The Global Diffusion of Plant Biotechnology: International Adoption and Research in 2004

C. Ford Runge, Ph.D.
Distinguished McKnight University Professor of Applied Economics and Law
Director, Center for International Food and Agricultural Policy
University of Minnesota

Barry Ryan, M.S.
Research Associate
University of Minnesota

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- Less than a decade after first commercialization, the international adoption and diffusion of biotech crops has now gone global, especially in developing countries. While much international press attention has focused on opposition to biotechnology, especially in Europe, there is increasing adoption and diffusion of biotech crops and expanded research in many parts of the world, including Asia, Latin America and parts of Africa. We see continuing expansion of commercial and scientific possibilities for plant biotech in the next decade and beyond.

- Worldwide biotech crop value reached $44 billion in 2003-2004 in the five countries accounting for about 98 percent of all biotech crop hectares and values (1 hectare = 2.47 acres). The leading five countries in global biotech crop value in 2003-2004 were the United States ($27.5 billion), Argentina ($8.9 billion), China ($3.9 billion), Canada ($2.0 billion) and Brazil ($1.6 billion). Four biotech crops ─ soybeans, cotton, maize (corn) and canola ─ accounted for virtually all of the biotech values and planted area.

- Eight other countries have joined the leading five in meaningful levels of commercial biotech crop production: South Africa, Mexico, Australia, India, Romania, Spain, Philippines, and Uruguay.

- Research and development (R&D) activity represented by field trials and laboratory/greenhouse experiments extends well beyond the five leading countries. Sixty-three countries have been involved in some phase of biotech plant research and development, from laboratory/greenhouse experiments, to field trials, to regulatory approval and commercial production.

- When biotech plant R&D is arrayed for field crops, vegetables, fruits and other crops (as in Tables 7-10), it is clear that the technology is diffusing to many parts of the world. For example, 16 field crops have been the subject of biotech research or development in 55 countries.

- Many biotech plant varieties already have regulatory approval, and could be taken from field studies to commercial production quite rapidly, allowing substantial adoption within a few growing seasons. Two obvious examples are soybeans and maize in China, which had a total production in 2003-2004 of 16.2 million and 114 million metric tons, respectively. If half of this production was biotech, it would add about $2.5 billion to the total value of biotech crop production at 2003-2004 prices. When the deeper levels of activity preceding commercialization are explored at an international level, it is clear that a wide array of biotech plants is of potential interest (and value) in both developed and developing countries.

- The direction of global plant biotechnology suggests that major expansions in biotech crop hectares are still to come, especially in Asia, Latin America and parts of Africa. Apart from this expansion, we expect the range of biotech crops approved commercially to continue to grow, resulting in new markets and opportunities, especially in developing countries. In fact, the greatest gains would be in the developing countries, where Gross Domestic Product could be expected to rise by as much as 2 percent.

- If the European Union continues to restrict activity in the sector, it will slow down this global diffusion, but it cannot stop it. As it becomes increasingly isolated, it will discourage its young scientists and technicians from pursuing European careers. If, on the other hand, the EU engages biotech in an orderly regulatory framework harmonized with the rest of the world, it will encourage a more rapid international diffusion of the technology. More nations will join the top tiers of commercial production, and emerging nations will continue to expand the sector. It is unlikely that Europe will catch up with North America as a sphere of plant biotech influence, but its scientific and technical capabilities will allow it to recover relatively quickly.

Regional and Country Summary

- Some phase of biotech plant R&D is occurring in Africa, Latin America, Asia and the Pacific, Western and Eastern Europe and North America.

- In Africa, the leading country is South Africa, with a total commercial market value for its biotech maize, soybeans and cotton of $146.9 million. There also are important developments in Kenya and Egypt, and some activity in Morocco and Tunisia. Work in Zimbabwe has been disrupted by political instability.

- Latin American and the Caribbean nations are home to some of the most aggressive adopters of plant biotech and appear poised to move to adopt more varieties in the near future. In Latin America and the Caribbean, the adoption process is led by Argentina, with Brazil likely to emerge rapidly as a leader as well. Chile is an important potential base of plant biotech activity, and Colombia has begun to plant biotech cotton. Cuba has no market approvals, but is active in field trials and experimental studies, and Mexico has an active commercial and scientific plant biotech sector.

- Twelve countries in the Asia-Pacific region are involved in some aspect of plant biotech. Australia has the most active sector, planting biotech cotton and approving for import six other biotech crops. Perhaps the most significant single potential actor in Asia is China, which is aggressively engaged in biotech adoption and research. India has at least 20 academic and research institutions engaged in biotech research covering 16 crops, and Indonesia also has commercial approvals, field studies and experiments. The Philippines has approved a biotech maize variety. South Korea has approved three lines of maize and soybeans, and has launched a 20-year plant biotech research program. Japan had granted import approval to six biotech crops in 2003, and has studied in the lab various biotech fruits, vegetables and grains. Malaysia launched its Biotechnology Agenda in 2004. Finally, Thailand has conducted field studies on cotton, rice and several vegetables, and experiments on biotech cassava, papaya and long beans.

- In Western Europe (EU member states Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Netherlands, Portugal, Spain, Sweden and the United Kingdom, as well as non-EU-member Switzerland) regulatory import, as well as environmental release, approvals have been granted for a limited group of biotech crops. In the EU, these include biotech canola, chicory, maize, soybeans and tobacco. In all, 1,849 field trials were conducted from 1991 to August 2004.

- All 14 EU members in Western Europe have reported field trials to the Joint Research Center of the European Commission in Brussels. In descending order the largest number of biotech field trials in Western Europe's EU countries has been France (520), Italy (270), Spain (263), the United Kingdom (199), Germany (138), Belgium (129), Sweden (68), Denmark (38), Greece (19), Finland (16), Portugal (11), Ireland (50) and Austria (3).

- In Eastern Europe (including Armenia, Boznia-Herzogovina, Bulgaria, Croatia, The Czech Republic, Georgia, Hungary, Poland, Romania, Serbia-Montenegro, Slovenia, the Ukraine and Russia) there has been some biotech commercial approval, field trials or lab/greenhouse activity but at a much lower rate than in Western Europe. The Balkans, in particular, has suffered from war and economic disruption.

- North America remains the epicenter of R&D on plant biotech, with the United States and Canada in the top five producing nations in terms of 2003-2004 commercial biotech crop value: $2.0 billion in Canada and $27.5 billion in the United States. Thousands of field trials have been conducted in the two countries. Canada has produced, approved, or field tested more field crops than any other country. In the United States, approvals have been granted for canola, chicory, cotton, flax and linseed, maize, melon, papaya, potatoes, rice, soybeans, squash, sugar beets, tobacco, and tomato.

Introduction and Overview

For thousands of years, farmers carefully selected crops with higher yields and resistance to disease and pests. Through trial and error, plant varieties came down through the centuries with steadily altered genetic traits. At the turn of the 20th century, the experiments of an obscure Austrian monk, Gregor Mendel (1822-1884), who had researched the inherited characteristics of peas, were rediscovered and confirmed by German plant breeder and biologist Karl Erich Correns (1864-1933). Correns reintroduced the principles that led to modern genetics, allowing plants to be bred through a form of systematic experimentation based on the probability that certain traits would be passed from one generation to the next. These principles made plant breeding a form of calculated trial and error. Statisticians such as R. A. Fisher (1890-1962) developed general methods for the design and analysis of plant breeding experiments when it is not possible to control for every factor that can affect the outcome. These insights into the genetic patterns of life ushered in the modern era of plant breeding, and the capacity for tens of thousands of improvements and hybrid varieties, from fruits and vegetables to ornamental flowers and trees. This research and experimentation continues today, with new and improved plant varieties appearing each year due to new hybrids and genetic crosses.

Beginning in the 1950s and 1960s, insight into life forms at the subgenetic level resulted from the late Francis Crick and James Watsons' Nobel Prize-winning work on the molecular structure of DNA. Their insight eventually allowed genetic material to be identified in one organism and inserted into another, so that genetic traits could be transferred to other (even unrelated) species. The result was biotechnology, part of the broader field of genetic mapping, analysis and research called genomics. In contrast to earlier methods of plant breeding, the new techniques allowed a much wider set of traits to be introduced into plants, in a much shorter period of time. These included resistance to herbicides in soybeans, corn and canola, pest resistance in corn and cotton, cold and drought tolerance, tolerance to salt in soils, enhanced nutrition and vitamin content and many other traits. Beginning in 1996, the first biotech crops were marketed in the United States. Since then, biotech corn, soybeans, and cotton have grown to account in 2004 for 46, 86, and 76 percent of total U.S. crop acres respectively, up from the 2003-2004 planted area percentages of 40, 81, and 73 percent respectively.[1] The international adoption and diffusion of biotech crops, while less advanced than in the United States, has now gone global. While much international press attention has focused on opposition to biotechnology, especially in Europe, there is increasing adoption and diffusion of biotech crops and expanded research in many parts of the world.

This study surveys the global diffusion of biotech crop varieties as of the end of 2004. It analyzes adoption, research and development by crop and by country, and aggregates these data by region. Four major biotech crops have come to market to date: maize, cotton, soybeans, and canola. In addition, other commodities like papaya, squash, and tobacco have reached commercial production in the U.S. Many more commodities have been approved for commercial use in one or more countries, but have not been adopted in the marketplace. Included are chicory, tomatoes, rice, potatoes, flax, sugar beets, melon, and green peppers. Beyond these crops, many more food and fiber plants have been the subjects of field or laboratory research.

The study is divided into four parts. The countries and crops discussed are shown in Figures 1 and 2. Part I analyzes market adoption and commercial value in countries producing biotech crops in 2003/04. The focus is on the five countries and four crops that largely define today's agricultural biotech production. Part II summarizes the range of biotech activity during this technology's short life. It shows which field crops, fruits, and vegetables have been commercialized, approved for adoption, field tested, or simply researched in a laboratory or greenhouse in 63 countries around the world. Part III provides regional summaries and country-level profiles. These profiles offer data on each country's biotech involvement, and support the findings of Parts I and II. A full set of country profiles is contained in the Appendix. Part IV offers conclusions and a discussion of the prospects for further growth in plant biotech in the next decade and beyond. The overall picture is of a technology which, less than a decade after first commercialization, is poised to transform the nature of agricultural production and development in widely dispersed countries around the world.

Figure 1: Sixty-three Countries with Biotech Production or Research Activity.

AFRICA/MIDEAST	ASIA/PACIFIC	LATIN AMERICA	WESTERN EUROPE	EASTERN EUROPE
Egypt	Australia	Argentina	Austria	Armenia
Kenya	Bangladesh	Belize	Belgium	Bosnia Herzegovina
Morocco	China	Bolivia	Denmark	Bulgaria
South Africa	India	Brazil	Finland	Croatia
Tunisia	Indonesia	Chile	France	Czech Republic
Zimbabwe	Japan	Colombia	Germany	Georgia
(6)	Malaysia	Costa Rica	Greece	Hungary
	New Zealand	Cuba	Ireland	Moldova
	Pakistan	Guatemala	Italy	Romania
	Philippines	Honduras	Netherlands	Russia
	South Korea	Mexico	Portugal	Serbia/Montenegro
	Thailand	Paraguay	Spain	Slovenia
NORTH AMERICA	(12)	Peru	Sweden	Ukraine
Canada		Uruguay	Switzerland	(13)
United States		Venezuela	United Kingdom	
(2)		(15)	(15)	

Figure 2: Fifty-seven Crops of Biotech Research Interest.

Field Crops	Vegetables	Fruits	Miscellaneous
Alfalfa	Broccoli	Apple	Chicory
Barley	Cabbage	Banana	Cocoa
Canola	Carrot	Cantaloupe	Coffee
Cassava	Cauliflower	Cherry	Garlic
Clover	Cucumber	Citrus	Lupins
Cotton	Eggplant	Coconut	Mustard
Flax	Lettuce	Grape	Oil palm
Maize	Onion	Kiwi	Oilseed poppy
Rice	Pea/Bean	Mango	Olive
Safflower	Pepper	Melon	Peanut
Sorghum	Potato	Papaya	Tobacco
Soybean	Spinach	Pineapple	(11)
Sugar beet	Squash	Plum	
Sugar cane	Tomato	Raspberry	
Sunflower	(14)	Strawberry	
Wheat		Watermelon	
(16)		(16)	

Part I:

Global Commercial Adoption and Market Value of Biotech Crops

Commercial production of biotech crop varieties has reached significant levels in four important commodities: corn, soybeans, cotton, and canola. As well, nearly all biotech production occurs in five countries: the United States, Argentina, Canada, Brazil, and China. There are other biotech countries and biotech crops, but these contribute only modestly to worldwide biotech production value. We estimate the 2003/04 global market value of biotech crop production at $44 billion.

Four Major Crops and Five Leading Countries

Five countries had 67.5 million hectares planted to biotech varieties of maize, soybeans, cotton and canola in 2003/04 (Table 1).[2] They were the United States (42.8 million hectares); Argentina (13.9 million hectares); Canada (4.4 million hectares); Brazil (3.0 hectares); and China (2.8 million hectares). According to James (2003) these five countries and four crops constitute 98 percent of the total biotech cropland worldwide. Among the five countries 63 percent are planted in the United States, 21 percent in Argentina, 6 percent in Canada, and 4 percent each in Brazil and China. The rest of the world accounts for only 2 percent of the total area planted to biotech crop varieties.

In the United States, adoption of biotech varieties is led in area by corn and soybeans, followed by cotton and canola. In Argentina, corn, soybeans and cotton lead, while in Canada canola leads. Brazil's main biotech crop is soybeans (the area planted to biotech varieties in Brazil is widely believed to be underestimated). In China, the only reported acreage is in biotech cotton.

Table 1: Global Biotech Crop Area: Leading Countries

Five leading counties	Area in biotech crop production	Share of world biotech area	biotech crop varieties:
	67.5 million hectares	**98%**	
United States	42.8 million hectares	63%	maize, cotton, soy, canola
Argentina	13.9 million hectares	21%	soy, maize, cotton
Canada	4.4 million hectares	6%	canola, maize, soy
Brazil	3.0 million hectares	4%	soy
China	2.8 million hectares	4%	cotton

Source: James, 2003.

What is the value of this crop production? Using gross market values based on world prices we calculated in 2003/2004 the total value of biotech crops for the five leading countries and four leading crops at $43.9 billion (Table 2).[3] The United States accounted for $27.5 billion of this total, Argentina for $8.9 billion, China for $3.9 billion, Canada for $2.0 billion and Brazil for $1.6 billion.

Table 2: Global Biotech Crop Value: Leading Countries

2003/04	Biotech-related crop value*
Five countries:	**$43.9 billion**
United States	$27.5 billion
Argentina	$8.9 billion
China	$3.9 billion
Canada	$2.0 billion
Brazil	$1.6 billion

2003/04	Biotech-related crop value*
Four crops:	**$43.9 billion**
Soybean	$23.5 billion
Maize	$11.2 billion
Cotton	$7.8 billion
Canola	$1.4 billion

* Market value of crop production associated with biotech plant varieties
Source: USDA (2004a,b); FAO (2004); FAPRI (2004); James (2003).

When broken out by crop, of the $43.9 billion total, biotech soybeans were valued at $23.5 billion, maize at $11.2 billion, cotton at $7.8 billion, and canola at $1.4 billion. Tables 3 through 6 detail these calculations by country for soybeans, maize, cotton and canola respectively.

