (ADB 2001) can be accessed at http://www.adb.org/Documents/Books/Agri_Biotech/default.asp

8.7.11 International Food Policy Research Institute advocates biotechnology as an option

The book, "Seeds of Contention" (Pinstrup-Andersen and Schioler 2001a) and IFPRI's Food Policy Statement No.33 (Pinstrup-Andersen and Schioler 2001b) discuss how to resolve the debate over transgenic crops in order to alleviate hunger in developing countries. The reports conclude that redistribution of food supplies or increasing grain yields through conventional breeding are not sufficient to meet food demands in developing countries. As an alternative option the report proposes the adoption of transgenic crops using sound scientific procedures to ensure safety for people and the environment. To ensure that the poorer developing countries benefit from biotechnology and transgenic crops, the report proposes that donor industrial country governments and organizations permit the developing world to make their "own decision about the use of genetic engineering technology based on domestic perceptions about benefits and risks." The report calls on corporations that own the intellectual property rights of biotechnology applications to be less restrictive in sharing the technology with developing countries so that transgenic crops can contribute to food security for the poor in developing countries.

8.7.12 The American Phytopathological Society (APS) supports biotechnology

The American Phytopathological Society (APS), the largest organization of plant health scientists in the world, comprising over 5,000 members, issued a statement in support of biotechnology (APS 2001b) http://www.apsnet.org/members/ppb/ps/APS%20Biotech%20Statement.pdf.

Dr. Sue Tolin, a plant pathologist at Virginia Polytechnic Institute and State University, states that "Virtually all aspects of plant pathology are affected by biotechnology. Advances in this area played a critical role in our ability to identify and control plant pathogens that cause billions of dollars of crop losses each year, particularly in developing countries where diseases routinely destroy important food crops."

Among the benefits outlined in the APS statement is that biotechnology is an important tool for reducing the use of synthetic pesticides for controlling plant diseases, and minimizing adverse environmental impacts of modern agriculture practices. The APS acknowledges that consideration of risks associated with plant disease management through biotechnology must also be taken into account. "Biotechnology must be practiced in a responsible way, respectful of human, economic and environmental impacts," states Noel Keen, current APS President. For the full statement, contact Molly CERN (APS 2001b) at mcerny@scisoc.org. The associated press release (Associated Press 2001) can be accessed at http://www.apsnet.org/media/press/biotech2.asp.

8.7.13 American Society of Plant Physiologists/American Society of Plant Biologists (ASPP/ASPB) statement on plant biotechnology

A position statement on plant biotechnology was released in 2001 by the Executive Committee of the American Society of Plant Physiologists/American Society of Plant Biologists (ASPP/ASPB 2001). The 6,000 member organization states "ASPB believes strongly that, with continued responsible regulation and oversight, biotechnology will bring many significant health and environmental benefits to the world and its people". The complete statement is available at http://www.aspb.org/publicaffairs/aspb_statement_on_genetic_modifi.cfm

8.7.14 UK - Encouraging report on transgenic/GM crops

A report of the British Agriculture and Environment Biotechnology Commission

(BAEBC 2001) not only lowered the environmental hurdle for the commercialization of genetically modified (GM) crops but also recognized the need for more general public acceptance. The commission recognizes that any environmental impact of GM crops may not necessarily be negative. Hence, this view taken together with research on environment enhancing cultural practices, should be taken into consideration in the final analysis and decision-making. It further recommended clarity and precision in government press releases and publications, "so that messages are not distorted and cannot easily be misinterpreted."

The commission, established in June 2000, was tasked "to offer strategic advice to Government on biotechnology issues which impact on agriculture and the environment" and to liaise with other government bodies.

More information on the report (BAEBC 2001) can be obtained from http://www.openi.co.uk/oi010917.htm

8.7.15 German Senate Commission supports transgenic crops

Germany's Senate Commission on Genetic Research stated that using genetically modified (GM) plants and microorganisms in food production helps to ensure food security for the world population and to protect sustainable agriculture. The central public funding organization for academic research in Germany, Deutsche Forschungsgemeinschaft (DFG), issued the statement on genetic engineering and food. It is now being disseminated to political and scientific communities. Ernst-Ludwig Winnacker, DFG president, said that the report comes at a time when the genetically engineered production of animal and plant based food is a controversial matter of public debate. The report comments on conceivable risks resulting from the cultivation and consumption of genetically modified plants or food and refers to safety precautions to protect the consumer. It recommends sticking to the "tried and tested regulations" on tests mandated by the law on genetic engineering and food. The commission is urging a uniform implementation of national and European guidelines supplemented by provisions covering GM seed for animal feed and food. The complete text (German Senate Commission on Biotechnology 2001) is available at http://www.dfg.de/aktuell/publikationen.html

8.7.16 REDBIO Foundation – The Goiania Declaration on Biotechnology

The recently released biotechnology position statement from Goiania, a Latin American organization, focuses "towards a biotechnology at the service of sustainable development of the Latin American and the Caribbean forestry and agricultural sectors." This declaration was endorsed by the REDBIO Foundation. http://www.ric.fao.org/redes/redbio/pdf/ingles.pdf

8.7.17 Indian Science Congress Association statement on biotechnology

The following are excerpts from the official statement from the Congress which addressed the topic of "Food, Nutrition and Environmental Security" at New Delhi in January 2001:

"Attaining food security has been a major challenge for the nation since independence. In order to meet the demand of our ever-increasing population growing at the rate of 1.8 per cent, we would need 260-264 million metric tons of food grains in 2030. In addition, 130-152 metric tons of milk, 151-193 metric tons of vegetables, 84-106 metric tons of fruits, 10-14 metric tons of meat, 4-5 metric tons of eggs, 10-14 metric tons of fish and 12 metric tons of edible oil would be required to provide adequate nutrition to a population of 1.3 billion people."

"Agriculture in India has attained resilience mainly on account of improved technologies and better crop varieties, better infrastructure, irrigation, weather forecasts and diversified agriculture. Efficient agriculture rests heavily on management of natural resources, such as soil, water, energy and biological diversity. In meeting the needs of population pressure, farming will have to meet the twin objectives of producing more and conserving natural resources. Obviously this would be achieved through the role of science and effective interactions among scientists to generate required technologies."

"Strategies to achieve food and nutritional security would involve application of new technologies like biotechnology, information technology, meteorology, microelectronics, communications, etc. in a big way. While these technologies are powerful tools in our arsenal to meet the emerging challenges, they need to be used with great scientific care and discretion."

"As we stand on the cusp of a new millennium, face to face with formidable challenges and equipped with equally powerful technologies, the question before our scientific community is not "are we going to meet the challenge?" but "can we do it without harming our environmental assets or, better still, can we do it by conserving our environmental assets?"

8.7.18 Visions of Indian Leaders on biotechnology – politicians, policy makers, senior statesmen in science, and farmers

In 2050, India will become the world's most populous country with an estimated population of 1.53 billion compared with China at 1.48 billion people (FAO 2001). To conclude this section, below is a collection of closing quotations on biotechnology from Indian leaders – representing politicians, policy makers, senior statesmen in science, and last, but certainly not least, farmers - the guardians of agriculture which is the mother of all sciences.

*Vision of a politician - **Prime Minister Atal Behari Vajpayee***

"My government is determined to take steps which will help us double our food production and make India hunger-free in ten years. It is indeed alarming that the per capita availability of food grains, which is already abysmal, has been decreasing. It is a matter of grave concern."

(First Broadcast to the Nation, March 22, 1998)

"Biotechnology is a frontier area of science with a high promise for the welfare of humanity. The new generation of biotechnology developed as a result of intensive work in India has opened up research of national relevance. I am confident that the fruits of biotechnology would be harnessed for the benefit of millions of our poor people as we move into the next millennium."

*The goal of a policy maker - **Dr. R. S. Paroda,** Director-General, Indian Council of Agricultural Research*

"We wish to take full advantage of biotechnology and strengthen the private and public sector base for research and development of such crops."

(The Times of India, September 27, 2000)

*Reflections of a senior statesman in agriculture - **Dr. M.S. Swaminathan**, a senior statesman in science, Father of the Green Revolution in India and recipient of the first World Food Prize*

"Scientists now have unique opportunities for designing farming systems to achieve the triple goals of more food, more income and more livelihood per hectare of land provided we harness the tools of eco-technologies, resulting from a blend of traditional knowledge, with frontier technologies. Such tools include biotechnology, information and communications technology… Those who advocate going back to the old methods of farming ignore the fact that only a century ago when the population of undivided India was 281 million, famines claimed 30 million lives between 1870 and 1900...New technologies supported by appropriate services and public policies have helped to prove doomsday predictions wrong and have led to the agricultural revolution (the green revolution) becoming one of the most significant of the scientific and socially meaningful revolutions of the century."

(The Hindu Survey of Indian Agriculture, 2000)

*Concerns of a farmer - **P Chengal Reddy,** President of the Federation of Andhra Pradesh Farmers Associations*

"Farmers are being denied the right to choose for themselves with 'urbanised' advocacy groups deciding what is good for them."

(Hindu Business Line, July 21, 2001)

9. OVERVIEW OF ATTRIBUTES AND BENEFITS ASSOCIATED WITH TRANSGENIC CROPS

The aim in this section is not to provide an exhaustive analysis of the attributes and benefits associated with transgenic crops, but to provide a general overview, with a focus on a selected listing of recent references and case studies. The estimates of economic benefits associated with transgenic crops in this publication (section 9.5) are entirely based on information generated from studies by independent public sector institutions. The studies, which generated the estimates, employed a range of methodologies and should be considered as indicative of the order of magnitude of economic benefits. It is hoped that this overview will stimulate more independent studies on the benefits associated with the large area of almost 45 million hectares of transgenic crops planted globally in 2000.

The first generation of transgenic crops deployed during the first five-year period (1996-2000) feature two crop protection traits - herbicide tolerance (HT) and insect resistance (IR) traits. The two traits, HT and IR are deployed independently or as stacked genes (HT/IR) on over 99% of the 44.2 million hectares of transgenic crops globally in 2000. Herbicide tolerant plants of soybean, canola, maize and cotton occupied 74% of the 44.2 million hectares whereas insect resistant maize and cotton occupied 19% with the stacked gene HT/IR in cotton and maize occupying 7% in 2000. The balance of <1 % was occupied by minor traits like virus resistance in crops such as potatoes and squash.

The first generation of transgenic crops has attributes that have resulted in improved control of weeds and insects which together can reduce yields globally by up to 24%. Insect pests are responsible for 13.8% of potential production, diseases 11.6% and weeds 9.5% for a total of 35.9% (James et al 1972, Cramer 1967). Transgenic crops featuring HT and IR genes offer a greatly simplified pest management system which has contributed to increasing the overall efficiency of crop production. Equally, or more important from some perspectives, HT and IR transgenic crops have provided significant environmental benefits resulting in decreased use of pesticides, improved quality of ground and surface water, and an increase in biodiversity. The adoption of GM crops has also facilitated the adoption of reduced tillage cropping systems which in turn contribute to conservation of natural resources and sustainability. In addition, *Bt* maize is less susceptible to infection by species of the fungus *Fusarium* which produce mycotoxins such as fumonisin, which is carcinogenic when fed experimentally to rats (NTP 1999). Thus, the attributes of transgenic crops offer significant advantages including substantial economic benefits to producers. Consumers also benefit indirectly from lower costs of production and directly through access to more affordable food, feed, and products from *Bt* corn, which is less likely to contain levels of mycotoxin that can be harmful in conventional corn.