Soybeans were planted to 88 million hectares worldwide in 2003/04, with global production estimated at 190 million metric tons, and the world price averaging $250 per metric ton. The top five biotech countries represented 84% of land area planted to soybeans and 90% of production. More than half (54 percent) of soybean production in the top five biotech countries is from biotech varieties (Table 3).

Table 3: Global Biotech Soybean Value: Leading Countries

Soybean 2003/04 *price = $250/MT*	Crop area (1) M Ha	Production (2) MMT	Biotech adoption rate	Biotech-related crop value (3)
Five countries:	**74.2**	**171.8**	**54%**	**$23.5 billion**
United States	29.2	65.8	81%	$13.3 billion
Brazil	21.3	53.5	12%	$1.6 billion
Argentina	14.0	34.0	98%	$8.3 billion
China	8.7	16.2	-	-
Canada	1.1	2.3	50%	$284 million
Rest of the world	*13.8*	*18.3*	-	-

(1) area in million hectare; (2) production in million metric tons; (3) assumes world price $250/metric ton
Source: USDA (2004a,b); FAO (2004); FAPRI (2004); James (2003).

Total biotech soybean market value in 2003/04 was $23.5 billion - the highest of any biotech crop. The United States had the largest area in soybeans and highest biotech crop value ($13.3 billion). Brazil had the next largest biotech soy area, but due to a low (official) adoption rate, generated only $1.6 billion in biotech market value. Some reports suggest that the real biotech adoption rate in Brazil is as high as 30%, which would more than double Brazil's biotech soybean production value. Argentina grew $8.3 billion in biotech soybeans in 2003/04. China grew 8.7 million hectares of conventional soybeans, but had no biotech production. The Canadian soybean area is just over a million hectares, and about half were biotech varieties.

Maize was grown on 140 million hectares worldwide in 2003-2004, producing 614 million metric tons, at an average world price of $100 per metric ton. The top five biotech countries represent 70 percent of worldwide maize production and 49 percent of the global maize land area. Biotech varieties are grown on 19 percent of maize production land in the top five biotech countries, which collectively produced $11.2 billion in biotech maize (Table 4).

Table 4: Global Biotech Maize Value: Leading Countries

Maize 2003/04 *price = $100/MT*	Crop area * M Ha	Production ** MMT	Biotech adoption rate	Biotech-related crop value***
Five countries:	**68.5**	**434.5**	**19%**	**$11.2 billion**
United States	28.8	256.9	40%	$10.3 billion
China	23.5	114.0	-	-
Brazil	12.6	41.5	-	-
Argentina	2.1	12.5	40%	$500 million
Canada	1.2	9.6	40%	$384 million
Rest of the world	*71.9*	*179.5*	-	-

* area in million hectares; ** million metric tons; *** average world price of $100/metric ton
Source: USDA (2004a,b); FAO (2004); FAPRI (2004); James (2003).

The United States is the leading biotech maize producer, with $10.3 billion in production market value. China's maize production area is nearly as large as the United States, but China does not grow biotech varieties commercially. Brazil has no reported biotech maize production, but significant maize production land area. Argentina has a modest area of land planted to maize, and an estimated $500 million in biotech soybean market value. Canada grew $384 million in biotech maize, based on a 40 percent adoption rate.

Cotton was planted to 32.6 million hectares worldwide in 2003/04. Production (lint only) is estimated at 93.5 million bales of 480 pounds each. The adjusted world price averaged 59 cents per pound. Half of the world's cotton production takes place in the top five biotech countries, and 61 percent of that is from biotech varieties (Table 5).

Table 5: Global Biotech Cotton Value: Leading Countries

Cotton 2003/04 *price = $0.59/lb.*	Crop area * M Ha	Production ** M Bales	Biotech adoption rate	Biotech-related crop value***
Five countries:	**11.2**	**46.7**	**61%**	**$7.8 billion**
China	5.1	22.4	62%	$3.9 billion
United States	4.9	18.3	73%	$3.8 billion
Brazil	1.0	5.7	-	-
Argentina	0.3	0.4	60%	$75 million
Canada	-	-	-	-
Rest of the world	*21.4*	*46.8*	-	-

(1) area in million hectare; (2) million metric tons; (3) assumes world price 59-cents per pound
Source: USDA (2004a,b); FAO (2004); FAPRI (2004); James (2003).

The global value of the biotech cotton in 2003/04 was $7.8 billion. China has the most area in cotton, the highest production and yields, and generates the most biotech cotton market value. The United States has almost as much area as China, higher adoption, lower yields, but essentially the same biotech production value. Argentina grew $75 million in biotech cotton on a relatively modest land area. This assumes a 60% adoption rate, although some reports suggest it may be as low as 20%. Brazil has more area in cotton production than Argentina, but no biotech adoption. No cotton is grown in Canada.

<u>Canola</u> (or rapeseed) was planted to 26 million hectares worldwide in 2003/04, with total production estimated at 39 million metric tons, and an average world price of $285 per metric ton. The top five biotech countries account for half the worldwide land area devoted to canola, and half the global production (Table 6).

Table 6: Global Biotech Canola Value: Leading Countries

Canola 2003/04 *price = $285/MT*	Crop area * M Ha	Production ** MMT	Biotech adoption rate	Biotech-related crop value***
Five countries:	**12.6**	**18.8**	**28%**	**$1.43 billion**
China	7.5	11.4	-	-
Canada	4.7	6.7	68%	$1.29 billion
United States	.4	.7	73%	$138 million
Argentina	-	-	-	-
Brazil	-	-	-	-
Rest of the world	*13.4*	*20.2*	-	-

(1) area in million hectare; (2) million metric tons; (3) assumes world price $285 per metric ton
Source: USDA (2004a,b); FAO (2004); FAPRI (2004); James (2003).

Among these top five countries, 28 percent of canola was a biotech variety. In 2003/04 the worldwide market value of the biotech canola crop was $1.4 billion. China grows the most canola among the five countries, but none in biotech varieties. Canada has the next largest land area planted to canola worldwide, but the majority of this crop is biotech, generating nearly $1.3 billion in biotech market value. The United States, by contrast, has modest canola production, but still produces $138 million in biotech canola value. Argentina and Brazil have no meaningful canola production and no biotech varieties in use.

Other Commercial Biotech Countries and Crops

Other countries grow biotech varieties of soybeans, cotton, and maize, apart from the five leading nations, and James identifies 13 countries with biotech crop production, with 8 of these at meaningful levels.[4] Combined, these countries grew more than 600,000 hectares of biotech crops commercially in 2003/04, producing an additional $160 million in global biotech crop value. South Africa planted 400,000 hectares to a combination of maize, soybeans, and cotton, is the only country in Africa to produce a biotech crop, and could arguably be included as a top biotech country with its estimated $147 million in biotech crop value. In Latin America, Colombia grew 5,000 hectares of Bt cotton. Honduras planted less than 1,000 hectares of Bt maize, while Mexico also planted small areas of commercial biotech soybeans and Bt cotton. Uruguay grew 60,000 hectares of biotech soy, and produced its first crop of Bt maize. In the Asia-Pacific region, Australia planted 100,000 hectares or 59 percent of its cotton area in biotech varieties in 2003/04. The Philippines planted Bt corn for the first time on 20,000 hectares. India grew Bt cotton on 100,000 hectares, and Indonesia had unconfirmed reports of Bt cotton production. Several European countries grew biotech corn or soybeans in 2003/04. Romania grew 70,000 hectares of biotech soybeans. Spain put 32,000 hectares or 6 percent of its maize area in Bt varieties. Bulgaria had a few thousand acres of herbicide tolerant maize production, and Germany also had a small area of Bt maize.

Finally, there are other biotech food and fiber plants in commercial production around the globe. They have a relatively minor economic impact, compared with the four major crops, but are important to the areas and farmers that grow them. More details on these crops can be found in the country profiles in the Appendix and in Part III below. For example, biotech papaya varieties are grown in the United States that account for about half of the average $20 million papaya crop. Biotech tobacco is also grown in the United States, but the market penetration is too small to measure. Reports from other countries indicate market availability of biotech tomatoes and sweet peppers in China. Again, compared to soybeans, maize, or cotton the market impacts are relatively minor. As we will show in Part II, there are many more crops approved for use that could have significant market value potential.

Part II:

Biotech Crop Adoption, Research and Development in 2004

Commercial biotech crop production is the final stage in a four step process. The first step begins in government and private sector laboratories or greenhouses, where scientists investigate potential biotech traits and genetic strategies. If these lab results are successful, the plant may advance to the second step, open air field trials, where breeding and testing continue in a real life environment. The third step to commercialization is securing regulatory approval in each country where the plant will be grown, and/or consumed by humans or animals. The fourth and final step is market acceptance and widespread production, like the four major crops described earlier. Part II summarizes the wide array of food and fiber plants that have undergone biotech research over the last two decades. Fifty-seven plants were identified and divided into four groups: field crops, vegetables, fruits, and other plants. The timeframe of this assessment is as far back as the biotech research records of each country allow, although not every research effort, in every county, is documented in the same detail. The country-by-country profiles in Part III provide data for each biotech trait and plant under investigation, as well as other facts about research in the area.

The matrices of Tables 7-10 note by country and crop the highest level of biotech research a plant has reached over time. For some commodities or countries interest never progressed past the laboratory, in other cases the process matured to commercial production. The labels for each country and crop (P,A,F,L) indicate the most advanced stage of biotech development that the country and crop has achieved: commercial production (P), regulatory approval (A), field trial (F), or laboratory/greenhouse study (L). Note, however, that even where the matrices show a plant in commercial production (P) or with regulatory approval (A), the same crop may also be in another stage of research for some other biotech trait. Indeed, all four major commercial biotech crops have lab, field, and regulatory investigations ongoing somewhere in the world today. Most regulatory approvals are for the environmental release and human or animal consumption of a biotech variety. In some cases -- indicated in the matrices by an (a) -- the approval is for consumption from imports only, and can apply to the entire crop or individual lines. One opposite exception is the export-only approval (p) for Chilean corn and soybean seed production.

Sixty-three countries were identified as having participated in biotech plant research activity at some point in the technology's development. This participation can range from a single greenhouse experiment to the widespread adoption of biotech crop varieties. Most countries are identified separately in the tables, but European countries are treated collectively in two groups, West and East. The reader can find more details in the county profiles of the Appendix. Generally speaking, Western Europe is the "original" 15 members of the EU, while the 13 Eastern European countries include many parts of the former Soviet Union.

<u>Field crops</u>

Sixteen field crops have been the subject of biotech research or development in 55 countries (Table 7). Soybeans, cotton, maize, and canola have widespread commercial application, as well as regulatory approval in many countries. Sugar beets, flax, and rice also have the necessary approvals in the United States and Canada. Australia grows biotech cotton, and has given import approval to biotech maize, soybean, canola, and sugar beets.

Table 7 - Global Biotech Activity: Field Crops - highest level of biotech development

FIELD CROPS by COUNTRY	Soybean	Cotton	Maize	Canola	Sugar beet	Rice	Flax	Wheat	Sugar cane	Barley	Alfalfa	Cassava	Sunflower	Clover	Safflower	Sorghum
Canada	P	A	P	P	A	A	A	F		F	F		F	F	F	
United States	P	P	P	P	A	A	A	F	F	F	F				F	
Australia	a	P	a	a	a			F	F	F				F		
West Europe (15/15)	a	F	P	a	F	F		F		F	F		F			
Argentina	P	P	P		F			F	L	L	F		F			
Mexico	A	P	F	F		F	F	F								
China	F	P	F	L	L	F		L		L						L
Japan	a	a	a	a	a	F		L								
South Africa	P	P	P	F					F							
Brazil	P	F	F			F			F	L						
East Europe (8/13)	P		A	F	L		L	F		L	F		F			
Indonesia	F	a	F			L			L			L				
Uruguay	P		P													
Egypt		A	F	A				F	F	L						
India		P		F		L										
Colombia		P										L				
Philippines			P			L										
Paraguay	P															
Chile	p		p													
South Korea	a		a													
Honduras			A													
Belize	F	F	F													
Cuba			L			L			F							
Thailand		F				F						L				
Venezuela						L			L			F				
Zimbabwe		F										F				
Bolivia	F	F														
Costa Rica			L			F										
New Zealand				F												
Malaysia						L										
Pakistan		L				L										
Morocco								L								
Bangladesh						L										
Kenya			L													

commercial Production	P
regulatory Approval	A
Field study	F
Lab / greenhouse	L

Source: AGBIOS (2004); FAO (2004); ISB (2002); WISARD (2004); BINAS (2003).

Biotech rice has been studied in as many countries, particularly in the developing world, as have soybeans or cotton. Wheat is another important global field crop that has biotech field studies in more than 10 countries. Sugar cane, barley, alfalfa, cassava, sunflowers, palm oil, clover and safflower have all been field trial subjects. Sorghum is the only crop with just a laboratory experiment, and that was in China.

Countries are listed somewhat arbitrarily in the matrices, but the objective is to help identify countries with interest in biotech crop science. Canada has studied or approved a larger number of field crops than any other country. In the United States regulatory approval of biotech varieties has been granted for soybeans, cotton, maize, canola, sugar beets, flax and rice, while field study has occurred for sugar cane, barley, wheat, alfalfa and safflowers. Among other developed countries, Japan, Australia and Western Europe have one or more biotech field crops with production or import approval. In the developing countries, South Africa and Argentina lead the list of regulatory approvals for soybeans, cotton and maize. Brazil, Egypt, Mexico, Uruguay, China, the Philippines, Indonesia, India, South Korea and Russia also have approvals.

<u>Vegetables</u>

Fourteen vegetables have drawn biotech research interest in 50 countries, including 13 Western Europe and 10 Eastern European countries. Potatoes and tomatoes are most researched and have the most regulatory approvals (Table 8). But squash in the United States and Canada and sweet peppers and tomatoes in China also have approval for commercial production. Peas and beans are combined into one category for this analysis, despite the numerous varieties that have been field tested, from lentils to long beans. More specific details on particular varieties are found in the country profiles. The widest biotech vegetable research interest is in Western European countries, reaching beyond the noted crops, to lettuce, cabbage, carrots, eggplant, onions and cucumbers. The leading countries for regulatory approvals are Canada and the United States (potatoes, tomatoes, squash); Australia (potatoes); Japan (potatoes, tomatoes); China (tomatoes, green peppers); and Mexico (tomatoes).

Table 8 - Global Biotech Activity: Vegetables - highest level of biotech development

VEGETABLES by COUNTRY	Potato	Tomato	Squash	Pepper	Pea/Bean	Lettuce	Cucumber	Cabbage	Carrot	Eggplant	Onion	Cauliflower	Broccoli	Spinach
West Europe (13/15)	F	F	F		F	F		F	F	F		F	F	F
United States	A	A	P		F	F	F				F			
Canada	A	A	A											
Australia	a	F			F	F								
Japan	a	a			F	L	F					F	F	
China	F	P		P				F	L					
Mexico	F	A	F	F										
Brazil	F	F			F	L			F					
Egypt	F	F	F		L		F							
Thailand		F		F	L									
Argentina	F	F												
East Europe (10/13)	F	L			F									
Cuba	F	L												
Zimbabwe	F													
Bolivia	F													
Peru	F													
South Africa	F													
Kenya	F													
Guatemala		F												
New Zealand											F			
South Korea				F										
Indonesia	L	L		L										
Malaysia				L	L					L				
India	L	L						L		F				
Chile	L	L												
Colombia	L	L												
Bangladesh					L									
Philippines		L												
Tunisia	L													

commercial Production	P
regulatory Approval	A
Field study	F
Lab / greenhouse	L

Source: AGBIOS (2004), FAO (2004), ISB (2002), WISARD (2004), BINAS (2003).

Fruits

Sixteen fruits have seen biotech research interest in 29 countries. In 11 countries the investigation reached field testing (Table 9). By country, the Western Europe group of 15 countries had the most research activity. The United States and Canada, however, have regulatory approval for papaya, which is commercially produced in Hawaii. Papaya is the most researched fruit, with at least 15 countries in some stage of investigation. Melon also has U.S. market approval for environmental release and human consumption. Banana (and the kindred plantain) has been the subject of biotech research in nine countries, including the United States. Apples, pineapple and grapes have multiple field study countries, whereas, plums, strawberries, watermelon, citrus, cherries, cantaloupe, kiwi and raspberry may only have one country and trial. Two fruits, mango and coconut, have only reached the laboratory stage.

Table 9 - Global Biotech Activity: Fruits - highest level of biotech development

FRUITS by COUNTRY	Papaya	Melon	Banana	Pineapple	Apple	Grape	Plum	Strawberry	Watermelon	Citrus	Cherry	Cantaloupe	Kiwi	Raspberry	Mango	Coconut
United States	P	A	F		F		F		F							
West Europe (8/15)		F			F	F	F	F	F	F	F	F	F	F		
Australia	F			F	F	F										
Canada	A					F										
Mexico	F	F	F	F												
Cuba	F		L	L						L						
Philippines	L		F												L	L
China	F	F														
Egypt		F	L									F				
Japan	L	F						L								
East Europe (3/13)						L	F									
South Africa								F								
Brazil	F															
Malaysia	L	L	L	L												
Chile		L			L	L	L									
Venezuela	L		L												L	
Colombia			L													
Costa Rica			L													
Bangladesh	L															
Thailand	L															

commercial Production	P
regulatory Approval	A
Field study	F
Lab / greenhouse	L

Source: AGBIOS (2004); FAO (2004); ISB (2002); WISARD (2004); BINAS (2003).

Papaya is the only commercially available biotech fruit product, and grown only in the United States Hawaiian Islands. Field studies have also been conducted in numerous other countries, such as South Africa (strawberries); Mexico (papaya, banana, pineapple, melon); Australia (papaya, pineapple, apples, grapes); and China (papaya, melon). Laboratory and/or greenhouse experiments have occurred in Chile (melon, apples, grapes, and stone fruit) plus numerous other countries.

Other crops

Eleven crops not discussed thus far have been researched, tested, or approved in 29 countries (Table 10). Except for tobacco, this group of crops has not been as widely researched for biotech potential. Another exception is chicory, which has regulatory approval in both the United States and Western Europe. Biotech tobacco is produced commercially in the U.S., and has regulatory import approval in Western Europe. Tobacco has attracted field study and/or laboratory experiments in numerous other countries, including Argentina, Brazil, Mexico, Chile, Venezuela, the Philippines, Indonesia, India, Bangladesh, South Korea and Malaysia. Other biotech crops with field study or lab work are groundnuts (China); coffee (Indonesia, Venezuela); peanuts (Indonesia, Bangladesh); Indian mustard (Australia); brown mustard (Canada); cocoa (Argentina); lupins (Australia) and oilseed poppy (Australia).

Table 10 - Global Biotech Activity: Other Crops - highest level of biotech development

OTHER CROPS by COUNTRY	Tobacco	Chicory	Mustard	Peanut	Coffee	Lupins	Oilseed poppy	Olive	Oil palm	Cocoa	Garlic
United States	P	A		F	F						
West Europe (9/15)	a	A	F					F			
Australia			F			F	F				
China	F			F							
Brazil	F									L	
Canada			F								
East Europe (3/13)	F										
South Korea	F										
India	F										
Mexico	F										
Indonesia	L			L	L				L	L	
Chile	L										L
Bangladesh	L			L							
Malaysia	L								L		
Venezuela					L						
Philippines	L										
Argentina	L										
Cuba					L						
Japan	L										

commercial Production	P
regulatory Approval	A
Field study	F
Lab / greenhouse	L

Source: AGBIOS (2004); FAO (2004); ISB (2002); WISARD (2004); BINAS (2003).

In summary, around the world, many biotech plant varieties already have regulatory approval, and could be taken from field studies to commercial production quite rapidly, allowing substantial adoption within a few growing seasons. Two obvious examples are soybeans and maize in China. China had total soybean and maize production in 2003-2004 of 16.2 and 114 million metric tons, respectively. If half of this production was biotech, it would add about $2.5 billion to the total value of biotech crop production at 2003-2004 prices. When the deeper levels of activity preceding commercialization are explored at an international level, it is clear that a wide array of biotech plants is of potential interest (and value) in both developed and developing countries. We turn now to a geographic assessment of this activity by region of the world.

Part III:

Regional Summary and Country Profiles

In Part III, we examine the countries engaged in commercial biotech adoption, research and development in different regions of the world. These regional and country profiles provide a geographic context to the activities summarized in Tables 7 through 10, and offer more in-depth information. Country profiles are organized as assessments of the status and performance of biotech crops in Africa, Latin America and the Caribbean, the Asia-Pacific region, Europe and North America.[5] An Appendix provides the detailed data underlying the analysis. Regional assessments identify commercial approvals, production, field studies past and ongoing, as well as laboratory or greenhouse research.

As in Tables 7-10, regulatory approval information for 19 countries is based on information collected by AGBIOS, a Canadian firm.[7] The Food and Agriculture Organization (FAO) of the U.N. has limited data on experimental research and field trial studies for developing countries, but lacks clear information on timeframes and specific traits.[8] The Information Systems for Biotechnology (ISB) of the University of Vermont coordinates USDA APHIS data on U.S. field trials, and has links to 35 other countries for field study information.[9] In addition, three other sources of data were tapped: the Web-based Information Services for Agricultural Research and Development (WISARD) project;[10] the Biosafety Information and Advisory Service (BINAS) of the U.N. Industrial Development Organization (UNIDO);[11] and the U.S. Department of State.[12] Overview statistics for each country are based on U.S. Central Intelligence Agency data.[13] Drawing on these sources, we constructed regional profiles for each of the country groupings.

Africa and the Middle East

Countries with biotech crop activity in Africa include South Africa, Kenya, Zimbabwe, Morocco, Tunisia and Egypt. All told, FAO data indicates three biotech commercial crop developments, 18 field trials and 11 experiments in these countries. *South Africa* is the leader, and ranks sixth (after the top five adopting nations noted above) in biotech crop hectares. James (2003) estimates 400,000 South African hectares planted to biotech maize, soybeans and cotton in 2003-2004, an increase of one-third over 2002. Monsanto's herbicide tolerant maize was approved for release in 2003, with South Africa the first country to grant approval after the United States. Monsanto has received South African approval for Yieldgard® maize, as well as approval for one Roundup Ready® soybean variety and one cotton variety. Total commercial market value for South Africa's biotech maize, soybeans and cotton at 2002-2003 world prices for these commodities of $100mt, $250mt and 59¢lb respectively was $130 million, $2.9 million, and $14 million, for a total of $146.9 million. Three South African field trials for maize have been undertaken for glyphosate tolerance and phosphinothricin tolerance. Five cotton field trials have focused on glyphosate tolerance and other resistances. Two field trials on canola are recorded for glyphosate and phosphinothricin tolerance. Field trials have also been undertaken for strawberries, sugar cane and potatoes. South Africa has to develop a national biotech research strategy but has faced a high rate of attrition of its scientists to the United States.[14]

Kenya has also made efforts to develop research and development of plant biotech, particularly biotech maize.[15] Supported by scientists at the Kenya Agricultural Research Institute (KARI), the University of Nairobi and Kenyatta University, research programs are underway in Lepidoptera resistance for maize (primarily European corn borer). Michigan State University has been supporting some of this research.[16] In addition to maize, field trials have occurred on sweet potato for viral resistance to sweet potato feather molt virus (SPFMV) which can reduce yields by up to 80 percent. Under a non-exclusive, royalty-free licensing agreement with Monsanto signed in 1998, KARI may use and develop transgenic virus resistance technology for sweet potatoes and transfer it to any country in Africa.[17]

Zimbabwe is a third African country that has been active in plant biotech research, especially at the University of Zimbabwe, where work has occurred on Lepidoptera resistant cotton, mosaic-virus resistant cassava, sweet potatoes resistant to mottle virus, cowpeas with virus and herbicide tolerance, and marker genes for parasitic weeds such as *striga asiatica*.[18] This work has been disrupted by political instability. Zimbabwe's Tobacco Research Board is working on herbicide tolerance and disease resistance, as well as male sterile lines. This work has been conducted in various institutes and research centers, including the Biological Research Institute (BRI) of Zimbabwe, and the Ministries of Land, Agriculture and Water Development and of Environment.[19]

Morocco has experimented with biotech wheat, and some biotech research is underway at Morocco's Institut National de la Recherche Agronomique (INRA), Ecole Nationale l'Agriculture de Meknés (ENA) and the Institut Agronomique et Vétérinaire Hassan II (IAV). This and other plant biotech work is coordinated by Morocco's Ministry of Agriculture, Rural Development and Fisheries and Ministry of Higher Education and Scientific Research.

In *Tunisia*, experiments have been conducted on biotech potato varieties with viral resistance. The Institut National de Recherches en Genie Rural, Eaux et Forets has a research center focused on biotech, the Centre de Biotechnologie de Sfux (CBS) and research is also conducted at the Institut National de Recherche Scientifique et Technique (INRST) at Jendouba and Tunis El Manar universities.

Egypt has commercialized virus resistant canola and is planting drought resistant cotton. It is supported in its biotech research through agreements with American Land Grant colleges and universities, such as Michigan State.[20] Field studies have been conducted on nine biotech crops (cucumbers, maize, melon, potato, cantaloupe, squash, sugar cane, tomato and wheat). These studies have tested virus resistance in cucumber, melon, cantaloupe, squash, sugar cane and tomato, as well as Lepidoptera resistance in maize and potatoes and salt tolerance in wheat. Experimental studies have been conducted in Egypt on biotech banana (heat tolerance, virus resistance), barley (salt tolerance), cotton (heat tolerance), fava bean (necrotic yellow virus resistance) and cotton (Lepidoptera resistance). Within Egypt's Agricultural Research Center (ARC), the Agricultural Genetic Engineering Research Institute (AGERI), together with Cairo University, the University of Alexandria and Ain Shams University have led much of the research effort.[21]

Latin America and the Caribbean

Latin America and the Caribbean nations are home to some of the most aggressive adopters of plant biotech and appear poised to move to adopt more varieties in the near future. The Food and Agriculture Organization (FAO) shows a total of five commercial biotech crops grown in the region, 110 different field trials, and 86 plant biotech experiments in 12 Latin American and Caribbean countries.[22] This adoption process is led by *Argentina*, one of the most fertile and productive land masses on earth. James reports that 13.9 million hectares of biotech soybeans, cotton and maize were grown in Argentina in 2003-2004. Almost 100 percent of Argentina's soybean crop is herbicide tolerant, while 40 percent of its maize is insect-resistant. As noted earlier, the combined value of these biotech varieties was $8.9 billion in 2003-2004, making Argentina the second ranking country by value for biotech plants worldwide.

Each year for the last seven, biotech soybeans have gained market share in Argentina, driven by savings due to reduced chemical costs and more stable yields, estimated at $35-55 per hectare[23]. As the world's third largest soybean producer, and a major exporter, this makes Argentine farmers highly competitive in world markets. Argentina has nine biotech product lines approved for environmental release and/or consumption as food or feed. The only approved biotech soybean variety in Argentina is Monsanto's Roundup-Ready® line (GTS-40-3-2), approved in 1996. Cotton, produced mainly in the northern province of Chaco, shows one pest-resistant biotech varieties approved for use, according to AGBIOS. These are Monsanto's Bollgard cotton, approved in 1998, and its herbicide tolerant cotton approved for environmental use in 1999 and food/feed use in 2002.

In maize production, 40 percent of Argentina's $500 million 2003/04 crop was biotech, with six varieties approved for use. These are Bayer's Liberty Link lines with herbicide tolerance (T14 and T25); DeKalb Bt Xtra (TBD-418) with herbicide tolerance; Monsanto Yieldgard (MON810); Monsanto Roundup-Ready® (GA21) and Syngenta NaturGard KnockOut (SYN-176) with resistance both to European corn borer and tolerance to herbicide. All of these lines were approved by 1998. In 2001, Syngenta's line SYN-BT11 was approved, with tolerance for the herbicide phosphinothricin (PPT).

Apart from these commercial approvals, Argentina is also a biotech research center in Latin America, despite its recent economic crises. Numerous national research centers and universities are involved in the effort, notably the Instituto National de Tecnologia Agropecuaria (INTA), the Instituto di Investigaciones Fisiologicas y Ecologicas Vinculadas a la Agricultura Universidad Nacional de Buenos Aires (UBA) and the Asociación Argentina de Consorcios Regionales de Experimentación Agrícola. Field trials have been conducted on alfalfa, cotton, maize, potato, soybean, sugar beet, sunflower, tomato and wheat. Lab experiments have been undertaken on alfalfa, barley, potato and sugar cane.

Although approvals for biotech crops were halted in 1998 in response to European resistance, by 2001 cotton approvals were granted, and Argentina has moved ahead of the rest of the Mercosur trade group (Brazil, Paraguay and Uruguay) in developing a commercial authorization process involving field tests, toxicology assessments, and export market impact analysis.

Bolivia has also been involved in some limited trials of biotech crops. Encouraged by the Bolivian Ministry of Agriculture, field trials in cotton, potatoes and soybeans are underway, although Bolivia's cotton sector has largely yielded to competition from Brazil and Peru.

After Argentina, *Brazil* is the next leader in adopting plant biotech in Latin America. Estimating actual Brazilian activity is difficult due to less than transparent claims resulting from concerns over European importers' opposition to biotech. Estimates identify only soybeans as a commercial biotech crop only as of 2003-2004. Of the 53.5 million metric tons of Brazilian soybeans produced on 21.3 million hectares in 2003-2004, officially only 12 percent were biotech varieties, although unofficial estimates put the adoption rate as high as 30 percent. Using the lower figure and 2003-2004 soybean prices of $250/metric ton, the total value of Brazil's official biotech crop was $1.6 billion. If the 30 percent estimate is used, this value is $4.0 billion. In particular, in Rio Grande del Sul, the third-ranking state in soybean production in Brazil, some estimates put biotech adoption rates at 90 percent.

Commercially, only Monsanto's herbicide tolerant soybeans are approved in Brazil. However, 27 field studies have been conducted on various crops. These include herbicide tolerant and virus resistant edible beans, carrots for carotenoid genes, herbicide tolerant and insect resistant cotton, maize with herbicide tolerance and insect resistance, virus resistant papaya, virus resistant potato, herbicide tolerant rice, herbicide tolerant and insect resistant soybeans, sugar cane with multiple resistances, virus resistant tobacco, tomatoes resistant to gemini and tospovirus, and solanaceae used to isolate virus genes for resistance traits.