9.1 Reduction in Use of Pesticides

During the five-year period 1996 to 2000, when the first transgenic crops were adopted, there has been a consistent reduction in the amount of pesticides used in the production of transgenic crops. *Bt* and herbicide tolerant crop varieties of soybean, corn, cotton and canola have contributed to a reduction in the total use of pesticides in many different countries. Table 16 summarizes the pesticide reductions associated with transgenic crops in USA, China and Canada. Studies have shown that US growers who planted *Bt* cotton eliminated 900 metric tons of insecticide active ingredient in 1998, and 1,200 metric tons in 1999 (Carpenter and Gianessi 2001). Significant reductions have also been reported in China and in Argentina, where pesticide reductions resulting from the deployment of *Bt* cotton ranged from 60 to 80% (Pray et al 2001, Xia et al 1999, Elena 2001, Jia 1998). China used 15,000 metric tons less insecticide in 1999 due to the use of *Bt* cotton (Table 16). In Canada, a 2000 study indicated that canola growers planting herbicide tolerant varieties eliminated 6,000 metric tons (Table 16) of herbicide product (Canola Council of Canada 2001).

Studies on the impact of herbicide tolerant soybeans on herbicide use have reported varied results, with some indicating no change in herbicide use whereas other studies reported a small reduction in overall herbicide use on soybean (Carpenter 2001a, Carpenter and Gianessi 2001, Fernandez-Cornejo and McBride 2000, Heimlich et al 2000, and USDA 2000). In summary, the major benefit of herbicide tolerant soybean is that it allows growers to conveniently control weeds with usually one spray at a lower cost than before when several sprays were required, some of

Table 16. Summary of Pesticide Reductions for Selected Transgenic Crops in USA, China and Canada, 1998 to 2000

Country/Year/Crop	Internal Commercial Market
USA/1998/Bt Cotton	Reduction of 900 metric tons of insecticide (active ingredient, a.i.)[1]
USA/1999/Bt Cotton	Reduction of 1,200 metric tons of insecticide (active ingredient, a.i.)[1]
China/1999/Bt Cotton	Reduction of 15,000 metric tons of insecticide (formulated)[2]
Canada/2000/Herbicide Tolerant Canola	Reduction of 6,000 tons of herbicide[3]

Source: Compiled by Clive James, 2001 from the following data: [1]Carpenter & Gianessi 2001; [2]Pray et al 2001; [3]Canola Council of Canada 2001 which damaged the soybeans and resulted in residues that were damaging for following crops such as corn.

9.2 Improved Pest Control and Productivity

9.2.1 Improved insect pest management

The most important benefit of the first generation of *Bt* transgenic crops is that they provide producers with improved methods of insect pest control. Insect pests reduce crop yields through significant crop losses estimated to be about 14% of global crop production. Farmers use a variety of programs to protect their crops from insect pests including transgenic *Bt* crops that provide season-long protection against several damaging insect pests. As noted above, use of *Bt* crops also reduce or eliminate the need for insecticide sprays. Effective deployment of *Bt* crops eliminates the yield loss that results from less than optimal pest control by insecticides and allows the farmer more flexibility and time for other farm duties (Carpenter and Gianessi 2001). Under some circumstances, farmers are better able to control the insect pests with *Bt* crops than with conventional insecticide sprays and this more effective control results in higher yields (Carpenter and Gianessi 2001). For example, because of improved control of European corn borer (ECB), farmers in the US in 1998 and 1999 produced 1.5 million tons and 1.7 million tons more corn respectively with *Bt* corn (Table 17).

In 1998, US cotton growers produced 80,704 tons more cotton because of planting *Bt* cotton and coincidentally eliminated 900 metric tons of insecticides (active ingredient). Similarly, US *Bt* cotton growers produced 117,935 tons more cotton in 1999 and at the same time eliminated the need for 1,200 metric tons of insecticide active ingredient in 1999. Corn growers who planted *Bt* corn in the US precluded the need to treat 800,000 hectares of corn with insecticides in 1998 and similarly 400,000 hectares in 1999 (Carpenter and Gianessi 2001). Similar benefits have been reported for *Bt* cotton in China where the quantity of formulated insecticide applied to non-Bt cotton in 1999 was 48 kg per hectare which is more than 5 times the quantity applied to *Bt* cotton – an 80% reduction in insecticides on *Bt* cotton (Pray et al 2001, Pray et al 2000, Huang et al 2001). It was estimated that the quantity of

Table 17. Aggregate Impacts of Transgenic *Bt* Corn and *Bt* Cotton in the USA in 1998 and 1999: Increases in Production (metric tons)

Crop	1998	1999
Bt Corn	1,500,000	1,700,000
Bt Cotton	80,740	117,935

Source: Carpenter and Gianessi 2001, Modified.

formulated insecticides applied to *Bt* cotton in China in 1999 was reduced by at least 15,000 tons (Pray et al 2001, Pray et al 2000, Huang et al 2001). In large experiments in India in 1998-99 (James 2000, with information provided by Dr. R. Barwale) non-*Bt* cotton required 7 insecticide sprays at all 40 locations whereas *Bt* cotton required no insecticides at 38 sites and minimal protection at the remaining two sites.

9.2.2 Improved weed control

Herbicide tolerant crops offer the farmer greatly improved weed control options. Under some circumstances, a single application of one herbicide to a herbicide tolerant crop can replace multiple applications of mixtures of two or more herbicides. Thus, herbicide tolerant crops greatly simplify and facilitate the logistics of herbicide application including more flexibility re the timing of herbicide applications and also precludes errors during mixing of different herbicides and in determining the correct rate for each product (Canola Council of Canada 2001, Carpenter and Gianessi 2000, Kalaitzandonakes et al 2001). For example, for herbicide tolerant soybeans, cotton or oilseed rape (canola) a grower will often use a single application of herbicide for weed control, instead of a mixture of several herbicides that may be applied in sequence. The herbicides used for herbicide tolerant crops usually control a broad spectrum of weed species.

Before the introduction of herbicide tolerant soybeans, cotton, corn and canola, farmers had to apply several pre- and post-emergence herbicides which required significant resources with limited management flexibility. The advent of herbicide tolerant crops has allowed farmers for the first time to control weeds more effectively with usually only one herbicide application at a significantly lower cost – thus the major gain to farmers has been less expensive, more effective and more flexible weed control. The decrease in the number of herbicides used indicates that growers are using fewer active ingredients, that often require fewer passes over the field, which in turn contributes to energy and fuel savings, resource-efficiency and to less demands on farm management (Carpenter and Gianessi 2001). In a 2000 Canadian study of canola, over 80% of growers reported that weed control was more effective with herbicide tolerant canola varieties compared to conventional and that HT canola yields were >10% higher than conventional canola (Canola Council of Canada 2001).

9.2.3 Herbicide tolerance and no-till systems

Transgenic crops can also make a very important contribution to more sustainable farming systems. For example, the use of herbicide tolerant crops is compatible with farming systems that reduce or eliminate the need for tillage or cultivation. Reduced tillage farming systems are beneficial because they greatly reduce soil erosion and sediment runoff from fields into watersheds. Reduced tillage also conserves moisture, nutrients and soil structure. Given that tillage is one of the primary means of weed control, some speculated that a reduction in the amount of tillage would create weed management problems for growers. However, experience has shown that the reverse is true and that herbicide tolerant crops provide an alternative effective means of controlling weeds, and thus provide growers with a new sustainable solution to improved farming systems. Indeed the use of herbicide tolerant crops and insect resistant crops are a powerful and important component of Integrated Pest Management (IPM) farming systems that enable farmers to implement long term sustainable systems of crop production. In Argentina since the introduction of herbicide tolerant soybeans in conjunction with no-till, farmers have gained significant benefits and management flexibility (AAPRESID 2001). With such significant benefits, not surprisingly the adoption rate of herbicide tolerant soybean in Argentina is close to 100% (95%) and the adoption rate of no-till is increasing rapidly not only in soybeans but in other crops such as maize and wheat. In 1999/2000, there were 5 million hectares of no-till soybeans in Argentina along with 4 million hectares of other no-till crops for a total of 9 million hectares (AAPRESID 2001).

The adoption of no-till systems, will be governed by the characteristics of the specific agro-ecosystem. Farmers who wish to utilize no-till systems can do so using either conventional crops or herbicide tolerant crops with the latter being fully compatible with no-till. For certain crops such as cotton and canola where conventional chemical weed control programs are not adequate or may require mechanical cultivation, herbicide tolerant crops may be particularly appropriate. In Canada, canola farmers planting herbicide tolerant canola are more likely to use no-till or reduced tillage than growers using conventional canola. (Canola Council of Canada 2001). Similarly, US cotton farmers planting herbicide tolerant cotton use no-till more often than their counterparts using conventional cotton.

9.2.4 Herbicide tolerance and yield

Yield is the key indicator of crop productivity and is a function of many complex interactions governed by many genes. However, in relation to weed management, yield is most directly affected by the efficacy of the herbicide that precludes yield reduction due to competition from weeds and by the level of herbicide phytotoxicity or the damage caused by removing weeds mechanically. Yield comparisons between herbicide tolerant and conventional crops are often complicated by several factors that confound the analysis of the data. For example, yield studies that are done under weed-free conditions to compare the genetic yield potential of the varieties tested, may not reflect the benefits of superior weed control with herbicide tolerant crops that can affect yield under commercial farm scale conditions. There is evidence that when tested under farm conditions, herbicide tolerant varieties of canola yield 10% or more compared with conventional varieties (Canola Council of Canada 2001).

Another confounding factor is the varieties that are selected for comparison in a yield trial of a herbicide tolerant variety and a conventional variety. In the first years of commercial planting, the herbicide tolerant trait was often not available in all of the best performing varieties in each region due to the lag in conventional backcrossing of the trait into the best performing most recent germplasm. As a result, yield comparisons between the best conventional varieties and the first herbicide tolerant varieties resulted in differences more related to the higher genetic potential of the best conventional variety rather than the effect of the herbicide tolerant trait. This discrepancy was most notably reported in the first years of testing of herbicide tolerant soybeans but is now decreasing (Carpenter 2001) given that the trait has been incorporated in all the leading top performing varieties. Future yield comparisons, using these varieties should provide more meaningful information, which is not confounded by differences in genetic potential.

Analysis of experimental data to compare the yield potential of conventional soybeans with herbicide tolerant soybeans has generated inconsistent results and has been the subject of much discussion. Most of the published studies have analyzed data from university-based experiments. Carpenter (2001) cautions about extrapolating from the analysis of data from these university-based experiments where conditions are not comparable to farmers' fields and where comparison between conventional and herbicide tolerant may not be meaningful due to various factors including those discussed above. Suffice to note that because of variability and representational issues, caution needs to be exercised when drawing conclusions about the respective yield potential of herbicide tolerant and conventional soybeans at this time. It is noteworthy that farmers, who are shrewd and discerning judges of crop performance, have consistently increased their plantings of herbicide tolerant soybeans from 1996 to 2000. In Argentina, adoption of HT soybean reached 95% in 2000, the highest adoption rate for any GM crop in the world, and 54% in the USA, with further increases in adoption expected in 2001.

9.2.5 Contribution to soil conservation, improved water quality and sustainability

A recent study by the American Soybean Association (ASA 2001 http://www.soygrowers.com) involved a survey of the farming practices of 452 farmers in 19 states. The survey reports that soybean growers in the US have significantly increased the amount of conservation tillage farming and that the primary reason for this adoption was the availability of herbicide tolerant soybean (Roundup Ready soybean). Low-till or no-till conservation tillage significantly reduces the need for land preparation and conserves moisture and nutrients and significantly reduces erosion of topsoil. Thus the use of herbicide tolerant soybean in the US contributes significantly to sustainability and is the principal factor that has facilitated the adoption of conservation tillage in soybean in the US. The findings are very similar to those in Brazil where herbicide tolerant soybean has made a major contribution to a more sustainable agricultural practice that conserves fuel, soil, moisture, nutrients and controls erosion (AAPRESID 2001). More specifically the US survey reports that:

- 53% of soybean growers in the US are making fewer tillage passes since 1996
- 73% of soybean growers in the US now leave more crop residue on their fields compared to 1996
- 54% of farmers credited the adoption of herbicide tolerant soybean (RR soybean)as the principal factor that had the greatest impact on their adoption of reduced tillage or no-tillage soybeans.