There are also 11 Brazilian crops that are the subject of experimental studies. These are barley (fungi resistance), cocoa (fungi resistance), lettuce (unspecified), maize (aluminum and phosphorus deficiency), rice (salt tolerance and fungi resistance), soybeans (insect resistance) and sugar cane (insect resistance).

The lead Brazilian agency for agricultural research, EMBRAPA, has conducted field studies on virus resistant papaya and edible beans, and is seeking a license to study virus resistance in potatoes. EMBRAPA has developed its own, competing version of herbicide tolerant soybeans, resistant to imidazolinone rather than glyphosate. Indicative of growing commercial interest in plant biotech are emerging companies such as Codetec, which markets four soybean varieties with various traits, including herbicide tolerance.[24]

Although it has no market approvals, *Chile* is a potentially important base for plant biotech activity, in part due to its relative political and economic stability and strength in technical research.[25] Chile has launched 16 experimental studies: three on apples (fungi resistance), three on potatoes (virus resistance), three on tobacco (unspecified) and three on tomatoes (unspecified) as well as on garlic (fungi resistance), melon (virus resistance), and stone fruit (ripening). Chile anticipates an export platform for biotech fruit by 2008. As a major fruit exporter with $1.5 in sales in 2003, its public and private sector are poised to compete with Argentina and Brazil in the plant biotech sphere. Apart from at least 30 private sector companies working in the area, its Ministry of Agriculture and its Forestry divisions, together with the

Institute for Plant Biotechnology and Biotechnology at the Universidad de Chile are leading the way.

Colombia's plant biotech activity is relatively limited, although it was the first to grow Bt cotton in Latin America in 2002.[26] It has also had field trials in Bt cotton, and experimental studies in cassava (unspecified), plantain (virus resistance), potato (virus resistance) and tree tomato (fungi resistance). One center of international research on plant biotech, the Centre International de Agricultura Tropical (CIAT) is located in Colombia.

Costa Rica has no market approvals or field trials, but two experimental projects: maize (virus resistance) and rice (virus resistance). Research in Costa Rica is led by the Ministries of Agriculture and the Environment, and the Centro Agronómico Tropical de Investigación y Enseňanza (CATIE) and its Institute for Agrarian Development (IDA), as well as the University of Costa Rica (UCR) and the National Council of Scientific and Technological Research (CONICIT).

Cuba has no market approvals, but is remarkably active in field and experimental studies. Its seven field studies include three on sugar cane (fungus, herbicide and insect resistance), two on potatoes (fungi and herbicide resistance), one on papaya (virus resistance) and one on sweet potatoes (insect resistance). Its experimental studies include three each on rice (insect, fungi and herbicide resistance), sugar cane[27] (insect and fungi resistance, lignin content), and pineapple (insect, fungi and herbicide resistance). They also include two on banana (herbicide and fungi resistance), two on citrus (virus and fungal resistance), two on coffee (insect and herbicide resistance), two on tomato (virus and fungal resistance) and one each on maize (insect resistance), papaya (fungal resistance), and potato (virus resistance).

In *Honduras*, there are no market approvals and only one field trial on maize (insect resistance) although commercial approval for Bt maize is pending.

Mexico has three market approvals and an active biotech research program, with an estimated 100 scientists specializing in biotech, and active private sector actors such as Savia and Cinvestav. Mexico first planted biotech cotton commercially in 1996, the same year as the United States. By 2000, biotech cotton accounted for 261,300 hectares, one-third of Mexico's growing area.[28] Market approvals have been granted for Monsanto's glyphosate resistant soybeans (granted in 1998), its insect resistant cotton (granted in 1997) and Calgene's slow-softening tomato (granted in 1995). Many agricultural research institutes are active in biotech, including the CGIAR research center CYMMIT, outside Mexico City, and the Centre of Biotechnology at the Universidad Autónoma Agraria Antonio Navro (UAAAN) Institute Tecnologico Agropecuarie. Two experimental studies on rice (unspecified) and wheat (aluminum tolerance) are joined by a total of 33 field studies. Four of these are on cotton (insect and herbicide resistance), four on maize (insect and herbicide resistance), and three each on tomato (insect and virus resistance and enhanced ripening), and wheat (herbicide and other resistance). There are two field studies each on canola (laurate oil composition and unspecified), melon (ripening and virus resistance), papaya (ripening and virus resistance), potato (insect and virus resistance), soybeans (herbicide resistances) and tobacco (fungi and virus resistance). Plants with one field study each include banana (ripening), chili pepper (ripening), flax (unspecified), pineapple (ripening), rice (unspecified), squash (virus resistance) and zucchini (virus resistances). All told, Mexico is rapidly developing an active plant biotech sector, despite the political controversy that has surrounded transgenic maize.

In October, 2004, *Paraguay*, the world's number four soybean exporter, approved four biotech soybean varieties developed by Monsanto. While technically beyond the time frame of this study, evidence supports the view that 50 percent or more of the Paraguayan soybean crop is already biotech, planted with bootlegged Argentine seed.[29]

Peru has no market approvals, but five experimental studies. Peru is home to the CGIAR potato research institute (CIP). All of Peru's experiments involve tubers: three on potatoes (fungi and virus resistance and toxicant reduction) and two on sweet potatoes (flour quality and virus resistance). One field study also concerns potatoes (insect resistance to tuber moth).

Uruguay grew Bt corn for the first time in 2003-2004, and had 60,000 hectares of biotech soybeans planted in the same year.[30] It has one market approval, for Monsanto's glyphosate tolerant soybean (line GTS 90-3-2), granted in 1997. We found no record of experimental or field studies in our databases.

Venezuela has one biotech field study underway on cassava (high yield) and seven experimental studies, including banana (bacteria resistance), coffee (virus resistance), mango, papaya, rice and sugar cane (all unspecified). A national strategy for Venezuelan agricultural biotechnology is in preparation in cooperation with the Instituto Nacional de Investigaciones Agricolas de Venezuela (INIA) and labs such as the Instituto Venezolano de Investigaciones Cientificas (IVIC) and several universities.

<u>Asia and the Pacific</u>

Twelve countries in the Asia-Pacific region are involved in some aspect of plant biotech. The leading national programs are in Australia, China, India, Indonesia and the Philippines, followed by more modest activities in Bangladesh, Japan, Malaysia, Pakistan, Korea and Thailand.

Australia has a very active scientific and commercial biotech sector. In 2003-2004, Australia planted 100,000 hectares to biotech cotton (59 percent of total cotton area).[31] In addition to four authorized biotech cotton lines with herbicide and insect resistance (three are Monsanto lines and one Calgene), Australia has approved six other biotech crops, although in most cases for import only. One is maize. Eight biotech maize varieties are authorized. Four of these are Monsanto's herbicide and insect resistant lines, two approved in 1998, one in 2002 and one in 2003. Two are Syngenta lines with herbicide and insect resistance, approved in 1998 and 2001. One each are lines from Bayer (herbicide tolerant – 1998) and DeKalb (herbicide and insect resistant – 1998).

In soybeans, two biotech varieties are approved in Australia: a Monsanto glyphosate tolerant line approved in 1996 and a Dupont Canada line with high oleic acid expression approved in 2000. Argentine canola is represented in six approved lines: two Bayer lines with herbicide tolerance approved in 2002 and 2003, three Aventis (now Bayer) herbicide tolerant lines approved in the same years, and one Monsanto Westar line with herbicide tolerance approved in 2003.[32]

Biotech sugar beets with herbicide tolerance in a Monsanto-Novartis In-Vigor line were approved for food and feed use in 2002. Finally, three potato lines are approved for import: all Monsanto NewLeaf varieties resistant to Colorado potato beetle in 2001.

The Australia Commonwealth Scientific and Industrial Research Organization (CSIRO) and Agrifood Awareness Australia (AFAA) together report a large number of biotech field trials. These include fruit crops such as apples (antibiotic resistance), grapevine (fruit color), pineapple (biochemical properties and flowering), tomatoes (herbicide tolerance) and papaya (antibiotic resistance, fruit quality). They also include grains, oilseeds and lupins, such as barley (starch breakdown, herbicide tolerance), wheat (herbicide tolerance, ampicillin resistance), canola (fungi resistance, herbicide tolerance, insensitivity to daylight, plant structure, pod scattering), oilseed poppy (increased alkaloids), Indian mustard (herbicide tolerance) and lupins (color bioassay selection, herbicide tolerance, nutritional value). Finally are other field crops such as cotton (herbicide tolerance, insect resistance, tolerance to water logging), field peas (insect resistance, nutritional quality), lettuce (antibacterial resistance, virus tolerance), subterranean clover (herbicide tolerance, nutritional quality) and white clover (virus resistance).[33]

Bangladesh, despite its poverty, has undertaken a number of experimental trials on biotech crops. These include jute (fungi resistance), lentils (unspecified), mungbean (increased yield), papaya (virus resistance), peanuts (technological attributes), rice (salt tolerance) and tobacco (unspecified).[34] Bangladesh continues to face challenges in creating a regulatory system allowing commercialization. There is disagreement over which agencies should take the lead on biosafety issues, the Bangladesh Ministry of Science and Information and Communication Technology (ICT) or the Ministry of Environment and Forestry, and how their responsibilities should be divided.[35]

Perhaps the most significant single potential actor in Asia and the Pacific, as in so many other Asian matters, is *China*. The general nature of this report, together with a lack of transparency by Chinese authorities, prevents a needed and detailed assessment of the full range of China's activities in plant biotech. Even so, enough is known to provide a fairly clear picture. China's disposition to biotech might be characterized as aggressively engaged.[36] From 1996 to 2000, 141 biotech crops were developed, 45 of which were approved for field trials, 65 for environmental release and 31 for commercialization.[37] James reports that in 2003-2004, China will plant 2.8 million hectares to Bt cotton, an adoption rate of 68 percent. As reported above, this production had a market value of $3.9 billion. China granted commercial approval to Monsanto's insect resistant cotton in 1997 including (but not limited to) lines resistant to bollworm, pink bollworm and tobacco budworm. In December, 2003, China announced that it would grant approval for imports of U.S. biotech soybeans, and in April, 2004, it approved four corn and seven canola varieties.[38] In addition, FAO reports that commercialization is underway for virus resistant green pepper, virus resistant and prolonged ripening of tomatoes. In field trials, China has at least 13 different biotech plants. These include chilies (virus resistance), cabbage (virus resistance), maize (high lysine and insect resistance), cotton (verticilium and fusaviam resistance), groundnuts (virus resistance), melon (virus resistance), papaya (virus resistance), potatoes (wilt and virus resistance), rice (insect resistance, salt tolerance and virus resistance), soybeans (insect resistance), tobacco (virus resistance), sweet pepper (virus resistance) and tomatoes (frost resistance). It is evident from these trials that the Chinese have placed great emphasis on biotech traits of virus resistance.

In the experimental phase, China has undertaken work on barley (unspecified), carrots (mycobacterium proteins), maize (salt tolerance), canola (unspecified), papaya (growth delay and fruit ripening), sorghum (salt tolerance), wheat (wilt resistance) and sugar beets (aluminum tolerance).

These trials and experiments provide only a surface view of Chinese R&D activity. China's government funding for biotech places it second only to the United States, with hundreds of millions of dollars invested in the late 1990s and early 2000s.[39] In a survey of 20 of China's government-financed plant biotechnology research institutes, analysts at the University of California-Berkeley concluded that these expenditures "demonstrate the seriousness of China's commitment to plant biotechnology." In 2000, these were about five times the levels of investments in India, and 50 times those of EMBRAPA in Brazil. Chinese officials planned to raise research budgets in plant biotech by 400 percent from 2001-2006, causing China to account for as much as one-third of global public spending on plant biotechnology. In the next 10 years, it is estimated that about half of China's fields will be planted to biotech crops.[40]

India has at least 20 academic and research institutions involved in plant biotech research covering 16 crops, while seven private companies are working on 10 crops, according to Biotech Consortium India Ltd. Other estimates put the number of public biotech research units at 50. A number of multi-institutional efforts have also been launched to develop virus resistance in cotton, mungbean and tomatoes, and resistance to rice fungus disease and nutritionally balanced potatoes. In March, 2002, India granted approval for Monsanto's insect resistant (Bt) cotton (MON531/757/1076), the result of a joint venture between Monsanto and Mahyco, of Mumbai, India. Average yield increases using Bt varieties are 30 percent over non-Bt hybrids.[41] Organized opposition to plant biotech in India has been strong, led by activists and organizations such as Greenpeace, who have challenged field trails in the Indian Supreme Court. Another group, Delhi-based Gene Campaign, filed a petition in the Delhi High Court charging that commercial approval of Bt cotton was negligent.[42] In the face of this opposition, the Indian government's policy is to continue plant biotech research while strengthening their R&D and improving their capacity to evaluate safety and environmental issues.[43]

In addition to the commercial approval of insect resistant cotton, India has undertaken field trials on canola (moisture stress), cotton (insect resistance) and tobacco (insect resistance). It has experimental studies underway on cabbage (insect resistance), potatoes (starch composition, insect resistance, and moisture stress), rice (fungi resistance) and tomatoes (delayed ripening). This research is under girded by a substantial university-based research capability, including the Indian Agricultural Research Institute, the Central Tubar Crops Research Institute, the Indian Institute of Science (IIS) of Assam Agricultural University (AAU), Punjab

Agricultural University (PAU) and Kerala Agricultural University (KAU).[44]

Indonesia also has plant biotech at all three levels of activity: commercial, field studies and experiments. It has commercially approved insect resistant cotton. Indonesia has undertaken field studies for cotton (insect and herbicide resistance), maize (insect and herbicide resistance) and soybeans (herbicide resistance). At the experimental phase, it has work underway for cocoa (insect resistance), cassava (starch composition), coffee (fungi resistance), maize (insect resistance), oil palm (insect resistance), peanuts (virus resistance), peppers (unspecified), potatoes (insect and virus resistance), rice (insect resistance), soybeans (insect resistance), sugar cane (drought tolerance), sweet potatoes (virus resistance), tobacco (virus resistance) and tomatoes (unspecified).

Pakistan has only two plant biotech experiments identified by FAO: insect resistant cotton and fungi resistant rice. It has lagged in developing regulatory and approval guidelines for commercialization, and black market plantings of biotech maize, wheat, cotton and vegetables are common. At the laboratory level, Pakistan has developed biotech lines of cotton, sugar cane, soybeans, and tomatoes, according to government scientists.[45] There is also considerable interest in biotech mango production.[46]

In the *Philippines*, there is one crop approved for commercialization: Monsanto's insect resistant (Bt) maize, approved in 2002, resulting in yield gains averaging 40 percent in nine field trials. Field trials are underway for biotech bananas (virus resistance) and maize (insect resistance). Experimental studies have been conducted on coconut (lauric acid content), mangoes (delayed ripening), papaya (delayed ripening and virus resistance), rice (resistances to fungi, insects and bacteria and salt tolerance), and tomatoes (delayed ripening). Four leading multinational firms – Monsanto, Syngenta, Pioneer-Hybrid and Bayer – are seeking licenses for commercial production of biotech soybeans, cotton, maize, canola, potatoes and sugar beets.[47]

South Korea has approved three lines for import only: Monsanto's herbicide tolerant maize in 2002, maize resistant to European corn borer in 2002 and herbicide tolerant soybeans in 2000. It has field trials on two crops: hot pepper (virus resistance) and tobacco (virus resistance). Despite this limited activity to date, South Korea has initiated a $100 million, 20-year program, the 21st Century Research Program, to fund future biotechnology and robotics. The Korea Research Institute of Bioscience and Biotechnology in Seoul identifies the main plant biotech research areas as functional analysis of crop genomes, indigenous biodiversity, stem cell biology, proteomics and bioregulators and novel compounds.[48]

Japan granted regulatory approval, some for import only, to six biotech crops in 2003: canola (herbicide tolerance), cotton (herbicide tolerance and insect resistance), maize (herbicide tolerance and insect resistance), potatoes (insect resistance, virus resistance – for import only), soybeans (herbicide tolerance, high oleic and) and sugar beets (herbicide tolerance – for feed import only).[49] It has had field studies dating to 1996 for melon (virus resistance), as well as cucumber (fungi and virus resistance – 1999), adzuki beans (insect resistance – 1999), tomatoes (delayed ripening, pectin-enriched, virus resistance – 2000), broccoli (herbicide tolerance, male sterility – 2001), cauliflower (herbicide tolerance, male sterility – 2001) and most significantly, rice (herbicide tolerance, virus resistance, low allergenicity, low protein, cold resistance – 2003).[50] In the laboratory, Japan has experimented with lettuce (ferritin enriched – 2000), papaya (virus resistance – 2000), strawberries (mildew resistance – 2000), tobacco (virus resistance, GUS enzyme – 2000) and wheat (herbicide tolerance – 2001).[51]

Malaysia has been actively promoting itself as a test-bed of biotech ideas. Heading a 40 member delegation to the Biotechnology Industry Organization (BIO) in 2004, the Malaysian

Minister of Science, Technology and Innovation announced the country's Biotechnology Agenda, including the formulation of three research institutes for genomics and molecular biology, pharmaceuticals and nutraceuticals.[52] The Malaysian Agricultural Research and Development Institute (MARDI) is increasing its funding base and research capability in order to capitalize on biotechnology experiments underway.[53] These experiments include work on biotech banana (unspecified), chili pepper (virus resistance), eggplant (unspecified), muskmelon (unspecified), oil palm (biodegradable plastics), papaya (virus resistance, extended shelf life), peppers (virus resistance), pineapple (blackheart tolerance), rice (fungi resistance), tobacco (unspecified) and wingbean (fungi resistance).

New Zealand's Environmental Risk Management Authority reports a canola field trial for herbicide tolerance in 1998. In 2003, field studies were approved for herbicide tolerant onion.[54]

The final Asian nation with a small plant biotech sector is *Thailand*. Since 1983, when Thailand's National Center for Genetic Engineering and Biotechnology was established, Thailand has been an eager participant in plant biotech research and development, although political resistance from NGO's has grown in recent years. FAO reports field studies on cotton (insect resistance), rice (salt and drought tolerance), tomatoes (delayed ripening, virus resistance) and pepper (virus resistance). At the experimental level, it has work on cassava (unspecified), papaya (virus resistance) and yard long beans (aphid-borne virus resistance). The Thailand Biodiversity Center also reports R&D on virus resistance in rice, product quality traits in papaya, and herbicide tolerance in pineapple.[55]

<u>Europe</u>

While much world press attention has focused on European resistance to plant biotech from green lobbies and negative public opinion, there has been substantial investment and activity in European biotech R&D since the early 1990s. The amount and complexity of this activity is reviewed in a study conducted for the European Commission's Joint Research Centre. Survey data was collected on activities in the pipeline capable of further development in the next decade and beyond.[56] Consistent with the methodology used in this study, plant biotech activities were divided by the Joint Research Centre into three phases: (a) approval for commercial sale; (b) field trials; and (c) laboratory and/or greenhouse tests.

Under Directive 90/220/EEC, 14 biotech plants produced by various companies were approved for commercialization in the European Union (EU) through 1998: 4 maize lines, 4 oilseed rape (canola) lines, and one chicory, soybean and tobacco line. These authorizations covered cultivation, import and processing for food or feed purposes, or breeding activities.[57] In addition, 13 applications that were pending authorization under the Directive were favorably reviewed by the Scientific Committee on Plants (SCP). These included 5 maize lines, 3 oilseed rape (canola) lines, 2 cotton lines, one fodder beet line and one potato line. The biotech potato line had a modified starch metabolism, and one maize line had both insect resistance and herbicide tolerance ("stacked" traits).

In 1999, field trials, which had been quite active throughout the 1990s, fell off dramatically after the decision of the EU Council of Environment Ministers to block new commercial releases, falling 87 percent between 1998 and 2002. The June 1999 *de facto* moratorium suspended all approval applications until implementation of a revised form of Directive 90/220/EEC, providing a legal safety framework, together with labeling and traceability requirements. This moratorium became the basis of serious frictions between the EU and biotech exporting nations such as the United States, Canada and Argentina. Although the moratorium now appears to be near an end, political opposition to plant biotech remains strong in the countries whose environment ministers supported it: Denmark, Italy, Luxembourg, France, Greece, Germany and Belgium.

Under a new Directive, 2001/18/EC, some pending applications were withdrawn, some resubmitted, and some new applications were made. As of March, 2003, 19 applications had been submitted under the new directive. These included 5 lines of herbicide tolerant oilseed rape (canola), 2 lines of herbicide tolerant maize, 2 lines of herbicide tolerant sugar beets, and one line each of herbicide tolerant fodder beet, herbicide tolerant soybeans, herbicide tolerant cotton, insect resistant cotton and modified starch content potato. In addition were 5 lines of "stacked" insect resistant and herbicide tolerant maize.[58]

Overall, the EU's plant biotech sector was dealt a serious blow by the 1999 moratorium on commercial release. In its analysis, the European Commission's Joint Research Centre found that numerous research projects were delayed or postponed due primarily to the unclear legal status of EU plant biotech, low consumer acceptance of biotech products, uncertain future markets and requirements for future testing.[59] As research has stalled, European scientists have been drawn to more receptive research environments. As Syngenta CEO Michael Pragnell noted in mid-2004, "When we combine regulatory uncertainty with the prevailing European mistrust of technology in its broadest sense, there is a serious risk that research investment will move elsewhere or disappear altogether."[60] Yet, despite this somewhat clouded outlook, substantial investments have been made in European plant biotech R&D, and many can eventually find commercial application, given an appropriately structured regulatory environment. In the discussion to follow, we divide Europe into 15 Western European and 12 Eastern European countries.

Western Europe

Of the 15 countries active in plant biotech in Western Europe, 14 are members of the newly enlarged European Union: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Netherlands, Portugal, Spain, Sweden, and the United Kingdom. Switzerland, while not an EU member, nonetheless has substantial plant biotech activity.[61] Because much of the regulatory framework affecting biotech now originates in Brussels, the approvals and other measures (such as the moratorium on importation of biotech maize) are EU-wide. However, national governments have their own research and development programs and different dispositions toward adoption of plant biotech, depending on their own national politics and interests. All 14 EU members in Western Europe have reported field trials to the Joint Research Centre of the European Commission in Brussels.

In the EU *writ large*, numerous biotech crops have received production or import approval, even though their commercial availability may vary widely from country to country. These include several lines of Argentine canola: a glufosinate ammonium herbicide tolerant line from Bayer (1996), a phosphinothriun herbicide tolerant line (1997, 1998) and a glyphosate herbicide tolerant line from Monsanto (1997). In 1996, glufosinate ammonium herbicide tolerant chicory was approved. In maize, approval was granted in 1998 to a glufosinate ammonium tolerant line from Bayer, to an insect resistant Monsanto line in 1998, and to an insect and herbicide resistant Syngenta line in 1997. In soybeans, Monsanto received approval in 1996 for its glyphosate tolerant line, and in tobacco, a line tolerant to herbicides broxonyail and ioxynil was approved for the Societé National d'Exploitation in 1994. In all, the EU's Joint Research Centre records 1849 field trials for food and fiber (excluding trees and flowers) between 1991 and August, 2004 in the 15 countries of Western Europe.[62] In rank order, the countries with the largest number of field studies are discussed below.

France had 520 biotech field studies. In the last full year for which data is available (2003), it had 17. Among the crops receiving primary attention were maize, oilseed rape, sugar beets and tobacco. In addition, chicory, cotton, grapes, lettuce, melon, potatoes, rice and sunflowers have been the subject of field studies.

Italy had 270 biotech field studies, although only two in 2003, reflecting continuing opposition by Italy's Green parties to the technology. Primary emphasis was on maize, tomatoes and sugar beets, with additional tests on chicory, eggplant, grapes, kiwi, lettuce, melon, rape, olives, potatoes, raspberries, rice, soybeans, squash, strawberries, cherries, tobacco, watermelon and wheat.

Spain had 263 biotech field studies, with nine in 2003. Main emphasis was on maize, rice and cotton. Additional field studies were conducted on alfalfa, cantaloupe, plums, melons, oilseed rape, oranges, potatoes, rice, soybeans, squash, strawberries, sunflowers, sugar beets, tobacco and wheat. James reports that in 2003-2004, six percent of Spain's maize crop was planted to biotech varieties.[63]

In the *United Kingdom* (U.K.), there were 199 biotech field studies, with eight in 2003. Main attention was to oilseed rape, potatoes and sugar beets, with additional tests on barley, chicory, maize, apples, peas, strawberries, tobacco, tomatoes and wheat.

In *Germany*, 138 biotech field studies were conducted. Primary emphasis went to potatoes, rape and sugar beets, with additional tests on apples, grapes, peas, soybeans, spinach, tobacco and wheat. A small amount of insect resistant maize was planted in Germany in 2003-2004.[64]

The Netherlands had 138 biotech field studies. Primary emphasis went to potatoes, sugar beets and oilseed rape. Also of interest were apples, cabbage, carrots, chicory, maize, ryegrass, sunflower and tomatoes.

Belgium had 129 biotech field studies, with one in 2003. Primary emphasis was on oilseed rape, maize and sugar beets. Also of interest were apples, alfalfa, cauliflower, chicory, Indian mustard, potatoes and wheat.

Sweden had 68 biotech field studies. Primary emphasis was on oilseed rape, potatoes and sugar beets. Additional field studies were performed on apples and mustard.

Denmark had 38 field studies. Interest focused on sugar beets, potatoes, oilseed rape and maize.

Greece had 19 biotech field studies. Primary attention was to cotton, maize, sugar beets and tomatoes.

Finland had 16 biotech field studies. Its interest was in barley, broccoli, cabbage, cauliflower, oilseed rape, potatoes, sugar beets and tobacco.

Portugal had 11 biotech field studies, but has had only one field test since 1999. Its interest was in maize, tomatoes and potatoes.

Ireland had 5 biotech field studies. Its most recent was in 2002. Interest has been primarily in sugar beets.

Austria had 3 biotech field studies, although its most recent dates to 1997. Its interest was in potatoes and maize.

Finally, although not an EU member (and thus not included in the Joint Research Centre survey), *Switzerland* has granted regulatory approval for biotech maize and soybeans. According to ABGIOS, insect resistant Bt Monsanto maize was granted approval in 2000, while Syngenta received approval for its own insect resistant and herbicide tolerant maize in 1997 and 1998.

Monsanto's glyphosate tolerant soybeans received Swiss approval in 1996.

Eastern Europe

Eastern Europe includes 13 countries in Central and Eastern Europe. Some of these are part of the enlarged EU-25 as of May 1, 2004.[65] Several are designated as EU "candidate countries."[66] Some are the result of the dissolution of the former Soviet Union and the former Yugoslavia. They include Armenia, Bosnia-Herzegovina, Bulgaria, Croatia, the Czech Republic, Georgia, Hungary, Poland, Romania, Serbia and Montenegro, Slovenia, the Ukraine and Russia. Those that fall in the EU-25 are subject to the directives and issues discussed in connection with Western Europe. Data on these countries was drawn from AGBIOS[67] from the JRC review of Europe,[68] and from a separate review by FAO of selected countries in the Balkans, the Caucasus and Moldova.[69]

Armenia has had two laboratory studies: one on biotech potatoes (starch composition) and one on tobacco (unspecified).[70]

Boznia-Herzogovina has had laboratory studies of fungi resistant potatoes, led by the Institute for Genetic Engineering and Biotechnology (INGEB). The Balkans war largely disrupted the agricultural economy and research activity: agriculture contributed 24.6 percent to GDP in 1996; this fell to 16 percent in 2000.

Bulgaria has been involved in plant biotech research since the early 1990s, when field trials were conducted on local tobacco varieties with resistance to viral and bacterial infection. These trials were stopped in 1998 at the recommendation of major tobacco buyers. In 1995, three field trials with biotech alfalfa were conducted to develop a marker system for kanamycin resistance at the request of the Institute of Genetic Engineering. The area of Bulgaria available for field trials (mainly maize) was enlarged by Bulgaria's Biosafety Council to 20,000 hectares in 2002. Field trials are underway on herbicide tolerant biotech maize, New Leaf potatoes, and fungi resistant sunflowers. Laboratory studies have been conducted on tobacco, potatoes and sugar beets (virus resistance), tobacco (resistance to heavy metals), potatoes (enhanced nutritional value and pathogen resistance), tomatoes (raised levels of beta-carotene), alfalfa (reduced lignin and improved digestibility), grapes (cold, virus and bacteria resistance) and barley (herbicide tolerance).[71] James reports that a few thousand hectares of herbicide tolerant biotech maize were grown in Bulgaria in 2003-2004.