Several recent studies in the US have used computer models, used by EPA, to study the potential effects of commercialization of transgenic crops on water quality in acquifers and watersheds. Predictions suggested that the substitution of conventional pesticides (Insecticides and herbicides) with *Bt* crops and herbicide tolerant crops would impact positively on water quality. Some initial experiments to monitor water quality have confirmed the predictions that transgenic crops have the potential to have a significant positive impact on water quality. The following studies are underway:

- Computer models predict that the substitution of preemergent corn herbicides with postemergent herbicides (Round up or Liberty) used with herbicide tolerant corn would significantly reduce herbicide concentrations in vulnerable watersheds in the Midwest. (Wauchope et al In Press). The herbicides used on herbicide tolerant corn have lower application rates than conventional pesticides and they have a greater ability to bind to the soil, both of which result in lower herbicide residues in water.
- The computer model predictions of Estes et al 2001, suggest that the substitution of conventional pesticides by *Bt* cotton, *Bt* corn and herbicide tolerant corn is likely to impact positively on water quality by significantly reducing pesticide concentrations in ground and surface water.
- A monitoring study on *Bt* corn in the Mississippi Delta (Cullum and Smith 2001) has confirmed computer predictions that, compared with conventional cotton, the level of pyrethroid insecticides was substantially lower in *Bt* cotton plantings.
- Research has shown that substituting pre-emergence corn herbicides with the post-emergence products glufosinate and glyphosate should reduce the level of herbicide in runoff and result in a positive environmental impact (Shipitalo and Malone 2000).

9.3 Protection of Non-Target Organisms

Studies in *Bt* cotton and potatoes have confirmed that recorded populations of non-target insects, including economically important predatory species, are larger in *Bt* crops than in conventional fields treated with broad-spectrum insecticides. In the US cotton studies have reported that populations of predatory bugs (*Orius* and *Geocoris* species), spiders and ants are all significantly higher in *Bt* cotton fields compared with conventional cotton fields treated with insecticides (Head et al 2001, Roof and DuRant 1997). Biodiversity of insect species is enhanced by the adoption of *Bt* cotton in China (Pray et al 2001). Some 31 species of insects were recorded in *Bt* cotton fields of which 23 were beneficial, compared with only 14 insects species in non-*Bt* cotton fields of which 5 were beneficial. Other data from China corroborate the fact that lower insecticide use in *Bt* cotton fields is associated with predator populations that are 24% greater than in fields of conventional cotton (Xia et al 1999). Similarly, populations of predatory bugs, ladybird beetles and spiders have been reported to be greater in *Bt* potato fields than in fields of conventional potatoes treated with insecticidal sprays (Reed et al 2001).

Populations of arthropod predators in *Bt* crops can control secondary pest species thereby reducing the need to apply pesticides for control of these pests, which, unlike the target pests, are not controlled by the *Bt* expressed in the plant. In the US, pest aphid populations have been reported to be lower in *Bt* cotton fields compared with insecticide-treated conventional cotton fields, reflecting the effects of biological control (Head et al 2001). In another study, certain secondary lepidopteran pests (*Spodoptera* species) were less likely to occur at economic levels in *Bt* cotton than in conventional cotton, attributed to higher numbers of generalist predators in *Bt* cotton fields (Smith 1997). Beneficial arthropods alone have been reported to keep aphids below damaging levels in *Bt* potato fields (Reed et al 2001).

The recent set of papers, (Hellmich *et al* 2001, Oberhauser *et a*l 2001, Pleasants *et al* 2001, Sears *et al* 2001, and Stanley-Horn *et al* 2001, and Zangerl *et al* 2001) discussed elsewhere in this document (8.2), published by the US National Academy of Sciences, provide reassuring evidence that the early and widely publicized claim by critics that the monarch butterfly was being threatened by *Bt* corn proved to be unfounded.

9. 4 Food Safety and Health Hazards

9.4.1 Safer *Bt* corn with lower levels of mycotoxin

Fusarium is a fungal pathogen that is associated with corn in all regions of the world. *Fusarium* can infect all parts of the corn plant including the ears, where it can result in ear rot and produce mycotoxins. Some *Fusarium* species, e.g. *F. verticillioides* and *F. proliferatum,* enter corn through primary wounds caused by the European corn borer (*Ostrinia nubilalis)* and produce secondary toxic metabolites called fumonisins, which are toxic (SCF 2000). Fumonisins have been detected in corn wherever it is grown with higher prevalence in countries with warm and subtropical conditions (Miller 1999).

Approximately 59% of corn grain samples collected globally are contaminated with fumonisins (Visconti 2000), with the highest incidence of contamination occurring in Oceana (82%) followed by Africa (77%), North and South America (63%). The incidence of contamination of corn kernels in commercially available corn products for human consumption varied from 47% to 82%. These samples were frequently contaminated with the FB1 fumonisin (the most prevalent fumonisin produced by *Fusaria*) at levels close to 1 mg/kg, although exceptionally high levels have been found in South Africa (up to 117 mg/kg) and China (up to 150 mg/kg) where there is also high incidence of esophageal cancer (Visconti 2000). Fumonisins can produce fatal brain damage (leukoencephalomalacia) in horses when fed at levels of ≥10 mg/kg or greater in corn, equivalent to a daily dosage of 0.1 to 0.2 mg/kg body weight (US FDA 2000). Fumonisins cause pulmonary edema in swine, liver and kidney damage in many species, and liver and kidney cancer in rodents when fed at dietary levels up to 150 mg/kg (NTP 1999). In regions of Africa and China where there are high levels of fumonisin contamination in corn, higher rates of esophageal and liver cancer have been reported in subsistence farmers who consume the corn as a major dietary staple (Marasas 1999). While there are a number of risk factors present in these populations, some epidemiologists have proposed that the high cancer rates may be related to fumonisin exposure (SCF 2000). Since fumonisins are found routinely in corn grown in different regions of the world, the health risks to humans and farm animals exposed to these toxins in the diet have been assessed and some countries have set tolerances. Switzerland has set a fumonisin limit of 1 mg/kg for imported corn (FAO 1997). The US FDA recently proposed limits of 3-4 mg/kg fumonisins in corn used for human food, 5 mg/kg in corn for horses, and higher levels for corn fed to other farm animals (US FDA 2000). The Joint FAO/WHO Expert Committee on Food additives recently established a provisional maximum tolerable daily intake (PMTDI) of 2 g/kg/day intake of fumonisins for human consumption (FAO/WHO 2001). The same TDI was proposed earlier by the EU Scientific Committee on Food (SCF 2000).

Mycotoxigenic fungi, such as Fusaria, that produce fumonisins enter corn plants though tissue damaged by boring insects. Borer insects are among the most important insect pests of corn worldwide. Corn plants that have been genetically modified to produce the Cry1Ab insect control protein from *Bacillus thuringiensis* (Bt) are protected against damage from corn borers. Munkvold, from Iowa State University, was the first to report that corn, which expressed the Cry1Ab protein throughout the plant, had significantly reduced ear rot and fumonisin levels (up to 90% reduction) compared to conventional corn plants. This was demonstrated consistently over several years of field trials (Munkvold et al 1999). More recently Munkvold's findings have been corroborated by USDA which found a similar significant reduction in fumonisin levels in corn varieties that expressed *Bt* insect control proteins throughout the plant (Dowd 2000). Recent reports have confirmed similar levels of reduction of fungal contamination and fumonisin levels in *Bt* corn grown in Italy, France and Spain which produces the Cry1Ab protein throughout the plant (Cahagnier and

Melcion 2000; Pietri and Piva 2000). Additional trials are underway in other countries to see if similar reductions (3 to 40 fold) in fumonisins are observed in countries where high insect pressure and high fumonisin contamination are common. Protection of corn against insect damage and subsequent fungal infection may have important health implications for farmers and farm animals that are routinely exposed to fumonisins in corn they grow.

Transgenic technology offers the potential to reduce the occurrence of other important mycotoxin contaminants such as aflatoxins and ochratoxins in food crops. This could be achieved by incorporating insect resistant genes into crops to control a broader spectrum of insect pests that cause damage and thus preclude toxigenic fungi from invading the plants. Alternatively, other ways may be discovered to either reduce fungal growth in plants or detoxify mycotoxins produced in plants.

9.4.2 *Bt* cotton decreases pesticide poisonings

There are 50,000 pesticide poisonings per year reported in China of which 50 result in death. There is preliminary evidence that farmers using *Bt* cotton suffer less pesticide poisonings (5% of farmers reporting poisonings) than farmers growing conventional cotton who reported poisonings at more than four-fold higher at 22%, (Pray et al 2001, Pray et al 2000, Huang et al 2001). *Bt* cotton farmers used 80% less insecticides than the 48 kg per hectare of formulated insecticides used by farmers growing conventional cotton varieties. This preliminary finding has important implications given that over half of the global hectarage is in developing countries where small farmers are at particular risk to pesticide poisoning when applying insecticide with hand sprayers under difficult and often unsafe conditions.

9. 5 Economic Advantage to Farmers Growing Transgenic Crops

The economic advantage (or disadvantage) to farmers, expressed as gains or (losses) respectively, for the production of a specific crop is a key integrator and useful index for comparing the overall performance of any crop with other crop options, e.g. comparing transgenic and conventional crops. Economic advantage is always foremost in the mind of all farmers, large or small, acknowledging that small farmers will often assign a higher value to material rather than economic value. All farmers, including small resource-poor farmers, who may be illiterate, are shrewd and discerning judges of the performance of crops, which can literally impact on the ability of subsistence farmers to survive. The unprecedented high rate of acceptance and adoption of transgenic crops by small and large farmers in industrial and developing countries is arguably, from the farmer viewpoint, the most important testimony in favor of the thesis that transgenic crops provide higher and more stable economic advantages than their conventional counterparts. The scientific community, understandably, relies on systematic studies that measure economic advantage in order to establish whether transgenic crops result in greater economic benefits than corresponding conventional crops.

Studies to measure economic advantage of GM crops have used a variety of analytical approaches, ranging from regression analysis to rent creation studies, on-farm field experiments and farm surveys. Studies typically calculate the economic advantage (loss) per hectare and also express benefits or (losses) at the national level, which takes into account the area planted to transgenic crops in the country. Recent studies in both industrial and developing countries to measure national economic advantage or (losses) associated with transgenic crops are summarized, and referenced here, for the four major transgenic crops viz: herbicide tolerant soybean (Table 18), *Bt* cotton (Table 19), herbicide tolerant canola (Table 20) and *Bt* corn (Table 21).

In order to gain a "global" perspective of the economic advantage to farmers growing the major transgenic crops, data for 1999, the most recent complete set of data that is available for all the major four crops, is summarized in a multi-country table (Table 22). Finally, several studies are presented that characterize the distribution of benefits to the various stakeholders – farmers, consumers, the developers and distributors of transgenic crops. It is important to stress that the aim here, in concert with the global context of this review, is to provide a general overview of the economic benefits of transgenic crops rather than a detailed analysis of the individual studies which are referenced so that the readers can access further information to meet their specific needs. The economic benefit studies presented here include herbicide tolerant soybean in the USA and Argentina; *Bt* cotton studies in the USA, China and Argentina; herbicide tolerant canola in Canada; and *Bt* corn in the USA. Collectively these cover 92 % of the 39.9 million hectares of transgenic crops grown globally in 1999. Published studies of the economic benefits of herbicide tolerant corn and cotton were not available and hence information could not be included. It is hoped that publication in this review of the information on the economic benefits associated with transgenic crops will serve to stimulate additional and more comprehensive studies in the future.