Croatia, like the rest of the Balkan countries, was severely disrupted by war. Areas planted to wheat fell by half between 1991 and 1992 along with yields. Once self-sufficient in food, Croatia is now a net importer. Even so, relatively advanced plant biotech research is conducted at several universities and government laboratories such as the University of Zagreb and the Croatian Society of Biotechnology and Biotechnical Foundation.[72] Between 1997 and 1999, field trials on herbicide tolerant maize were undertaken with Aventis Crop Science, Monsanto and Pioneer. However, in 2001 the government began legislating bans on production and imports of biotech foods pending agreement on a Biosafety Protocol, and a strong "Croatia GM-free" campaign is promoting the country as a source of non-biotech soybean seeds.[73]

The Czech Republic has granted commercial approval to herbicide tolerant soybeans from Monsanto, but only for import and processing, not growing. Under the Republic's Variety Act, numerous field trials have been approved: 38 between 1997 and 2002, rising to 19 in 1999 but falling to 2 in 2002. As of mid-2003, reports indicated that Monsanto had been testing insect resistant biotech corn for three growing seasons in Moravia.[74] Field trails were conducted on sugar beets, maize, oilseed rape and wheat for herbicide tolerance, and maize for insect resistance. Approvals for field trials were also given for biotech flax, potatoes and plums, all for virus resistance. The main participants in these trials are Monsanto, Aventis Crop Science, Syngenta, Pioneer Hi Bred and Novum Seeds, as well as the Czech Institute for Plant Molecular Biology and the Institute of Biology of the Czech Academy of Sciences. At the laboratory level, R&D has focused on potatoes (disease resistance, storage), barley and wheat (improved digestibility), and unspecified traits of biotech cauliflower, oilseed rape, flax and peas.[75]

Georgia was invested in plant biotech until the breakup of the former Soviet Union, after which many talented researchers left and research infrastructure deteriorated, especially after the budget crisis of 1999. The Ministry of Agriculture and Food's Scientific Research Centre of Biotechnology in Tblisi has three of six departments devoted to biotechnology, but a total staff of only 29. The Ministry of Economy, Industry and Trade's Scientific Research Institute of Agrarian Biotechnology (staff of 56) is applying plant biotech methods to propagation of potatoes, grapevines, tomatoes and wheat. Biotech potatoes have been grown in Georgia without regulation, creating controversy throughout the Caucasian subregion.[76]

Hungary is one of the most active participants in plant biotech research in Eastern Europe.[77] From 1999 to 2002, it authorized 69 field trials, reaching a peak of 24 in 2001 and falling to 9 in 2002. The leading biotech plants in these trials were maize (herbicide tolerance and insect resistance), sugar beets (herbicide tolerance), potatoes (virus resistance) and tobacco (virus resistance) as well as turnips (male sterility and herbicide tolerance). These trials were all conducted by leading multinationals including Monsanto, Pioneer Hi Bred, Syngenta, Aventis Crop Science and KWS. Wheat trials (modified gluten content, herbicide tolerance) and some of those for potatoes, tobacco and maize were conducted by public research institute. At the laboratory and/or greenhouse level, Hungarian R&D is mainly involved with experiments on tobacco (light-regulated gene expression), alfalfa (plant development control), wheat and maize (metal tolerance), potatoes (pesticide resistance) and general studies of virus resistance and fungal infections in various plants.[78]

Poland has conducted a number of biotech field trials. In 1997, approvals were granted for trials on potatoes, maize and sugar beets. These approvals grew to 10-20 in 1998, then fell to 10 in 1999 and 9 in 2000. In addition to the three crops above, they included oilseed rape (winter and spring) and fodder beets. Most of the trials were for herbicide tolerance and virus resistance, and were conducted by the same large companies as in Hungary: Monsanto, Aventis Crop Science, Syngenta and KWS. Also involved was Poland's Institute for Biochemistry and Molecular Biology.[79]

Romania reportedly grew 70,000 hectares of herbicide tolerant soybeans in 2003-2004,[80] and has been growing biotech soybeans since 1999. The 2003-2004 biotech soybean plantings represented over half of all soybeans planted. At 2003-2004 soybean prices of $250 per metric ton, this represented about $4.2 million in value.[81] Romania is the fourth leading soybean producer in Europe, after Italy, Serbia/Montenegro and France. Apart from biotech soybeans, Romania also approved field trials for biotech potatoes, maize and sunflower seeds, with involvement by Monsanto and Pioneer Hi-Bred.

Serbia-Montenegro, like the other parts of the former Yugoslavia affected by the Balkans war, suffered serious setbacks in R&D. Despite these difficulties, the FAO reports a relatively large number of ongoing biotechnology projects.[82] The projects are organized at the University of Belgrade, the Institute of Molecular Genetics and Genetic Engineering (IMGGE), the Institute of Field and Vegetable Crops (IFVC) and the Maize Research Institute. The regulatory oversight of plant biotech has been harmonized with that of EU, with a National Council for Biological Safety and laws relating to presence of biotech components in feed and food. The main crops that have been the focus of research are sunflowers, sugar beets, wheat, maize and potatoes. FAO does not document specific field trials or laboratory tests.

Slovenia reports no field trials to date, although R&D in the laboratory has been performed on biotech potatoes (fungus resistance), flax (modified lignin and cellulose), plants with improved nutrition for feed, and plant-made pharmaceuticals.

The *Ukraine* has given seven approvals for field trials: to oilseed rape, maize, sugar beets and potatoes, all for either herbicide tolerance or insect resistance. As elsewhere, the main companies notifying the Ukraine were Aventis Crop Science, Monsanto and Syngenta. Between 1997 and 1999, Ukraine conducted field trials on Monsanto's New Leaf insect resistant potatoes on over 1,000 hectares, but the potatoes were ultimately destroyed after a decision by the Ministry of Health advising against human consumption.[83]

Russia approved Monsanto's herbicide tolerant soybeans in 1999. Although FAO reports no biotech field studies or experiments, other sources report biotech potatoes with insect resistance being tested in 2002, and biotech soybeans, maize and sugar beet approved for cultivation by the Russian Ministry of Health.[84] Beginning in 1996, Russia adopted a regulatory regime for plant biotech, which in 2000 expanded to a three-tiered health safety testing requirement conducted by the Bio-engineering Center of the Russian Academy of Sciences, the food Research Institute at the Russian Academy of Medical Sciences, and the State University of Applied Biotechnology. As of September, 2004, 13 types of food crops have passed this review and are permitted for food use: three strains of herbicide tolerant soybeans; three strains of herbicide tolerant maize, three strains of insect resistant maize, two strains of insect resistant potatoes, one strain of herbicide tolerant sugar beet, and one strain of herbicide resistant rice. Even so, Russia has not yet permitted biotech crops to be grown on Russian soil.[85]

North America

North America remains the epicenter of R&D on plant biotech, with more commercial approvals, field trials and laboratory/greenhouse research than any other part of the world. Because this activity in the United States was the subject of a 2003 assessment by the authors, this study will provide a brief update of the U.S. data, but concentrate especially on activity in Canada.

Canada planted 4.4 million hectares of biotech canola, maize and soybeans in 2003-2004.[86] As noted in discussion of the top five producing nations, this translated into $2.0 billion in biotech crop value, of which $284 million resulted from a 50 percent adoption rate for biotech soybeans, $384 million from a 40 percent adoption rate for biotech maize, and $1.29 billion from a 68 percent adoption rate of biotech canola. AGBIOS reports government regulatory approvals for a large number of crops and traits through 2003: Argentine canola, Polish canola, cotton, maize, papaya, rice, soybeans, squash, sugar beets, sunflower, and tomatoes. The number of biotech traits for these crops is too numerous to describe here, but is shown in the Appendix containing country-level data for Canada.

Field studies are also listed in the Appendix entry for Canada, according to data from the Canadian Food Inspection Agency.[87] In 2003 alone, 10 crops were studied in field trials undertaken on biotech alfalfa, brown mustard, canola, corn, lentils, potatoes, sugar beets, tobacco and wheat, testing traits of herbicide tolerance, insect and virus resistance, stress tolerance and others. These field studies included 13 crops in 2002, adding barley (fungal resistance), flax (stress tolerance, antibiotic resistance) and tomatoes (pathogen resistance) to the list. In 2001, 15 crops were studied in the field; in 2000, 15 crops were studied.

Canada clearly has the R&D infrastructure in place to continue a leading place in the industry, both through Agriculture Canada and Environment Canada, as well as in its leading research institutions, such as the University of Guelph, University of Saskatchewan, and Laval University. The Canadian Food Inspection Agency (CIFA) is responsible for the regulation of products derived from biotech plants, while Health Canada assesses human health and nutrition issues.[88]

The final country to be considered in this regional assessment is the *United States*. As noted in Part I, it is the leading adopter of biotech crops, with 42.8 million hectares of biotech soybeans, cotton, maize and canola in 2003-2004, worth $27.5 billion in value. Soybean, cotton, maize and canola adoption rates of hectares planted were 81 percent, 73 percent, 40 percent and 73 percent respectively in 2003-2004. Government regulatory approvals in the United States have been granted for Argentine canola, chicory, cotton, flax and linseed, maize, melon, papaya, potatoes, rice, soybeans, squash, sugar beets, tobacco and tomatoes. The biotech traits approved are too numerous to discuss individually, but are listed in the Appendix entry for the United States.

Since our previous analysis of the U.S. plant biotech sector,[89] which ended its assessment of field trials at June, 2003, the U.S. Department of Agriculture's APHIS has issued permits for 24 crops: maize, tobacco, alfalfa, soybeans, tomatoes, cotton, potatoes, peanuts, banana, barley, rice, sugar beets, sugar cane, onions, cucumbers, apples, lettuce, papaya, pea, plum, safflower, watermelon, wheat and canola. These field trials must be added to the more than 9,000 field trials recorded up to 2003. From 1991 to 2002, the distribution of traits on which field trials were undertaken showed 4,625 trials on maize, 259 on wheat, 668 on soybeans, 206 on canola, 635 on cotton and 220 on tobacco. The leading traits studied were herbicide and insect tolerance, modified ingredients, resistance to pathogens and marker traits.[90]

Part IV:

Conclusions and Future Directions

This study has evaluated the global diffusion of plant biotechnology as of 2004. It estimated the total value of the leading five countries producing biotech crops in 2003-2004 at $43.9 billion, resulting from production on 67.5 million hectares. The preponderance of the land in biotech crops is in the United States, which accounts for 63 percent of the area planted to them. Argentina accounts for 21 percent, Canada for 6 percent and Brazil and China for 4 percent each. These plantings of maize, soybeans, cotton and canola in the leading countries are already impressive, but there is still a huge land area potentially available for such plantings, especially in Argentina, Brazil and China, and also in Canada.

When one moves beyond these major crops, the proliferation of commercial and R&D activity represented by field trials and laboratory/greenhouse experiments extends well beyond the five leading countries. In the most comprehensive assessment of the ultimate consequences of widespread global adoption of biotech crops, the Australian Bureau of Agricultural Resource Economics in 2003 estimated an additional $210 billion in income by 2015.[91] The greatest gains would be in the developing countries, where Gross Domestic Product (GDP) could be expected to rise by as much as two percent. This estimate assumes that regulatory regimes will emerge allowing this adoption. In particular, if the European Union remains closed to further adoption of plant biotech, the global cost by 2015 would be $43 billion.

A reexamination of Tables 7-10 suggests two types of insights into the pattern of R&D diffusion: *tiers* of plant biotech activity by country, showing a group of leading nations, a group of emerging nations, and a group of countries to watch; (2) *spheres* of activity by region of the world. In conclusion, we will evaluate both of these aspects of the pattern of diffusion.

Tiers of Biotech Activity

The main field crops shown in Tables 7-10 illustrate the division of nations into leaders, emerging countries and those to watch for commercial adoption, field trials and laboratory/greenhouse experiments. The leading five countries in terms of commercial adoption – the United States, Argentina, Canada, Brazil and China – all fall in the first tier. In terms of overall activity, including field trials and laboratory/greenhouse experiments, Australia, Western Europe, Mexico and South Africa also belong in this group, although the particular role and future of the EU remains unclear.

At this point, activity falls off, showing a second tier of countries where activity is emerging, but where limited resources, inadequate regulation or restricted technical capacity constrain the adoption and R&D process. These countries include Indonesia, Egypt, and India. The remaining countries (as well as those not listed due to the absence of reported activity) constitute the third tier.

Within Europe, where we have chosen to aggregate countries into Western and Eastern European countries (including several parts of the former Soviet Union), there is substantial variation in the level of activity, with some countries such as France and Italy leading in the number of field trials while others such as Ireland and Austria show relatively little R&D activity. In the European Union, the 1999 moratorium on plant biotech approvals has slowed the entire R&D process. How the EU ultimately regulates plant biotech will also be important to developing countries seeking European markets, and new entrants to the EU, who will position themselves in the R&D process by reference to EU policies and markets.

<u>Spheres of Biotech Investment and Research</u>

A slightly different perspective on global plant biotech activity results from a geographical examination of spheres investment and research by location. As noted above, North America is the largest of these spheres. As such, it exercises a gravitational pull on global investment and human capital, drawing to it the best companies and researchers. The sphere of North American influence in plant biotech has grown at the expense of the European Union, from which investment capital and talent have fled. For example, Syngenta, a Swiss-based multinational, has chosen to locate its global plant biotech research at the Research Triangle in North Carolina.

The principal spheres of plant biotech influence outside of North America and Europe are in China, Argentina and Brazil, South Africa, Australia and India. Although none of these areas can match North America in overall investment and R&D, there is reason to expect China to emerge as an influential force in plant biotech in the years to come. In Latin America, Argentina and Brazil will in our estimate also emerge as leaders in the southern part of the Western Hemisphere. In Africa, South Africa has the scientific capability, political stability and investment resources to lead the continent in plant biotech. In Asia and the Pacific apart from China, Australia appears poised to move quickly to establish itself as a sphere of influence, as does India. In both Australia and India, investment and human capital resources make this growing influence possible.

A recent assessment of the constraints to diffusion of plant biotech in developing countries cited both the dominance of North America and Europe in research and development, and a simple lack of financial resources. These are remediable through technology-transfer partnerships and a recommitment to technical assistance funding, both bilateral and multilateral, especially aimed at improving regulatory capacity.[92]

Our final assessment of the diffusion of plant biotech is that important gains have been made in adoption in the less than 10 years since commercialization began in 1996, but that major expansions in biotech crop hectares are still to come, especially in Asia, Latin America and parts of Africa. Apart from this expansion, we expect the range of biotech crops approved commercially to continue to grow, resulting in new markets and opportunities, especially in developing countries. If the European Union continues to restrict activity in the sector, it will slow down this global diffusion, but it cannot stop it. As it becomes increasingly isolated, it will discourage its young scientists and technicians from pursuing European careers. If, on the other hand, the EU engages biotech in an orderly regulatory framework harmonized with the rest of the world, it will encourage a more rapid international diffusion of the technology. More nations will join the top tiers of commercial production, and emerging nations will continue to expand the sector. It is unlikely that Europe will catch up with North America as a sphere of plant biotech influence, but its scientific and technical capabilities will allow it to recover relatively quickly. We see continuing expansion of commercial and scientific possibilities for plant biotech in the next decade and beyond.

Appendix: Country Profiles

Country-level Data on Commercial Production, Regulatory Approvals,

Field Trials and Laboratory/Greenhouse Experiments

AFRICA and the MIDDLE EAST

- Egypt
- Kenya
- Morocco
- South Africa
- Tunisia
- Zimbabwe

Egypt

Population: 74.7 million GDP: $290 billion Government: $21.5 billion
Land area: 995,450 sq. ka. (slightly more than three times the size of New Mexico)
Arable land: 2.85% Crop land: 0.47% Climate: desert
Crops: cotton, rice, corn, wheat, beans, fruits, vegetables
Agriculture is 17% of GDP and 29% of labor force *CIA World Factbook*

FAO Biotechnologies in Developing Countries database shows:

Commercialization of virus resistant canola

Field study

- cucumber - ZYMV virus resistance
- maize - Lepidoptera (ECB) resistance
- melon - ZYMV virus resistance
- potato - Lepidoptera (PTM) resistance, PLRV and PVY virus resistance
- cantaloupe - ZYV virus resistance
- squash - ZYMV virus resistance
- sugar cane - SCMV virus resistance
- tomato - TYLCV virus resistance
- wheat - salt tolerance

Laboratory Trials

- banana - heat tolerance, virus resistance
- barley - salt tolerance
- cotton - heat tolerance
- faba bean - virus (Necrotic Yellow Virus) resistance
- cotton - Lepidoptera resistance

Responsibility for biotechnology research in agriculture is with Ministry of Agriculture and Land Reclamation; responsible for environmental aspects of biotechnology is Ministry of State of Environmental Affairs

Agricultural biotechnology research institutions include: Agricultural Research Centre (ARC), Agricultural Genetic Engineering Research Institute (AGERl) (within ARC) / National Research Centre, Agriculture Division Kairo University, Faculty of Agriculture University of Alexandria, Faculty of Agriculture / Ain Shams University Faculty of Agriculture

ALSO SEE

Biotechnology Research and Policy Activities of ABSP in Egypt, 1991-2002, Agricultural Biotechnology Support Project, Michigan State University, July 2002, http://www.iia.msu.edu/absp/egypt-absp.pdf

"Egypt researches biotech crops, sees income", Reuters, March 18, 2002

Kenya

Population: 32 million GDP: $33 billion Government: $2.9 billion
Land area: 0.57 million sq. ka. (slightly more than twice the size of Nevada)
Arable: 7% Crop land: <1% Climate: varies from tropical to arid
Crops: tea, coffee, corn, wheat, sugarcane, fruits and vegetables
Agriculture is 24% of GDP and 75% of labor force *CIA World Factbook*

FAO Biotechnologies in Developing Countries database shows:

Field study

- Sweet potato - viral resistance to sweet potato feather molt virus (SPFMV)

Laboratory Trials

- Maize - Lepidoptera resistance, specifically European corn borer (ECB) or stem borer.

Responsibility for biotechnology research in agriculture is with Ministry of Agriculture and Ministry of Education, Science and Technology; responsible for environmental aspects of biotechnology is Ministry of Environment and Natural Resources

Agricultural biotechnology research institutions include: Kenya Agricultural Research Institute (KARI) / Jomo Kenyatta University of Agriculture and Technology University of Nairobi ; Faculty of Agriculture Moi University; Kenyatta University (KU)

ALSO SEE:

Kenya, Agricultural Science and Technology Indicators (ASTI country brief no. 8) IFPRI, ISNAR, July 2003, http://www.asti.cgiar.org/pdf/kenya_cb8.pdf

Biotechnology Research and Policy Activities of ABSP in Kenya, 1991-2002, Agricultural Biotechnology Support Project, Michigan State University, July 2002, http://www.iia.msu.edu/absp/kenya-absp.pdf

"Kenya's brain drain", TRENDS in Plant Science, Vol. 6, No. 5, May 2001

"Kenya prepares to grow genetically modified maize", June 11, 2004, The Sunday Standard, see checkbiotech.org

Sweet potato feather molt virus (SPFMV), a disease that can reduce yields by 80 percent.

Kenya Agricultural Research Institute (KARI)
International Centere for Maize and Wheat Improvement (CIMMYT)

Morocco

Population: 31.7 million GDP: $122 billion Government: $14 billion
Land area: 446,300 sq. ka. (slightly larger than California)
Arable land: 20% Crop land: 2% Climate: Mediterranean
Crops: barley, wheat, citrus, wine, vegetables, olives
Agriculture is 15% of GDP and 50% of labor force *CIA World Factbook*

FAO Biotechnologies in Developing Countries database shows:

Laboratory Trials

- Wheat - unspecified objective

Responsibility for biotechnology research in agriculture is with Ministry of Agriculture, Rural Development and Fisheries and Ministry of Higher Education and Scientific Research; responsible for environmental aspects of biotechnology is Ministry of Land Management, Water and Environment

Agricultural biotechnology research institutions include: Institut National de la Recherche Agrono-mique (INRA) / École Nationale d'Agriculture de Meknès (ENA) / Institut Agronomique et Vétérinaire Hassan II (IAV)

South Africa

Population: 42.7 million	GDP: $428 billion	Government: $23 billion
Land area: 1.2 million sq. ka. (slightly less than twice the size of Texas)		
Arable land: 12%	Crop land: 0.77%	Climate: mostly semi arid
Crops: corn, wheat, sugarcane, fruits and vegetables		
Agriculture is 4.4% of GDP and 30% of labor force		*CIA World Factbook*

South Africa deserves special attention because it would be number six on the list of biotech country, with 1% of the biotech crop area worldwide in 2003/04. James estimates South Africa planted 400,000 hectare to biotech varieties of maize, soybean, and cotton in 2003/04, an increase of one-third over 2002. In all, 2003-2004 South African biotech crop values total $146.9 million

South Africa had 3.35 million hectare of maize in 2003/04, and produced 9.7 million metric tons. Blending white and yellow maize production, 13% of the maize crop was grown from a biotech variety. James puts Bt yellow (feed) maize at 200,000 Ha in 2003, up 25,000 Ha from the year before, and representing 20% of yellow maize crop. He also notes particularly strong growth in white (food) maize, from 6,000 ha in 2001 to 84,000 ha in 2003. He puts Bt white maize at 8% of the 1.8 million hectares 2003/04 crop. S.A. agriculture minister (Dec. 03) said 2.8% of total area was planted to white maize is GM, and 17.3% of total yellow maize area is from GM seed. Following the earlier analysis, the market value of the biotech maize production would be worth $130 million, at a world price of $100 per metric ton.

Cotton is estimated at 32,000 hectare in 2003/04, producing 50,000 bales (480 pounds each). The biotech adoption rate is estimated at 60%, based on a 3 year old Monsanto market forecast. In 2001, Monsanto estimated 55-60% of cotton sold in South Africa was transgenic, and predicted a 70% share in the future. The market value of biotech cotton at a world price of 59-cents would be about $14 million.

Soybeans are grown on just 108,000 hectares in South Africa, and are about half as valuable as cotton locally. (The hay crop is five times as valuable as soybeans.) Only 8% of the soy crop in South Africa is a biotech variety. At the adjusted world price of $250 per metric ton, the market value of biotech soy in South Africa is $2.9 million for 2003/04.

AGBIOS database of government regulatory approvals - [for environmental release, food and feed]

Maize:

- Monsanto Roundup-Ready maize approved for release in June 2003.
- Monsanto Yieldgard with traits for resistance to European corn borer (Ostrinia nubilalis) approved in 1997 (line MON810)

Cotton:

- Monsanto Bollgard Bt variety resistant to lepidopteran pests including, but not limited to, cotton bollworm, pink bollworm, and tobacco budworm (lines MON531/MON757/MON1076) environmental release and food/feed consumption approvals in 1997.

Soybean:

- Monsanto Roundup-Ready (line GTS 40-3-2) Glyphosate herbicide tolerant, approved for environmental release and food/feed consumption in 2001.

FAO Biotechnologies in Developing Countries database shows:

Field Trials

- Cotton - glyphosate tolerant, multiple resistances, and other unspecified traits
- Maize - glyphosate tolerance, phosphinothricin tolerance, and multiple resistances
- Canola - glufosinate tolerance and phosphinothricin tolerance
- Strawberries - glufosinate tolerant, resistance to fungi stilbene resveratol Vst1 and Vst2
- Sugar cane - glufosinate tolerance is indicated
- Potato - resistance to PLRV virus

Responsibility for biotechnology research in agriculture is with Department of Agriculture, the Agricultural Research Council (ARC) and Department of Science and Technology (DST); responsible for environmental aspects of biotechnology is Department of Environmental Affairs and Tourism

Agricultural biotechnology research institutions include: Agriculture South Africa / Roodeplaat Vegetable and Ornamental Plant Institute (ARC-VOPI) / Grain Crops Institute (ARC-GCI) / Institute for Tropical and Subtropical Crops Animal Improvement Institute (ARC-AII) / Infruitec-Nietvoorbij (ARC Infr.-Nietvorbij) / Small Grain Institute (ARC-SGI) / Council for Scientific and Industrial Research; / CSIR-Food, Biological and Chemical Technology University of Stellenbosch; Institute of Plant Biotechnology / University of the Free State; Faculty of Natural and Agricultural Science Rhodes University / University of Pretoria; Faculty of Agricultural Science and Faculty Veterinary Science

ALSO SEE:

"A National Biotechnology Strategy for South Africa", June 2001,
http://www.dst.gov.za/programmes/biodiversity/biotechstrategy.pdf
report suggests a high attrition rate among researchers to U.S. markets

South Africa, Agricultural Science and Technology Indicators (ASTI) IFPRI, ISNAR
http://www.asti.cgiar.org/pdf/SouthAfrica_CB14.pdf

Tunisia

Population: 9.9 million GDP: $67 billion Government: $5.2 billion
Land area: 155,360 sq. ka. (slightly larger than Georgia)
Arable land: 18.7% Crop land: 12.8% Climate: temperate north; desert south
Crops: olives, olive oil, grain, dairy, tomatoes, citrus fruit, beef, sugarbeet, date, almonds
Agriculture is 12% of GDP and 22% of labor force *CIA World Factbook*

FAO Biotechnologies in Developing Countries database shows:

Laboratory Trials

- Potato - viral resistance

Responsibility for biotechnology research in agriculture is with Ministry of Agriculture, Environment and Water Resources and Ministry of Higher Education, Scientific Research and Technology

Agricultural biotechnology research institutions include: Institut de la Recherche Agronomique de Tunisie / Institut National de Recherches en Genie Rural, Eaux et Forets Centre de Biotechnologie de Sfax (CBS) / Institut National de Recherche Scientifique et Technique (INRST) Jendouba University Tunis El Manar University

Zimbabwe

Population: 12.6 million GDP: $26 billion Government: $2.5 billion
Land area: 0.39 million sq. ka. (slightly larger than Montana)
Arable: 8.4% Crop land: 0.34% Climate: tropical
Crops: corn, cotton, tobacco, wheat, coffee, sugarcane, peanuts
Agriculture is 18% of GDP and 66% of labor force *CIA World Factbook*

FAO Biotechnologies in Developing Countries database shows:

Field study

- Cotton - Lepidoptera resistance

Responsibility for biotechnology research in agriculture is with Ministry of Lands, Agriculture and Water Development; responsible for environmental aspects of biotechnology is the Ministry of the Environment

Agricultural biotechnology research institutions include: Department of Research and Specialist Services (DRSS) / Veterinary Research Laboratory (VRL) / Scientific and Industrial Research and Development Centre (SIRDC) / Biotechnology Research Institute (BRI) / University of Zimbabwe; Faculty of Veterinary Science; Faculty of Agriculture

ALSO SEE:

"Future of plant science in Zimbabwe", TRENDS in Plant Science, Vol. 6, No. 10, October 2001

University of Zimbabwe

- Cotton in field trial for Lepidoptera resistance.
- Cassava to confer resistance to cassava mosaic virus (ACMV)
- Sweet potato to confer resistance to sweet potato feathery mottle virus (SPFMV)
- Striga asiatica, a parasitic weed and molecular markers
- Cowpea modified to confer virus and herbicide tolerance

Tobacco Research Board working on herbicide tolerance and disease resistance, male sterile lines,
The Biotechnology Trust of Zimbabwe

"Statistical Brief on the National Agricultural Research System of Zimbabwe", ISNAR, 1995, ftp://ftp.cgiar.org/isnar/indicator/pdf/20-Zimbabwe.pdf

LATIN AMERICA and the CARIBBEAN

- Argentina
- Belize
- Bolivia
- Brazil
- Chile
- Colombia
- Costa Rica
- Cuba
- Guatemala
- Honduras
- Mexico
- Paraguay
- Peru
- Uruguay
- Venezuela

Argentina

Population: 38.7 million   GDP: $404 billion   Government: $44 billion
Land area: 2.74 million sq. ka. (slightly less than three-tenths the size of United States)
Arable land: 9%   Crop land: 0.8%   Climate: mostly temperate
Crops: sunflower seeds, lemons, soybeans, grapes, corn, tobacco, peanuts, tea, wheat
Agriculture is 5% of GDP and (n.a.) % of labor force   *CIA World Factbook*

James (2003) found three biotech crops (soybeans, cotton, and maize) being grown on 13.9 million hectare in 2003/04, and as the Part I analysis showed the combined biotech market value was $8.9 billion.

Biotech soybeans have experienced a seventh consecutive year of growth in Argentina. Argentina is the world's third-largest soybean producer. Nearly all (98%) soy is from genetically modified varieties in 2003/04. Cotton was planted to 410,000 hectare in 2003/04. In the earlier analysis the adoption rate was assumed to have risen to 60%, generating $75 million in market value attributed to biotech cotton. Maize is grown on 2.1 million hectare in Argentina (FAS). An estimated 40% is biotech varieties. In the earlier analysis Argentine biotech maize production in 2003/04 was estimated at $500 million.

AGBIOS database of government regulatory approvals -
[for environmental release, food and feed, some import only]

Soybean:

- Monsanto Roundup-Ready (line GTS 40-3-2) glyphosate herbicide tolerance full approval 1996.

Cotton:

- Monsanto Bollgard resistant to lepidopteran pests including, but not limited to, cotton bollworm, pink bollworm, and tobacco budworm (lines MON531 only, not lines MON757/MON1076). Environmental release and food/feed consumption approvals in 1998
- Monsanto Roundup-Ready glyphosate herbicide tolerance (line MON1445 only not also lineMON1698). approved for environmental release 1999, and for food/feed use in 2002

Maize:

- Bayer Liberty-Link (lines T14, T25) Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. Approved for environmental release and food/feed use in 1998.
- DeKalb Bt Xtra (line TBD-418) resistance to European corn borer (Ostrinia nubilalis) and phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. environmental release approval 1998
- Monsanto Yieldgard (line MON810) resistance to European corn borer (Ostrinia nubilalis). Full approval in 1998.
- Monsanto Roundup-Ready (line GA21) glyphosate herbicide tolerance, environmental release approval in 1998
- Syngenta NaturGard KnockOut (line SYN-176) resistance to European corn borer (Ostrinia nubilalis) and phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. approved for environmental release in 1996, and food/feed approvals in 1998

- Syngenta line SYN-BT11 with phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. environmental release and food/feed use in 2001

FAO Biotechnologies in Developing Countries database shows:

Field study

- alfalfa - Lepidoptera resistant, herbicide tolerant
- cotton - Lepidoptera resistant, herbicide tolerant
- maize - herbicide tolerant, fungal resistant, oil composition
- potato - PVY virus resistant
- soybean - Lepidoptera resistant, herbicide tolerant, oil composition
- sugar beet - herbicide tolerant
- sunflower - herbicide tolerant, fungal resistant, Lepidoptera resistant
- tomato - virus resistant
- wheat - - herbicide tolerant, fungal resistant, high gluten content

Laboratory Trials

- alfalfa - fungal resistant, veterinary edible vaccines
- barley - unspecified
- potato - PVY virus resistant
- sugar cane - unspecified
- tobacco - salt tolerant

Responsibility for biotechnology research in agriculture is with Office for Agriculture, Livestock, Fisheries and Food at Ministry for Economics and Pro-duction; Secretaría de Ciencia, Tecnología e Innovación Produc-tiva; Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) and Ministry for Culture and Public Education; a National Advisory Committee for Agricultural Biotechnology (CONA-BIBA

Agricultural biotechnology research institutions include: Instituto National de Tecnologia Agropecuaria (INTA) Instituto di Investigaciones Fisiologicas y Ecologicas Vinculadas a la Agricultura Universidad Nacional de Buenos Aires(UBA) Asociación Argentina de Consorcios Regio-nales de Experimentación Agrícola

Belize

Population: 273,000	GDP: $1.3 billion	Government: $222 million
Land area: 22,800 sq. ka.	(slightly smaller than Massachusetts)	
Arable land: 2.9%	Crop land: 1.7%	Climate: tropical
Crops: banana, coca, citrus, sugar		
Agriculture is 23% of GDP and 27% of labor force		*CIA World Factbook*

Soybean field trials for herbicide tolerance are reported in:

Roca, W., C. Espinoza and A. Pauta. "Agricultural Applications of Biotechnology and the Potential for Biodiversity Valorization in Latin America and the Caribbean." AgBioForum 2004:7(1&2):13-22.