9.5.1 Herbicide Tolerant Soybean

Herbicide tolerant soybean was the most dominant transgenic crop in 2000 occupying 25.8 million hectares and equivalent to 59% of the global transgenic crop area of 44.2 million hectares (James 2000a). The data in Table 18 show that there have been increasing and consistently significant benefits for producers of herbicide tolerant soybean in the USA from 1996 to 1999 with benefits ranging from $12 million in 1996 to $216 million in 1999. US and Argentina grew 99% of the HT soybean in 1999.

Herbicide tolerant soybean was first grown in the US in 1996 when it only occupied 2% of the soybean crop area and national benefits were estimated at $ 12 million (James 1998). As the transgenic area of herbicide tolerant soybean grew from 2% in 1996 to 13% in 1997, so did the benefits which increased 9-fold to $

109 million (Carpenter and Gianessi 2001). A second study (Falck-Zepeda et al 2000a) of the benefits from transgenic soybean in the US in 1997 estimated economic advantage to farmers ranging from $ 127 million to $ 808 million – recent unpublished information to reassess some of the assumptions in this study (Traxler 2001) indicate that the actual economic advantage is closer to the lower of the two estimates ($ 127 million), which is of the same order of magnitude ($ 109 million) as the other study on HT soybean in the US in 1997 (Carpenter and Gianessi 2001). Between 1997 and 1998 the adoption rate of HT soybean almost tripled in the US from 13% in 1997 to 37% in 1998. A significant corresponding increase in benefits to $ 220 million (Carpenter and Gianessi 2001) was reported for 1998 (Table 18). Unlike the tripling of HT soybean area between 1997 and 1998 (13% to 37%) the increase in adoption rate between 1998 and 1999 was modest (37% to 47%) and the benefits for 1999 were estimated at $ 216 million (Carpenter and Gianessi 2001) when approximately 15 million hectares of HT soybean was grown in the USA, with an economic return of between $ 14 and $ 15 per hectare.

The only independent review of the economic advantages of herbicide soybean in Argentina in 1999 is an initial study conducted at the University of Austral, Argentina, (Gunningham 2000). The work compared costs of growing herbicide tolerant soybean and conventional soybean in 1998/1999 and concluded that, compared with conventional soybean, HT soybean resulted in a significant decrease in cost of production, and that HT soybean was complementary with no-till systems which allowed farmers to use significantly more land for soybean production. The gains per hectare for HT soybean, compared with conventional soybean cost of production of HT soybean was of the order of $35/hectare with virtually all the gain associated with the lower costs for herbicide. An approximate estimate of the national economic advantage to Argentinean farmers growing HT soybean in 1999 is $ 214 million for the 6.1 million hectares of HT soybean reported by the Ministry of Agriculture for 1998/1999. Higher efficiency of HT soybean production, which requires only one herbicide, compared with several for conventional soybean, allows more land to be planted with soybean and provides a much more flexible window for the application of the herbicide. This advantage in flexibility, along with the coincidental adoption of no-till was correlated with increasing productivity and an increase in area planted to soybean, from 6 million hectares in 1996 to 7.8 million hectares in 1999. Thus the soybean area in Argentina increased by 30% in the three year period 1996 to 1999. Soybean area in Argentina has continued to grow, reaching 10.2 million hectares in 2000, which is an increase of over two-thirds compared with the 6 million hectares in 1996. This significant increase would not have been possible without the introduction of HT soybean in conjunction with no-till or low-till systems, which allows direct seeding of soybean in Argentina and conservation of soil moisture and nutrients, as well as control of erosion.

A second study in Argentina in the following season, 1999/2000, conducted by a private sector company documented the detailed costs

Table 18. Summary of National Economic Advantages to Farmers Planting Transgenic Herbicide Tolerant (HT) Soybean in USA and Argentina, 1996 to 1999

Country/Year	$ millions
USA	
1996	12[1]
1997	109[2]
1997	127-808[3]
1998	220[2]
1999	216[2]
Argentina	
1999	214[1]
Total for USA and Argentina in 1999	**430**

Source: Compiled by Clive James, 2001 from the following data: [1]James 1998; [2]Carpenter and Gianessi 2001; [3] Falck-Zepeda et al 2000a; [4]Gunningham 2000

of production and corresponding income for a 1000 hectare block of soybean comprising no-till conventional and no-till HT soybean (Rossi 2000). The results from this study showed that the economic advantage to producers in 1999/2000 of growing HT soybean, compared with conventional soybean, was equivalent to $55.64 per hectare, again with virtually all the savings resulting from the lower costs associated with weed control. Based on this study, the national economic gains from planting HT soybean in Argentina in 1999/2000 when 6.4 million hectares of HT soybean were planted, is estimated at $356 million. This benefit is higher than the $214 million estimate for 1998/1999 when both the gain per hectare ($ 35) and area planted to HT soybean (6.1 million hectares) were lower. For the purposes of estimating the national economic gain for Argentinean farmers growing HT soybean in 1998/1999, and the "global" gains (Table 22) for both the US and Argentina the estimate of $214 million from the independent study is used (Table 18) in the knowledge that it is lower than the estimated benefits of $356 million in 1999/2000. According to observers in Argentina, the economic advantage to farmers of growing herbicide tolerant soybean benefits can range from $ 35 to $ 55 per hectare depending on the season.

The USA and Argentina grew 99% of the HT soybean globally in 1999 and the estimated combined economic advantage of $ 430 million is the "global" economic advantage for producers growing herbicide tolerant soybeans in the USA and Argentina in 1999 (Tables 18 and 22). Of the four principal transgenic crops, soybeans, which occupied 54% of the total global area of transgenics in 1999, generated by far the greatest absolute economic advantage ($ 430 million) to producers.

Benefits of Herbicide Tolerant Soybean

US studies (Carpenter and Gianessi 2001) report that the benefits of herbicide tolerant soybean in 1999 were mainly associated with the following factors:

- a simple and flexible weed

management program at a significantly lower cost compared with conventional soybeans;

- application of one herbicide as opposed to several for conventional soybean;
- less phytotoxicity to soybeans and the crops that follow which is often corn;
- In summary, the primary benefit has been a reduction in weed control cost estimated at $ 216 million for US soybean growers and $ 214 million for Argentinean growers in 1999. The economic advantage associated with HT soybean is principally because of lower production costs associated with lower weed control costs and more effective and efficient weed control (Carpenter and Gianessi 2001, Gunningham 2000).

The general advantages described above apply to both the US and Argentina where there is a synergistic complementarity between herbicide tolerant soybean and no-till or reduced-till. In 1996, the area of HT soybean was only 50,000 hectares in Argentina whereas the area of no-till was 2.86 million hectares. In the short space of three years, the area of HT soybean increased rapidly from 50,000 hectares in 1996 to 6.1 million in 1999, with no-till having also increased to 4.5 million hectares equivalent to 58% of the total soybean crop area. The compatibility between no till and transgenic herbicide tolerant soybean has facilitated the rapid coincidental adoption of HT soybean and no till. The no-till HT soybean system allows conservation of soil moisture, structure and nutrients and the control of soil erosion, which are important elements that collectively contribute to sustainability. The work of Dr. Victor Trucco in Argentina (APRRESID 2001) illustrates that there are significant argonomic and economic advantages to combining the two technologies of HT soybean and no-till which together make an important contribution to sustainability in Argentina.

9.5.2 *Bt* Cotton

A total of 1.5 million hectares of *Bt* cotton was grown globally in 2000 with an additional 1.7 million hectares of cotton with stacked genes of *Bt* and herbicide tolerance (HT). Together, *Bt* and *Bt* /HT cotton comprised 3% and 4% respectively of the total global area of 44.2 million hectares of transgenic crops in 2000 (James 2000a). In 2000, *Bt c*otton was grown in the following six countries listed in descending order of transgenic *Bt* cotton area- USA, China, Australia, Argentina, Mexico and South Africa. It is noteworthy that four are developing countries representing each of the three Southern continents, Africa, Asia and Latin America with one industrial country from North America and the other from Asia Pacific. The majority of the global cotton area is planted by countries in the developing world which requires substantial quantities of insecticides to control the major lepidopteran insect pests of *Bt c*otton which can be effectively controlled through the deployment of *Bt* cotton. Cotton consumes more insecticides than any crop, worth $1.5 billion in 2000 (Wood Mackenzie Agrochemical Service 2001).

Assessments of the benefits associated with *Bt* cotton planted in 1999 are available from three countries, USA, China and Argentina that represent 92% of the *Bt* cotton grown in 1999. The US first planted *Bt* cotton in 1996 when it occupied 12% of the total cotton crop area. In subsequent years *Bt* cotton (*Bt* and *Bt*/herbicide tolerance) steadily increased its share from 12% in 1996, to 18% in 1997, 23% in 1998, 32% in 1999, and 39% in 2000. Cotton growers in the US were the first to plant a significant proportion of the crop to transgenics and they still maintain that lead in 2000 with 72% of the cotton crop planted to transgenics that include *Bt*, *Bt* /HT and HT varieties. *Bt* cotton is deployed to control three major insect pests of cotton, tobacco cotton bollworm, tobacco budworm, and pink bollworm. Prior to the advent of *Bt* crops, farmers relied on intensive programs of insecticide sprays which were not only damaging to the environment, but were constantly becoming ineffective because of the development of resistant strains of the insect pests. Subsequent to the advent of *Bt* cotton, farmers have been able to practice more effective pest management programs featuring significantly fewer insecticide sprays, higher yields and greater economic advantage. In 1998 and 1999 US *Bt* cotton farmers reduced the amount of insecticide (active ingredient) used by 900 metric tons in 1998, and 1,200 metric tons in 1999 (Carpenter and Gianessi 2001).

The data in Table 19 show that US cotton farmers have realized consistently high economic advantages since the introduction of *Bt* cotton in 1996. The national economic advantage to US cotton farmers in 1996 was estimated to be $ 142 million (Falck-Zepeda et al 2000b). The same authors estimated the economic advantage to US *Bt* cotton farmers in 1997 at $ 80 million (Falck-Zepeda et al 2000a). The economic advantage to *Bt* cotton farmers in the US in 1998 and 1999 were reported to be $ 92 million and $ 99 million respectively (Carpenter and Gianessi 2001). Thus, for five consecutive years 1996 to 1999, US *Bt* cotton farmers have realized a national

Table 19. Summary of National Economic Advantages to Farmers Planting Transgenic *Bt* Cotton in USA, China and Argentina, 1996 to 1999

Country/Year	$ millions
USA	
1996	142[1]
1997	80[2]
1998	92[3]
1999	99[3]
China	
1999	139[4]
Argentina	
1999	1[5]
Total for USA, China and Argentina in 1999	**249**

Source: Compiled by Clive James, 2001 from the following sources: [1] Falck-Zepeda et al 2000b; [2] Falck-Zepeda et al 2000a; [3] Carpenter and Gianessi 2001; [4] Pray et al 2001; [5] Elena 2001 economic advantage/benefit averaging approximately $ 100 million per year.

Cotton is the most important cash crop in China but is subject to very heavy damage to bollworm. In the past, the cotton area in China was as high as 6.7 million hectares but severe damage due to cotton bollworm (*Helicoverpa armigera*) reduced this by 40% to an estimated 4.0 million hectares by 1999. An important implication is that China is now an importer of cotton whereas formerly it was an exporter. Loss due to cotton bollworm in 1992 (Jia 1998) was valued, at the national level, to be 10 billion RMB equivalent to US$ 1.2 billion (calculated at the official exchange rate of 8.27 RMB = US$1.00).

There are two suppliers of *Bt* cotton in China. The first is the Chinese Academy of Agricultural Sciences (CAAS) in collaboration with provincial academies and seed distribution organizations. The first commercial plantings of the CAAS *Bt* cottons in 1998 featured a single *Bt* gene (Cry1B/Cry1C) on 10,000 hectares planted in four provinces (Anhui, Shangdong, Shanxi, and Hubei) (Jia 1998, James 1998). By 1999, the CAAS single *Bt* cottons, and the stacked *Bt* /CpTI cottons (designed to provide more durable resistance), occupied an area 12 fold greater than 1998 to cover a total 120,000 hectares. It is estimated that at least 750,000 small farmers grew CAAS *Bt* cottons in 1999, most of which carried the single *Bt* gene. Estimates of the benefits associated with *Bt* cotton in 1998 (Jia 1998, James 1998) indicated that the benefits to farmers were due to significantly reduced needs for insecticides and the associated labor costs of applying them. Savings were conservatively estimated at 1,200 RMB to 1,500 RMB per hectare, equivalent to $ 145 to $ 182 per hectare which is a substantial increase in income for a small resource-poor farmer who is planting, on average approximately 0.15 hectare of *Bt* cotton. These estimates of economic gains do not include the additional significant social, environmental and health benefits associated with reduced applications of pesticides, which pose very serious health hazards to small producers applying a large number of insecticide sprays to control cotton bollworm in China.

The second supplier of *Bt* cotton in China is Monsanto/Delta Pine whose product is based on the variety 33B, which carries the Cry1A(c) gene. In 1998 this occupied 53,000 hectares in Hubei province and increased almost 2.5 fold to approximately 125,000 hectares in 1999. It is grown by an estimated 750,000 small farmers and occupying the same area as the Chinese *Bt* cotton in 1999 and 2000 when total area reached 500,000 hectares. Taking into account the *Bt* cottons deployed by both CAAS and Monsanto/Delta Pine in China there has been remarkable progress with both products since the *Bt* cottons were first deployed. In the brief space of 3 years, *Bt* cotton in China has increased from small introductory areas in 1997 to 63,000 hectares in 1998, to 245,000 hectares in 1999 (a 3.9 fold increase in one year), and 500,000 hectares in 2000. An estimated total of up to 3 million small farmers benefited from both CAAS and the Monsanto *Bt* cotton products in 2000. The initial 400,000 small farmers who first adopted *Bt* cotton in 1998 derived significant and multiple benefits from the technology. Because farmers who adopted *Bt* cotton in 1998 were very satisfied with the experience, they were keen to continue with the practice in 1999 and were joined by more than 1million other small cotton farmers which in turn led to the planting of 245,000 hectares of *Bt* cotton in 1999 and 500,000 hectares in 2000 planted by approximately 3 million small farmers.

A detailed survey and economic analysis of *Bt* cotton production in China was conducted in 1999 as a collaborative project between the Chinese Academy of Sciences and Rutgers University (Pray et al 2001, and Huang et al 2001). The survey involved a sample of 283 cotton farmers in northern China. The major findings were that farmers planting *Bt* cotton were able to reduce the number of insecticide applications substantially, and coincidentally benefit from high yield and lint quality. In China, the main economic impact of *Bt* cotton is to reduce the cost of cotton production by a significant 20 to 23% (Pray et al 2001, and Huang et al 2001). The derived benefits per hectare for small farmers growing *Bt* cotton in China in 1999 ranged from $ 330 to $ 400. This translates to a collective national economic benefit of $ 139 million (Table 19) for the 1.5 million Chinese small farmers that grew *Bt* cotton in 1999. It is noteworthy that the smaller farmers whose farms were less than one hectare gained more than twice as much income per unit of land from *Bt* cotton ($ 400 per hectare) compared with large farmers ($ 185 per hectare) farming 1 hectare or more.

The third and last study reported here was conducted in Argentina where most of the cotton production is on medium to large farms with around 10% of cotton production on small farms. Argentina grows up to 750,000 hectares of cotton and the first transgenic *Bt* cotton was introduced in 1998 when an introductory area of approximately 5,000 hectares was planted. The area of *Bt* cotton has increased slowly. A survey of *Bt* cotton growers in Argentina reported that *Bt* cotton generated an average incremental benefit of $ 65.05/ha (Elena 2001) which translated to a modest national benefit of less than $1 million on the 10,000 hectares planted in 1999 (Table 19). *Bt* cotton plantings in Argentina increased from 10,000 hectares in 1999 to 30 to 40,000 hectares in 2000.

Benefits of Bt cotton

- Effective control of the most destructive insect pests of corn – the corn borers;
- Significant reduction in quantity of insecticides (active ingredient), in the US a reduction of 900 metric tons of insecticide (a.i.) in 1998, and 1,200 metric tons (a.i.) in 1999; similarly in China a reduction of 15,000 metric tons of insecticide (formulated) in 1999;
- Increased yields and production, e.g. an additional production of 80,740 metric tons from *Bt* cotton in the US in 1998, and 117,935 metric tons in 1999;
- A safer environment with less pesticide residues;
- Fewer health hazards and pesticide

poisonings in China, particularly important for small farmers using hand sprayers for pesticide application in developing countries;

- Significant economic advantage to farmers totaling $ 92 million in the US in 1998 and $ 99 million in 1999; similarly in China a benefit of $ 139 million in 1999 with a range of $ 330 to $ 400 economic advantage per hectare.

9.5.3 Herbicide Tolerant Canola in Canada

Herbicide tolerant canola was the third most dominant transgenic crop globally in 2000 occupying 2.8 million hectares, equivalent to 6% of the global transgenic crop area of 44.2 million hectares (James 2000a). The data in Table 20 show the benefits for producers of herbicide tolerant canola in Canada from 1996 to 1999. About 2.5 million of hectares of HT canola were grown in Canada in 2000 with the balance of approximately 0.3 million hectares in the US. In Canada HT canola was first grown in 1996 when it only occupied 4% of the canola crop area but quickly increased to 12% in 1997, to 35% in 1998, 53% in 1999, and 55% in 2000 (Canola Council of Canada 2001). The data in Table 20 indicate that the economic advantage to farmers in 1996, when only 4% of the canola was planted to HT canola, was $ 5 million, increasing to $ 18 million in 1997 when adoption had tripled to 35%. The economic advantage associated with HT transgenic canola continued to increase to $ 46 million in 1998 and to $ 66 million in 1999, when more than half of the canola area in Canada was HT transgenic canola.

Benefits of Herbicide Tolerant Canola
Canadian studies (Canola Council of Canada 2001) report that in 1999 Canadian HT transgenic canola farmers earned an additional $Can 13.51/acre (Booth 2001) equivalent to $Can 33.37 or $US 22.02 per hectare (at the exchange rate of US $0.66 = Can $1.00) compared to growers who planted conventional varieties. This gain of $22.02 per hectare translated to a national benefit of US $ 66 million in 1999 for approximately 3 million hectares of HT canola in Canada in 1999. The benefits of herbicide tolerant canola in Canada in 1999 were mainly associated with the following factors:

- more effective and efficient weed control - ease and flexibility of

Table 20. Estimates of National Economic Advantages to Farmers Planting Transgenic Herbicide Tolerant Canola in Canada, 1996 to 1999

Year	$ millions
1996	5[1]
1997	18[2]
1998	46[2]
1999	66[2]
Total Canada in 1999	**66**

Source: Compiled by Clive James, 2001 from the following data: [1] James 1998; [2] Canola Council of Canada 2001 management was the key advantage cited by growers;

- earlier seeding, access to higher yielding varieties and moisture availability plus earlier harvesting were the three drivers that were instrumental in the adoption of HT canola;

- an increase in yield of approximately 200 kg. per hectare equivalent to a more than 10% increase in yield;

- cleaner harvest with less dockage for unclean grain;

- majority of HT canola farmers reported that they used zero or minimum till with only 18% of HT canola farmers practicing summer fallow compared with 36% for conventional canola;

- over 1 million hectares have been positively impacted by increased conservation tillage since the introduction of HT canola;

- cost of weed control for HT canola was 40% lower than conventional although the number of herbicide sprays were slightly higher for transgenic (2.07 versus 1.78);

- reduction in herbicide estimated at 1,500 tons in 1997 and 6,000 tons in 2000;

- fuel savings, associated with HT canola of 9.5 million liters in 1997 and 31.2 million liters in 2000;

- economic advantage of $ 22.02 per hectare equivalent to a national economic benefit to Canadian HT canola farmers of $ 66 million in 1999;

- in summary, the total economic and agronomic impact of transgenic canola has been very positive with agronomic advantages outweighing the significant economic gains to HT canola farmers.

9.5.4 *Bt* Corn

Bt corn was the second most dominant transgenic crop in 2000 occupying 6.8 million hectares equivalent to 15% of the global transgenic crop area of 44.2 million hectares (James 2000a). The USA is the world's largest producer of corn, which occupies 32 million hectares, about one quarter of the area of all US crops. The US corn crop is valued at about $18 billion annually, which is 20% of the value of all crops in the US (Carpenter and Gianessi 2001). In 2000, the USA grew 92% of the *Bt* corn grown worldwide. In 1999, the US grew 8.9 million hectares of *Bt* corn (26% of US corn crop) of which approximately 7 million hectares were *Bt* and 1.9 million hectares were the stacked genes of *Bt* and herbicide tolerance.

The data in Table 21 show that in the US the economic advantage to *Bt* growers were positive for 1996 and 1997, and negative for 1998 and 1999. *Bt* corn was deployed in the

Table 21. Estimates of National Economic Gains (Losses) to Farmers Planting Transgenic *Bt* Corn in USA, 1996 to 1999

Year	$ millions
USA	
1996	12[1]
1997	89[2]
1998	(26)[2]
1999	(35)[2]
Total USA in 1999	**(35)**

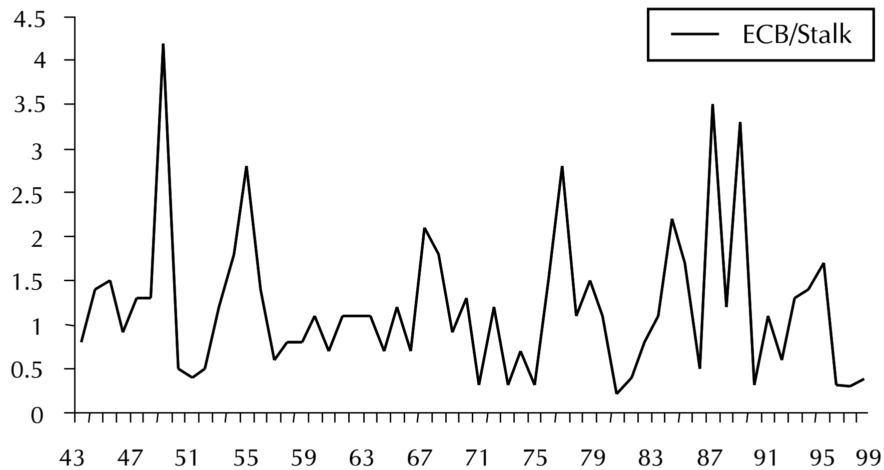
Source: Compiled by Clive James, 2001 from the following data: [1] James 1998; [2] Carpenter and Gianessi 2001

US to control the economically important insect pest European Corn Borer (ECB) which can cause annual yield losses of up to 7.5 million tons valued at up to $1billion per year. Given that the infestation level of ECB varies significantly from year to year, it is to be expected that the economic advantage to farmers deploying *Bt* corn to be positive in years when infestations are high (1996 and 1997) and negative when the infestations are low (1998 and 1999). This is exactly what happened in the US during the period 1996 to 1999 (Table 21).

Bt corn was first grown in the US in 1996 when it occupied 1% of the corn crop area. In 1996 the infestation level of ECB was moderately high (1.4 borers/stalk – see Figure 7) and national benefits were estimated at $ 12 million (James 1998) as noted in Table 21. The transgenic area of *Bt* corn in the US grew six-fold from 1% in 1996 to 6% in 1997, when ECB infestation was a little higher than 1996, at 1.6 borer /stalk; as a result of the increase in *Bt* corn area and higher ECB infestation in 1997, compared with 1996, benefits to farmers increased to $ 89 million in 1997 (Carpenter and Gianessi 2001).

Between 1997 and 1998 the area of *Bt* corn tripled from 6 to 18% but the ECB infestation level dropped precipitously to an historically low level of 0.3 borers/stalk. As a result, farmers deploying *Bt* corn in 1998 incurred a negative return of $ 26 million (Carpenter and Gianessi 2001). The area of *Bt* corn increased modestly between 1998 and 1999 from 18 to 26% but ECB infestation at the same historical low level as 1998 (0.3 borers/stalk). Farmers growing *Bt* corn in 1999 incurred a negative return of $35 million compared with $ 26 million in 1998 (Table 21). The negative economic advantage would be expected to be higher in1999 than 1998 because *Bt* corn was deployed on a larger area (26%) in 1999 compared with 18% in1998. Thus, the pattern of economic advantages for farmers using *Bt* corn during the period 1996 to 1999 is closely correlated with the level of infestation of ECB; the higher the ECB infestation the higher the economic advantage to farmers. Historically, infestation levels of ECB were monitored for the period 1986 to 1998 in Illinois (Figure 7). During this period farmers would have expected to gain from deploying *Bt* corn in 10 out of the 13 years, equivalent to a 77% probability of a positive economic return for *Bt* corn (Carpenter and Gianessi 2001).

Figure 7. European Corn Borer Densities in Illinois, 1943 to 2000



Source: Janet Carpenter, 2001 (Personal Communication). Updated from Carpenter and Gianessi 2001.

Benefits of Bt corn

Benefits will be directly related to the level of infestation by corn borers – there are different types of borers whose economic importance as pests will vary with geography. Detailed studies in the US (Carpenter and Gianessi 2001) report that the benefits for farmers deploying *Bt* corn in the US are mainly associated with the following circumstances:

- *Bt* corn, has for the first time, provided farmers access to a technology that allows cost-effective control of European corn borer which is very difficult to control with insecticides and for which there is an inadequate level of pest resistance in conventional corn varieties.

- Increases in yield and US corn production as a result of the elimination of significant yield losses to ECB. Annual increases in production of up to 7.5 million tons per year when there are severe infestations of ECB. *Bt* corn farmers in the US realized increases of production of 1.5 million tons in 1998 and 1.7 million tons in 1999 even when ECB infestation was at its lowest historically. There is speculation that the low levels of ECB in 1998 and 1999 could be partly due to effective control of ECB through *Bt* corn in1996 and 1997 when ECB levels were high in conventional corn, but effectively controlled in *Bt* corn.

- It is expected that deployment of *Bt* corn will result in economic gains to farmers 3 years out of 4 in the US.

- Elimination of the need for insecticides to control ECB - this translates to a modest reduction in usage of insecticides on corn at the national level that results in a safer environment. Deployment of *Bt* corn precluded the need for 800,000 hectares of *Bt* corn to be treated with insecticides in 1998, and 400,000 hectares in 1999.

- Lower levels of mycotoxin compared with conventional corn, which results in safer and healthier food and feed products derived from *Bt* corn.

- In summary, the primary benefit is cost-effective control of a major and economically important pest with significant concomitant increases in yield/ production and safer and healthier food and feed products.

9. 5. 5 "Global" overview of economic advantage to GM crop farmers in 1999

In order to gain a "global" perspective of the economic advantage to farmers planting transgenic crops, data for 1999, which is the most recent complete set of data that is available for all the major four crops, is summarized in a multi-country table (Table 22). The studies on economic advantages reviewed above are representative of transgenic crops globally because: they cover a high percentage (>90%) of the global area where each of the four major transgenic crops are deployed; they include the four major industrial and developing countries (USA, Canada, Argentina and China) that grow 99% of the transgenic crops in 1999; and they represent both large and small farmers. The data in Table 22 indicate that in absolute terms HT soybean provided the greatest "global" economic advantage to farmers. The global economic advantage for herbicide tolerant soybeans, which also occupied the highest proportion (54%) of the global area of transgenic crops in 1999, was $430 million. The annual economic advantage studies conducted in the US on HT soybean from 1996

Table 22. "Global" Economic Advantages to Farmers growing HT Soybean, *Bt* Cotton, HT Canola and *Bt* Corn in 1999

Crop/Countries	$ millions	$ Gain (Loss) per Hectare
HT Soybean (USA and Argentina)	430	20
Bt Cotton (USA, China and Argentina)	249	104
HT Canola (Canada)	66	22
Bt Corn (USA)	(35)	(4)
Total	**710**	

Source: Compiled by Clive James 2001 from Tables 18, 19, 20 and 21.

to 1999 indicate that the economic returns in the US have been consistently high during the four year period (Table 18).

Whereas the HT soybean global economic advantage is the highest of all crops, the economic advantage per hectare ($ 20) is at approximately the same level as canola ($ 22) but only 20% of that of *Bt* cotton, which has by far, the highest economic advantage per hectare at $104. In 1999, the “global” economic advantage to farmers for *Bt* cotton was an impressive $ 249 million. Studies in the US show that the national annual economic advantage for *Bt* cotton farmers has been fairly consistent at $ 128 million, $ 80 million, $92 and $99 million from 1996 to 1999 respectively. Whereas the economic advantage to *Bt* cotton farmers is likely to vary over time, simply because of the known inherent annual variability in insect pest infestations, to date it has been fairly consistent, with the highest economic advantage per hectare ($ 330 to $400) reported for China (Pray et al 2001). The high “global” and per hectare economic advantage for *Bt* cotton augers well for the crop and these significant benefits are likely to accelerate both the number of countries growing the crop and the adoption rates of *Bt* cotton in the near term. The fact that cotton is principally a fiber crop, and not a major food or feed crop, also makes it an attractive pilot transgenic crop for countries wishing to grow transgenic crops for the first time. Finally, in addition to its significant economic advantage *Bt* cotton has had considerable impact in reducing insecticides and thereby decreasing health hazards and insecticide poisonings for small farmers. This is a very important benefit given that environmental considerations are becoming increasingly important in a world that is more concerned about safety, health and the environment.

The Canola Council of Canada completed a four-year study (Canola Council of Canada 2001) to qualify and quantify the agronomic and economic benefits associated with transgenic canola in Canada during the period 1997 to 2000. The data in Table 20 summarizes the economic advantage to HT canola farmers in Canada in 1999 and indicate that the national economic gain for farmers was $ 66 million based on an economic advantage to HT canola growers of $ 22 per hectare. The Council study confirms that the benefits to farmers have been consistent during the last four years with the economic advantage to farmers increasing from Can$ 27 million (US$ 18) in 1997, to Can$ 69 million (US$46) in 1998 and US$ 66 million in 1999. The Council study further concluded that the cumulative economic impact of transgenic canola production in Canada during the four year period 1997 to 2000 to be up to Can$ 464 million (equivalent to US$ 300 million at exchange rate of 0.66) inclusive of direct (farmer) and indirect benefits to society. This translates to an average annual direct/indirect economic advantage of $ 77 million. In summary, the economic advantage for HT canola farmers in Canada has been positive and consistent since its introduction in 1996.

Whereas data in Table 21 indicate that US *Bt* corn farmers generated positive economic returns in both 1996 ($ 12 million) and 1997 ($ 119 million), data in Table 22 indicate that *Bt* corn is the only one of the four major transgenic crops to result in a negative economic return to US farmers in 1999. The reason is that the historically low level of infestation of ECB in 1999 in the US resulted in yield losses that were below the economic threshold for cost-effective control. This can be expected to happen in only one year in four. Indeed in 1999, whereas the US reported a negative economic return of $ 35 million, equivalent to $4 per hectare, on its 8.9 million hectares of *Bt* corn (Carpenter and Gianessi 2001), Argentina estimated a positive economic return on its 250,000 hectares of *Bt* corn as result of an estimated increase in yield of 10 to 20 % (ASA 2001).

It is noteworthy that variations in corn borer populations will continue to occur between years, between countries and current forecasting techniques do not allow reliable prediction of the probability of damage before planting. The negative economic advantage for 1999 does not imply that *Bt* corn technology does not offer significant economic advantages to corn farmers in both industrial and developing countries. On the contrary, US farmers can expect a positive economic advantage three years out of four. Further, *Bt* technology increased corn production for farmers deploying *Bt* corn in the US in 1998 and 1999 by 1.5 and 1.7 million tons respectively. In years of high infestation with ECB, corn production could be increased by 7.5 million tons.

In general, corn borer populations cause more damage in the developing countries than in industrial countries. Several developing countries including China and the Philippines have conducted advanced and promising field trails with *Bt* corn, and others like Argentina and South Africa are already deriving significant benefits and steadily expanding the area under cultivation with commercial transgenic *Bt* corn. Given the importance of corn as one of the three major staples and the significant advantages that *Bt* corn offers, the crop can make a unique contribution to the control of pests that do not lend themselves for effective control by other means. *Bt* corn can make a vital contribution to food, feed and security and is less likely to contain levels of mycotoxins that can be harmful in conventional corn.

In summary, the "global" economic advantages to farmers deploying HT soybean, *Bt* cotton, HT canola and *Bt* corn in 1999 are estimated to be of the order of $ 710 million (Table 22); of the $ 710 million approximately 60 % is derived from HT soybean, 30 % from *Bt* cotton and 10 % from HT canola. The estimate of $ 710 million is intended to provide an order of magnitude assessment of the direct economic advantage to 2 million small and large farmers who planted 39.9 million hectares of transgenic crops in 1999. In addition to the direct economic advantage that farmers generate from transgenic crops, several studies have shown that there are other significant indirect benefits to others in society, which are of the same order of magnitude. Thus, the "global" direct and indirect economic advantage associated with the 39.9 million hectares of transgenic crops in 1999 is likely to be of the order of $1 billion or more. More studies on the economic impact of transgenic crops are to be encouraged which will allow continued monitoring and assessment of the economic, environmental and social impact of transgenic crops. This will generate the information that will allow society to be better informed and knowledgeable about the contribution of GM crops to global food security.

9.5.6 Distribution of economic benefits to stakeholders

One of the "corporate" concerns often voiced by the critics of biotechnology relates to their perception that, the developers of transgenic crops (usually, but not exclusively private sector transnational corporations) are the major or sole beneficiaries from transgenic crops. Analysis of *Bt* cotton in the US over a three-year period 1996 to 1998 (Falck-Zepeda et al 1999) indicates that "farmers share the rents created by the technology almost equally with innovators even when a monopolistic structure for the input market is assumed." A summary of the findings of these US cotton studies, as well as other studies are presented here to characterize the distribution of benefits to the various stakeholders associated with transgenic crops – farmers, consumers, the developers of the technology, seed suppliers, consumers and global society at large as represented by the category Rest of the World in Table 23.

Two studies by the same authors featuring *Bt* cotton in the US in 1996 and 1997 are summarized in Table 23. The first study (Falck-Zepeda *et al* 2000b) indicates that of the total economic surplus of $ 240 million generated through the use of *Bt* cotton in the USA in 1996, the relative economic advantages to the various stakeholders were as follows: the largest share of the economic surplus went to US farmers 59% ($ 142 million), the developer of the technology 21% ($ 50 million), the seed supplier 5% ($ 12 million), US consumers 9% ($ 22 million) with the balance of 6% ($ 14

Table 23. Distribution of Economic Surplus Associated with Transgenic *Bt* Cotton Planted in USA in 1996 to 1997

Beneficiary	1996[1]		1997[2]	
	$ million	% total	$ million	% total
US Farmer Surplus	142	59	80	42
Technology Developer[3]	50	21	67	35
Seed Supplier	12	5	18	9
US Consumer	22	9	14	7
Net Rest of the World	14	6	11	7
Total Surplus	**240**	**100**	**190**	**100**

Source: Modified from Falck-Zepeda et al 2000b[1] and 2000a[2],
[3] Gross revenue - R&D, marketing and other costs not deducted.

Table 24. Distribution of Economic Surplus Associated with Transgenic Herbicide Tolerant Soybean Planted in USA in 1997

Beneficiary	Supply Elasticity = 0.22		Supply Elasticity = 0.92	
	$ million	% total	$ million	% total
US Farmer Surplus	808	76	127	29
Technology Developer[1]	78	7	78	18
Seed Supplier[1]	32	3	32	7
Net Rest of the World US	99	9	124	29
US Consumer	44	5	76	17
Total Surplus	**1,061**	**100**	**437**	**100**

Source: Modified from Falck-Zepeda et al 2000a.
[1] Gross revenue - R&D, marketing and other costs not deducted.

million) as economic surplus to the rest of the world. Note also that the share of the surplus to the technology developer and the seed supplier is gross revenue, with R & D marketing and other costs not deducted, whereas the share to the farmers and consumers are net gains. This under-estimates the relative gains to farmers and consumers versus the technology developer and seed supplier.

The findings of the second study (Falck-Zepeda et al 2000a) on the distribution of economic surplus associated with transgenic cotton planted in the US in 1997 is also summarized in Table 23. This study showed that of the total surplus of $ 190 million, again the largest share of the economic surplus went to farmers, 42% ($ 80 million), the developer of the technology 35% ($ 67 million), the seed supplier 9% ($ 18 million), US consumers 9%. The balance of 14% was equally shared by US consumers ($ 14 million) and others in society ($ 11 million) referred to as net rest of the world (Table 23).

A third study by the same authors assessed the distribution of the economic benefits associated with HT soybean grown in the US in 1997. The authors estimated the benefits using two different assumptions about US supply elasticity, which generated very different values (Table 24). Under the lower elasticity assumption, farmers captured 76% of the economic surplus compared with 7% for technology developers and 3% for seed suppliers. The balance of 14% was shared between the rest of the world (9%) and US consumers (5%). For the higher assumed elasticity model, farmers captured 29% of the economic surplus compared with 18% for technology developers and 7% for seed suppliers; the balance of 44% was shared between the rest of the world (29%) and US consumers (17%).

The final case study summarized here is for China (Pray et al 2001) which provides information on economic advantages to small farmers in China acquiring *Bt* cotton from two different developers of technology: one source is the public sector and the other the private sector. In the case of the *Bt* cotton developed by both public sector and private sector, the farmers' share of surplus (Table 25) was 83% (Pray et al 2001). Another important finding of the China *Bt* cotton study was that the smallest farmers, those farming less than 1 hectare, gained more than twice as much income per unit of land ($ 400 per hectare) from *Bt* cotton, as the larger farmers ($ 185 per hectare). This finding is important from an equity/distribution viewpoint and is deserving of further investigation for *Bt* cotton and other transgenic crops that offer promise to small resource poor farmers. It also has important implications in relation to the claim often made by critics of transgenic crops that they are inappropriate for small farmers. Indeed, by far the largest benefits reported to-date from the studies reviewed here, have been for small farmers who can least afford the loss in yield due to pests, and stand to gain the most from increases in income and suffer less health hazards resulting from fewer applications of conventional insecticide.

Taking into account all of the eight case studies on the distribution of benefits to stakeholders, there is no evidence (Table 25) to support the perception of the critics of biotechnology that the transnational corporate developers of transgenic crops are the major or sole beneficiaries from transgenic crops. On the contrary, the summary of relative benefits

Table 25. Distribution of Share of Economic Surplus from Transgenic Crops (expressed as %), for Different Stakeholders

	***Bt*[1] Cotton 1996 USA**	***Bt*[2] Cotton 1997 USA**	***Bt*[3] Cotton 1998 USA**	**HT[4] Soy 1997 USA**	***Bt*[5] Cotton 1997 Mexico**	***Bt*[5] Cotton 1998 Mexico**	***Bt*[6] Cotton Public 1999 China**	***Bt*[6] Cotton Private 1999 China**
Farmers	**59**	**42**	**46**	**29**	**61**	**90**	**83**	**83**
Tech Developer[7]	21	35	34	18	31	8	–	12
Seed Supplier[7]	5	9	9	7	8	2	17	5
Cosumers	9	7	7	17	–	–	–	–
Net Rest of World	6	7	4	29	–	–	–	–
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: Compiled by Clive James, 2001 from the following sources: [1] Falck-Zepeda et al 2000b; [2] Falck-Zepeda et al 2000a; [3] Falck-Zepeda et al 1999; [4] Falck-Zepeda et al 2000a; [5] Traxler et al in Press; [6] Pray et al 2001.
[7] Gross Revenue R&D, marketing and other costs not deducted.

expressed as % share of economic surpluses in Table 25 confirms that not only were farmers significant beneficiaries in all studies but were consistently the major beneficiaries in all eight studies with an average share of one third to one half or substantially more of the economic surplus. The studies to-date indicate that the relative economic advantages are not dissimilar to farmer/input supplier benefit ratios that apply to conventional agricultural products and are not heavily in favor of the developers of transgenic crops as some critics have suggested. It is noteworthy that the distribution of economic benefits for the five *Bt cotton* studies in Table 25 consistently indicate that the consumers/rest of the world share of the benefits is small (15% or less). This is not the case for the one soybean case study where US consumers share 17% of the surplus and the rest of the world 29%. for a total of 46 %. This is to be expected and is due to the price elasticity characteristics of the soybean crop largely traded for export on the international market. In the last five years soybean area and production has significantly increased and has been impacted by transgenics in both the USA and Argentina. The production area of HT soybean in Argentina has almost doubled in the last five years with significant area increases also reported for the US. In turn this has resulted in significant, if not visible benefits to consumers globally - 54% of the global transgenic crop area of 39.9 million hectares in 1999 was occupied by herbicide tolerant soybean. This aspect of the distribution of benefits to consumers associated with transgenics crops such as HT soybean is an area that is deserving of further studies by economists specializing in this area of research.

9. 6 Summary

In summary, the unprecedented rapid adoption of transgenic crops during the five-year period 1996 to 2000 reflects the significant multiple benefits realized by large and small farmers in the 15 industrial and developing countries that have grown transgenic crops commercially. There is an increasing body of evidence to confirm that improved weed and insect pest control is achieved with transgenic herbicide tolerant and insect resistant *Bt* crops. These GM crops also benefit from lower input and production costs which translate to significant economic advantages to farmers compared with corresponding conventional crops. The severity of weed and insect pests varies from year to year and hence this will directly impact on pest control costs and net economic advantage.

Despite the on-going debate on GM crops, particularly in countries of the European Union, millions of large and small farmers in both industrial and developing countries continue to increase their plantings of GM crops because of the significant multiple benefits they offer. Since 1996, when the first commercial GM crops were grown, the global GM crop area has grown by an unprecedented 25-fold increase. This high adoption rate is a strong vote of confidence in GM crops, reflecting grower satisfaction. Several studies have confirmed that farmers planting herbicide tolerant and insect resistant *Bt* crops are more efficient in managing their weed and insect pests. More specifically the use of transgenic crops result in: more sustainable and resource-efficient crop management practices that require less energy and conserve natural resources; more effective control of insect pests and weeds; less dependency on conventional pesticides that can be a health hazard to small farmers through reduced number of conventional herbicide and insecticide applications; greater operational flexibility in timing of herbicide and insecticide applications; conservation of soil moisture, structure, nutrients and control of soil erosion through no or low-tillage practices as well as improved ground and surface water quality with less pesticide residues; improved pest control, lower cost of production and improved yields all contribute to a greater economic advantage to farmers who can utilize the technology to develop more sustainable farming systems.

The adoption of biotech crops has contributed to a significant reduction in the overall amount of pesticides used in crop production, which has positive impact on biodiversity, non target insect species and predators and the environment generally. The use of *Bt* maize has reduced the levels of the fumonisin mycotoxin in maize grain that provide safer and healthier products. The potential health benefits associated with fewer pesticide poisonings on *Bt* cotton in China is an important finding, with significant implications for other developing countries where small farmers in particular may be at similar risk from heavy and over-use of conventional pesticides.

There is an increasing body of compelling evidence that transgenic crops are delivering significant economic benefits and some of these have been documented in this overview. The "global" economic advantage to farmers deploying HT soybean, *Bt* cotton, HT canola and *Bt* corn is estimated to be of the order of $700 million in 1999, of which approximately 50% is in the developing world. The estimate is intended to provide an order of magnitude assessment of the direct economic advantages to 2 million small and large farmers who planted 39.9 million hectares of transgenic crops in 1999.

In addition to these direct economic advantages that farmers derive from transgenic crops, all of the studies have confirmed that there are also indirect benefits to others in society that are significant. For crops such as herbicide tolerant soybean, these indirect benefits to consumers globally can be of the same order of magnitude as the direct economic advantages of $700 million to farmers in 1999. Thus, the "global" direct and indirect economic advantages associated with the 39.9 million hectares of transgenic crops in 1999 is likely to be of the order of $ 1 billion or more. There is no evidence to support the perception of the critics of biotechnology that the transnational developers of transgenic crops are the sole or major beneficiaries from transgenic crops. On the contrary, studies to-date confirm that not only are farmers significant beneficiaries, but they are the major beneficiaries, taking on average from one-third to one-half or more, of the total economic surplus generated by transgenic crops.

Acknowledging that there is a continuing need to monitor the deployment of any new technologies, countries not growing transgenic crops commercially at this time should take advantage of the opportunity to re-evaluate their policy and determine whether they might also benefit from this technology. Industrial and developing countries already growing transgenic crops commercially are in the best position to share their first-hand practical experience in an open exchange. ISAAA's mandate, through its Global Knowledge Center and portfolio of crop biotechnology transfer projects is to facilitate the sharing of such information and knowledge with developing countries and, upon request, assist them in accessing appropriate applications that can contribute to food, feed and fiber security, a safer environment and a more sustainable agriculture. Documenting the benefits, as well as the constraints, associated with transgenic crops is a necessary step in the sharing of information that supports a knowledge-based decision making process in which society should participate, be well informed and fully engaged in the decision-making on transgenic crops.

10. THE FUTURE - CONCLUDING COMMENTARY

An estimated 3.5 million farmers grew transgenic crops in 2000 and derived multiple benefits that included significant agronomic, environmental, health and economic advantages. In 2001 the number of farmers planting GM crops is expected to grow substantially to 5 million or more. Global area planted to transgenic crops is expected to continue to grow by 10% or more in 2001 despite the unprecedented high percentage of the principal crops already planted to transgenics in the USA, Argentina, Canada and China. In 2001, these top four countries are expected to report a further significant increase in the area of transgenic crops.

The other ten countries growing transgenic crops in 2000 are expected to report modest growth in GM crop area, except France and Germany, which will probably continue to grow a small token area of *Bt* maize. South Africa is expected to continue to diversify and expand its portfolio of transgenic crops, with Australia approving and commercializing more traits in cotton. Indonesia will commercialize *Bt* cotton for the first time. India is progressing towards approval of *Bt* cotton which could occur in early 2002. The commercialization of herbicide tolerant soybean in Brazil will be dependent on resolving the outstanding issues between the Ministries of Agriculture, Environment and Justice. The commercialization of GM crops in India and Brazil will represent a watershed for developing countries in that the three most populous countries in Asia – China, India, and Indonesia with 2.5 billion people, as well as the three major economies of Latin America – Argentina, Brazil and Mexico, plus South Africa will then all be commercializing and benefiting from transgenic crops.

The issue that will modulate adoption of specific products in some countries in 2001 will be public acceptance, which drives market demand, regulation and commodity prices. These issues will be the factors that will impact on commercial planting of transgenic crops and consumption of genetically modified derived foods in countries of the European Union. However, progress is expected in the near- to mid-term in the countries of Eastern Europe which have advanced field tests in progress. Several countries in the developing world are expected to proceed with field trials of *Bt* cotton, which has already delivered substantial benefits to both small and large farmers in several countries, notably China where approximately 3 million small farmers derived significant benefits in 2000.

The shift from the current generation of "input" agronomic traits to the next generation of "output" quality traits, is expected to proceed slowly and will be modulated by national regulations and possibly the next round of negotiations at the World Trade Organization (WTO). With the acceptance of the first "quality" products, which will improve the nutritional value of food and feed products, significant value will be added to the GM crop market and it should provide a stimulus to de-commoditize grain and oil seed markets. This shift will not only serve to significantly increase the value of the global transgenic crop market but will also broaden the beneficiary profile from growers to processors and consumers. Food products derived from transgenic crops that are healthier and more nutritious could impact on public acceptance, particularly in Europe.

Significant progress has been made in the first five-year period 1996 to 2000 with an accumulated area of 125 million hectares of transgenic crops planted in 15 industrial and developing countries. As new and novel products with input and output traits will become available for commercialization in the next five years, it is critical that these products be deployed in an integrated strategy in which both conventional and biotechnology applications are applied to attain the challenging goal of global food security. Adoption of such a strategy will allow society to continue to benefit from the vital contributions that both conventional and modern plant breeding offer. Biotechnology can play a critical role in achieving food security in the developing world in countries such as China, which has assigned high priority and a strategic value to biotechnology, and was the first country in the world to commercialize transgenic crops in the early 1990s. The experience of China, where 3.0 million small farmers benefited from planting *Bt* cotton in 2000, Argentina and South Africa should be shared with other countries in the developing world which face the same challenges.

Governments, supported by the global scientific and international development community, must ensure continued safe and effective testing and introduction of transgenic crops and implement regulatory programs that inspire public confidence. Leadership at the international level must be exerted by the international scientific community and development institutions to stimulate discussion and to share knowledge on transgenic crops with society. The public should be well informed and engaged in a dialogue about the impact of the technology on the environment, food safety, sustainability and global food security. Societies in food surplus countries must ensure that access to biotechnology is not denied or delayed to developing countries seeking to access the new technologies in their quest for food security, because the most compelling case for biotechnology, more specifically transgenic crops, is their potential vital contribution to global food security and the alleviation of hunger in the Third World.

In summary, we must ensure that society will continue to benefit from the vital contribution that plant breeding offers, using both conventional and biotechnology tools, because improved crop varieties are, and will continue to be the most cost-effective, environmentally safe, and sustainable way to ensure global food security in the future.

Shortly before this review went to press, two major events of global significance impacted on our continuing ability as a society to alleviate poverty and malnutrition. Following the terrorist attacks in the US on 11 September 2001, the World Bank predicted that poverty would increase with millions more people condemned to poverty in 2002 (World Bank 2001). More specifically, the Bank predicts that global poverty will increase by 10 million more people in 2002. Developing country growth rates could be as low as 2.9% in 2001 compared with 5.5% in 2000. For 2002, lowered growth rates for developing countries in the range of 3.5 - 3.8 percent are projected, compared with the 4.3 percent prediction made before 11 September. Africa is expected to suffer most of the economic damage from the continued economic slowdown of industrial countries with an additional 2 million Africans surviving on less than $1 a day. Africa is judged to be particularly vulnerable because many African nations do not have the means to stabilize their economies when agricultural commodity prices, on which they are dependent, fall. Consequently "farmers, rural laborers, and others tied to agriculture will bear a major portion of the burden" (World Bank 2001). The Bank recommended that donor countries increase aid, reduce trade barriers for developing countries, and urged the donor community to coordinate its economic reform policies.

The Potential Role of the World Trade Organization (WTO)

The other major global event that will impact more directly on the contribution of transgenic crops to the alleviation of poverty and hunger in the developing countries is the World Trade Organization Meeting held in Doha, Qatar, 9 to 13 November 2001, with 142 members in attendance. It is noteworthy that China, a world leader in transgenic crops, was admitted as a member of WTO on 10 November 2001. China's membership of WTO, has many significant implications for its own future strategy on GM crops, but could also be pivotal for other developing and industrial countries committed to utilizing GM crops to achieve global food, feed and fiber security. Unlike the last WTO meeting in Seattle, this time the world's major trading partners including the US and Europe had pre-meeting exchanges to discuss a draft of a new trade agreement that addresses trade liberalization in agriculture and textiles which comprise 70% of exports from developing countries; the TRIPS agreement (Trade Related aspects of Intellectual Property Rights) is also being reviewed, albeit in the context of public health and pharmaceuticals. There may be some important implications for agriculture. This represents significant progress which brings hope to many developing countries which have suffered under the terms of the Uruguay round concluded in 1994.

WTO is a key international organization that can ensure that GM crops are accessible to those developing countries that seek to use them to alleviate poverty and hunger and achieve food security. In the new round of trade talks WTO should address the key issues that would facilitate the implementation of the principal recommendation of the well-received 2001 UNDP Human Development Report - to utilize biotechnology and information technology to alleviate poverty in developing countries. More specifically WTO can address several critical issues that impact on developing countries seeking to utilize biotechnology to achieve food security. The most urgent and important issues for WTO to address and remedy are:

- Liberalization of agricultural trade. Abolishing all trade barriers could increase global income by $ 2.8 trillion over the next decade (World Bank 2001), with well over half of the benefits going to the poor. The World Bank has predicted that global trade liberalization could reduce the 1.3 billion people suffering from poverty today by 300 million to 1.0 billion by 2015. The removal or reduction of trade barriers in agriculture is assigned high priority by the US and developing countries. However the European and Japanese continue to oppose freer trade in agriculture, particularly export subsidies, and are concerned that environmental issues are not receiving the attention they deserve. Some observers interpret the European position on the environment as an indirect way of re-introducing protection policies for agriculture.

- The establishment of an exemplary advisory body to provide direction and leadership in the implementation of WTO's policy of basing all its decisions, re the use and transfer of transgenic material, on scientific fact and objective evidence – this is in stark contrast to the subjective decision-making of the Biosafety Protocol which requires no scientific justification for invoking the precautionary principle. Applying the precautionary principle to delay or deny access to transgenic crops to developing countries that seek to use them for food security clearly will increase rather than decrease the food security risk to the poor, hungry and malnourished in developing countries. The establishment of an advisory body by the WTO would seem appropriate at this time, particularly to align and rationalize decisions vis-à-vis the contradictions in the Biosafety Protocol re the use and transfer of transgenic material.

- Overseeing implementation of a TRIPS agreement that is equitable to all parties. The current WTO agreement on intellectual property rights (TRIPS) negotiated during the Uruguay round is a key issue and impacts directly on the deployment of transgenic crops in developing countries. The context of the current discussions on TRIPS will be in relation to pharmaceuticals and public health however there could be some important implications for agriculture. The US is reluctant to soften the TRIPS requirements but a group of developing countries, including South Africa, Brazil, and India are seeking an exemption to TRIPS for public health initiatives such as the control of AIDS. The renegotiated agreement on TRIPS could have implications for the ease of access, deployment and trading of transgenic crops for developing countries, and the views of China as a new member and a lead country in GM crops could be pivotal.

As this review went to press, the latest and encouraging news from WTO, was that members had reached consensus on the Doha Development Agenda, with Africa in particular welcoming the agreement because of the potential for more open markets for exports. The most difficult issue to resolve was the EU farm subsidies which the EU agreed to phase out, provided that it does not “prejudice the outcome” of the negotiations. However, some developing countries voiced concern that the EU may use environmental restrictions to preclude the importation of GM products. Reaching a consensus on freer trade was very important because it will provide WTO with the necessary solidarity among members prior to addressing the outstanding and important issues that need to be resolved in relation to biotechnology, that offers the developing countries a unique opportunity for alleviating poverty and achieving food security.

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APPENDIX

Table 1A. Latest Estimates for Seed Exports Worldwide, by Crop (US$ millions)

Crops	Seed Exports
Maize	530
Herbage crops	427
Potato	400
Beet	308
Wheat	75
Other Agricultural crops	750
Horticultural crops	1,150
Total	**3,640**

Source: FIS, 2001

Table 2A. Latest Estimates for Seed Exports: Major Exporting Countries (US$ millions)

Country	Agricultural Seeds	Horticultural Seeds	Total
USA	560	249	799
Netherlands	420	200	620
France	373	125	498
Denmark	150	40	190
Germany	150	35	185
Chile	84	60	144
Canada	104	18	122
Belgium	111	n.a.	111
Italy	70	41	111
Japan	5	100	105
Total	**2,027**	**868**	**32,895**

Source: FIS, 2001

Table 3A. Transgenic Crops Approved in EU under Directive 90/220

Crop/Trait/(Use)	Company	Date of Approval
1. Tobacco with bromoxynil tolerance	Seita	June 1994
2. Male sterile swede rape tolerant to glufosinate (for breeding)	PGS	February 1996
3. Soybeans tolerant to glyphosate (for import and processing)	Monsanto	April 1996
4. Male sterile chicory tolerant to glufosinate (for breeding)	Bejo-Zaden	May 1996
5. *Bt* maize tolerant to glufosinate	Ciba-Geigy	January 1997
6. Male sterile swede rape tolerant to glufosinate (RF1)	PGS	June 1997
7. Male sterile swede rape tolerant to glufosinate (RF2)	PGS	June 1997
8. Carnation with modified color	Florigene	December 1997
9. Swede rape tolerant to glufosinate (for import and processing)	AgrEvo	April 1998
10. Maize tolerant to glufosinate	AgrEvo	April 1998
11. Maize with Bt *cryIA(b)* (MON 810)	Monsanto	April 1998
12. Maize tolerant to glufosinate and expressing the Bt *cryIA(b)* gene Bt11 (for import and processing)	Novartis	April 1998
13. Carnation with improved vase life	Florigene	October 1998
14. Carnation with improved color	Florigene	October 1998

Source: Anonymous, EU Memo 01/277 (2001). Compiled by Clive James 2001.

APPENDIX

Table 4A. Transgenic Crops Pending Approval under Directive 90/220, as of March 2001

Crop/Trait/(Use)	Company	Date of Approval
1. Maize with Bt *CryIA(b)* gene MON 809 (all uses)	Pioneer	August 1996
2. Male sterile chicory (food and feed)	Bejo-Saden	September 1996
3. Swede rape tolerant to glufosinate (all uses)	AgrEvo	November 1996
4. Male sterile swede rape tolerant to glufosinate (all uses)	PGS	January 1997
5. Fodder beet tolerant to glufosinate (production of seeds and roots, and animal feed)	DLF Trifolium, Monsanto, and Danisco Seed	November 1997
6. Tomato, delayed ripening (processing)	Zeneca	November 1997
7. Cotton *Bt CryIA* (all uses)	Monsanto	November 1997
8. Cotton tolerant to herbicide (all uses)	Monsanto	November 1997
9. Potato with altered starch (uses - as any other potato)	Amylogene	May 1998
10. Swede rape tolerant to glufosinate (all uses)	AgrEvo	October 1998
11. Maize tolerant to glufosinate plus *Bt cryIA (b)* with Bt 11 gene	Novartis	May 1999
12. Maize tolerant to glyphosate plus *Bt cryIA (b), T25* MON 810	Pioneer	May 1999
13. Maize tolerant to glyphosate from Spain (GA 21) (all uses)	Monsanto	May 1999
14. Maize tolerant to glyphosate from UK (GA 21) (all uses)	Monsanto	October 1999

Source: Anonymous, EC Memo 01/277 (2001). Compiled by Clive James 2001.

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