Soybean, Maize, and Cotton field trials for herbicide tolerance and insect resistance are reported in:

Trigo, E., G. Traxler, C. Pray and R. Echeverria. "Agricultural Biotechnology and Rural Development in Latin America and the Caribbean." Inter-American Development Bank, Washington D.C., September 2002.

Bolivia

Population: 8.6 million GDP: $21 billion Government: $4 billion
Land area: 1.1 million sq. ka. (slightly less than three times the size of Montana)
Arable land: 7.3% Crop land: 0.21% Climate: tropical to cold / semiarid
Crops: soybeans, coffee, coca, cotton, corn, sugarcane, rice, potatoes
Agriculture is 20% of GDP and (n.a.) % of labor force *CIA World Factbook*

FAO Biotechnologies in Developing Countries database shows:

Field study

- cotton - Lepidoptera resistant
- potato - frost tolerant (anti-freezing fish protein)
- soybean - glyphosate tolerance

Responsibility for biotechnology research in agriculture is with Ministerio de Asuntos Campesinos y Agropecuarios (MACIA)

Agricultural biotechnology research institutions include: Centro de Investigacion Agricola Tropical Universidad Autonoma GR Moreno Universidad Major de San Andres, Faculty of Agriculture Universidad Major de San Simon

ALSO SEE:

Ministry of Agriculture - encouragement for field trials in cotton and soya
cotton industry almost gone (5,000 ha in 2002) in face of Brazil and Peru competition

Brazil

Population: 8.6 million GDP: $1.4 trillion Government: $100 billion
Land area: 8.4 million sq. ka. (slightly smaller than the US)
Arable land: 6.3% Crop land: 1.42% Climate: tropical, temperate in south
Crops: soybeans, coffee, soybeans, wheat, rice, corn, sugarcane, cocoa, citrus
Agriculture is 8% of GDP and 23% of labor force *CIA World Factbook*

The earlier analysis showed that the only commercial biotech crop in Brazil in 2003/04 were soybeans. Overall soy production reached 53.5 million metric tons, on 21.3 million hectare. Officially only 12% of the 2003/04 soy crop was of a biotech variety, but others put the adoption rate as high as 30%. GM food or crops were banned until 2003, but available on the black market. The estimated market value of the biotech soy production was $1.6 billion, making Brazil number five among the top 5 leading biotech countries.

AGBIOS database of government regulatory approvals - [for environmental release, food and feed]

Soybean:

- Monsanto Roundup-Ready with Glyphosate herbicide tolerance approved in 1998.

FAO Biotechnologies in Developing Countries database shows:

Field study

- Bean *Phaseolus vulgaris* - glufosinate tolerance, and resistance to golden mosaic virus
- Carrot - isolate carotenoid genes
- Cotton - glyphosate tolerance, and Lepidoptera resistance, and multiple resistance
- Maize - herbicide tolerance, Lepidopteran resistance, multiple resistance
- Papaya - PRSV virus resistance
- Potato - resistance to PVY and PLRV virus
- Rice - glufosinate tolerance
- Soybean - glufosinate and Imidazoline resistance, Lepidoptera resistance
- Sugar cane - herbicide resistance, Lepidoptera resistance, and resistance to SCMV (yellow) virus
- Tobacco - resistance to TSWV and PVY virus
- Tomato - resistance to Gemini and Tospovirus

Laboratory Trials

- Barley - resistance to fungi
- Cocoa - resistance to fungi
- Lettuce - unspecified
- Maize - aluminum and phosphorus deficiency
- Rice - salt tolerance, and resistance to fungi
- Soybean - insect resistance

- Sugar cane - resistance to borer or Lepidoptera

Responsibility for biotechnology research in agriculture is with Federal Ministry for Agriculture and Food Supply and Ministry of Science and Technology; responsible for environmental aspects of biotechnology is Ministry for Environment

Agricultural biotechnology research institutions include: Brazilian Agricultural Research Corporation Agricultural Research and Rural Extension Institute (EPAGRI) Instituto de Tecnologia de Alimentos (ITAL) Instituto Rio Grandense do Arroz Universidade de Brasília; Faculdade de Agronomia e Medicina Veterinária / University of São Paulo; Faculty of Veterinary Medicine and Zootechnology Escola Superior de Agricultura "Luiz de Queiroz"

ALSO SEE:

EMBRAPA first license to conduct field study was for GM papaya resistance to PRV virus
second test granted is for bean golden mosaic virus; next license will be virus resistant potato

crop research agency EMBRAPA has developed GM soy, similar to RR, tolerant to Imidazolinone

Codetec, one of a handful of biotech companies in Brazil, offer 4 varieties soy with Monsanto RR
also had setback on Asian rust research (biotech?)

"Agricultural R&D in Brazil: Policies, Investments, and Institutional Profile", IFPRI, 2001,
http://www.ifpri.org/themes/grp01/grp01_brazil.pdf

Chile

Population: 15.6 million GDP: $156 billion Government: $17 billion
Land area: 0.75 million sq. ka. (slightly smaller than twice the size of Montana)
Arable land: 2.65% Crop land: 0.42% Climate: temperate, variable
Crops: wheat, corn, grapes, beans, sugar beets, potatoes, fruit
Agriculture is 11% of GDP and 14% of labor force *CIA World Factbook*

FAO Biotechnologies in Developing Countries database shows:

Laboratory Trials

- Apple - (3) including resistance to fungi
- Garlic - unspecified objective
- Grape - resistance to fungi
- Melon - virus resistance
- Potato - (3) including virus resistance
- Stone fruit - alter fruit ripening
- Tobacco - (3) unspecified objectives
- Tomato - (3) unspecified objectives

Responsibility for biotechnology research in agriculture is with Ministry of Agriculture, Ministry of Education has a Commission on Scientific Investigation and Technology (CONICYT) that is also involved in biotech research policy

Agricultural biotechnology research institutions include: Instituto di Investigaciones Agropecuarias Instituto de Formento Pesquero (IFOP) Instituto Forestal de Chile (INFOR) /Universidad de Chile Universidad Austral de Chile Universidad de Talca, Institute for Plant Biology and Biotechnology

ALSO SEE:

Chile launches policy to boost biotech, briefing paper, Nature Biotechnology

Chile produces 10,000 hectare producing biotech seed for export, Agriculture Minister
Will export GM fruit by 2008, current fruit exports $1.5 billion
Public and private biotech investment $50 million year, 31 private sector companies

Colombia

Population: 41.6 million GDP: $251 billion Government: $24 billion
Land area: 1.03 million sq. ka. (slightly less than three times the size of Montana)
Arable land: 1.9% Crop land: 1.9% Climate: tropical coast / cool highlands
Crops: coffee, cut flowers, bananas, rice, tobacco, corn, sugarcane, cocoa beans, oilseed
Agriculture is 13% of GDP and 30% of labor force *CIA World Factbook*

James (2003) - Colombia first grew Bt cotton in 2002, by 2003 had planted area of about 5,000 hectares

FAO Biotechnologies in Developing Countries database shows:

Field study

- Cotton - lepidopteran resistance (commercialization expected in 2003)

Laboratory Trials

- Cassava - unspecified objective
- Plantain - virus resistance
- Potato - virus resistance and unspecified purpose
- Tree tomato - resistance to fungi

Responsibility for biotechnology research in agriculture is with Ministry of Agriculture and Rural Develpment, responsible for environmental aspects of biotechnology is Ministry of Environment

Agricultural biotechnology research institutions include: Institut Nacional de Pesca y Agricultura (INPA) / Corporación Colombiana de Investigación Agropecuaria (CORPOICA) /Centro de Investigación de la Caña de Azúcar de Colombia (CENICANA) / Corporación Centro de Investigación de la Acuicultura de Colombia (CENIACUA) / Universidad Nacional de Colombia Instituto Colombiano para el Desarrollo de la Ciencia y la Tecnología (COLCIENCIAS) / CGIAR centre CIAT (Centre International de Agricultura Tropical) is also located in Colombia

ALSO SEE:

"Agricultural R&D in Colombia: Policies, Investments, and Institutional Profile", IFPRI, July 2000, http://www.ifpri.org/themes/grp01/grp01_colombia.pdf

Costa Rica

Population: 3.9 million GDP: $32 billion Government: $1.9 billion
Land area: 50,660 sq. ka. (slightly smaller than West Virginia)
Arable land: 4.4% Crop land: 5.4% Climate: tropical and subtropical
Crops: coffee, pineapples, bananas, sugar, corn, rice, beans, potatoes
Agriculture is 9% of GDP and 20% of labor force *CIA World Factbook*

FAO Biotechnologies in Developing Countries database shows:

Laboratory Trials

- Maize - virus resistance
- Rice - virus resistance

Responsibility for biotechnology research in agriculture is with Ministry of Agriculture, for research in general Ministry of Science and Technology and for environmental aspects of biotechnology Ministry of the Environment

Agricultural biotechnology research institutions include: Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) Institute for Agrarian Development (IDA) / Instituto Tecnológico de Costa Rica (ITCR) Universidad de Costa Rica (UCR) Universidad Nacional (UNA)

ALSO SEE:

"Costa Rica: revealing data on public perception of GM crops", TRENDS in Plant Science, October 2002

banana resistant to black sigatoka disease, also rice and white corn virus resistance

Cuba

Population: 11.3 million GDP: $30.7 billion Government: $15 billion
Land area: 110,860 sq. ka. (slightly smaller than Pennsylvania)
Arable land: 33% Crop land: 7.6% Climate: tropical
Crops: sugar, tobacco, citrus, coffee, rice, potatoes, beans
Agriculture is 7.6% of GDP and 24% of labor force *CIA World Factbook*

FAO Biotechnologies in Developing Countries database shows:

Field studies

- Papaya - resistance to RSV virus
- Potato - resistance to late blight fungi, and glufosinate tolerance
- Sugar cane - fungus resistance, glufosinate tolerance, Lepidoptera resistance
- Sweet potato - Lepidoptera resistance

Laboratory Trials

- Banana - glufosinate tolerant, fungal resistance
- Citrus - tristeza virus resistance, fungal resistance
- Coffee - Lepidoptera resistance, glufosinate tolerant
- Maize - Lepidoptera resistance
- Papaya - fungal resistance
- Pineapple - Lepidoptera resistance, glufosinate tolerant, fungal resistance
- Potato - PLRV virus resistance
- Rice- Lepidoptera resistance, glufosinate tolerant, fungal resistance
- Sugar cane - Lepidoptera resistance, alter lignin content and high quality sugar, fungal resistance
- Tomato - Gemini virus resistance, fungal resistance

Responsibility for biotechnology research in agriculture as well as environmental aspects of biotechnology is the Ministry of Science Technology and Environment and the Ministry of Agriculture

Agricultural biotechnology research institutions include: Centre for Genetic Engineering and Biotechnology (CIGB) Centre for Biological Research (CIB) Institute of Plant Biotechnology (IBP) Centre for Plant Biotechnology (CBP) University of Havana, Faculty of Biology

ALSO SEE:

"Genetic engineering may save Cuban sugar"
Sugar cane and biotech, Havana Center for Genetic Engineering and Biotechnology

"Agricultural R&D in the Caribbean: An Institutional and Statistical Profile, ISNAR, June 2001,
ftp://ftp.cgiar.org/isnar/Publicat/PDF/rr-19.pdf

Guatemala

Population: 14.3 million	GDP: $57 billion	Government: $2.7 billion
Land area: 108,000 sq. ka.	(slightly smaller than Tennessee)	
Arable land: 12.5%	Crop land: 5.0%	Climate: tropical
Crops: sugarcane, maize, banana, coffee, beans		
Agriculture is 23% of GDP and 50% of labor force		*CIA World Factbook*

Tomato field trials conducted for virus resistance and product quality traits in 1994-95 are reported in:

Trigo, E., G. Traxler, C. Pray and R. Echeverria. "Agricultural Biotechnology and Rural Development in Latin America and the Caribbean." Inter-American Development Bank, Washington D.C., September 2002.

Honduras

Population: 6.7 million GDP: $16.3 billion Government: $607 million
Land area: 111,890 sq. ka. (slightly larger than Tennessee)
Arable land: 15% Crop land: 3.1% Climate: subtropical to temperate
Crops: bananas, coffee, citrus
Agriculture is 14% of GDP and 34% of labor force *CIA World Factbook*

James (2003) first GM crop in 2002 was Bt maize with production on about 500 acres

FAO Biotechnologies in Developing Countries database shows:

Field studies

- Maize - Lepidopteran resistance (Bt maize commercial approval expected in 2003)

Responsibility for biotechnology research in agriculture and environmental aspects of biotechnology is the Ministry of Natural Resources and the Environment

Mexico

Population: 105 million | GDP: $925 billion | Government: $136 billion
Land area: 1.92 million sq. ka. (slightly less than three times the size of Texas)
Arable land: 13.2% | Crop land: 1.1% | Climate: varies from tropical to desert
Crops: corn, wheat, soybeans, rice, beans, cotton, coffee, fruit, tomatoes
Agriculture is 5% of GDP and 20% of labor force | *CIA World Factbook*

James (2003) reports small area of biotech soy and Bt cotton.

AGBIOS database of government regulatory approvals - [for environmental release, food and feed]

Soybean

- Monsanto, Glyphosate herbicide tolerance, 1998

Cotton

- Monsanto 1997 Resistance to lepidopteran pests including, but not limited to, cotton bollworm, pink bollworm, tobacco budworm.

Tomato

- Calgene, Delayed softening through suppression of polygalacturonase enzyme activity. 1995

FAO Biotechnologies in Developing Countries database shows:

Field studies

- Banana - alter fruit ripening
- Canola - laurate oil composition, and other unspecified objective
- Chili pepper - alter fruit ripening
- Cotton - Lepidoptera resistance, glyphosate tolerant, bromoximil tolerant, multiple resistance
- Flax - unspecified objective
- Maize - Lepidoptera resistance, glyphosate tolerant, glufosinate tolerant, multiple resistance
- Mellon - alter fruit ripening, and CMV virus resistance
- Papaya - alter fruit ripening, and PRSV virus resistance
- Pineapple - alter fruit ripening
- Potato - Lepidoptera resistance, and PVY / PVX virus resistance
- Rice - unspecified objective SPS
- Soybean - glyphosate tolerant, glufosinate tolerant
- Squash - resistance to PMV, PAMV, SMV2 and ZAMV viruses
- Tobacco - fungi resistance, TMV virus resistance
- Tomato - Lepidoptera resistance, and CMV virus resistance, alter fruit ripening
- Wheat - glufosinate tolerant, other unspecified objective DHRF pathogen, multiple resistance
- Zucchini - resistance to PMV, PAMV, SMV2 and ZAMV viruses

Laboratory Trials

- Rice - unspecified objective
- Wheat - aluminum

Responsibility for biotechnology research in agriculture is with Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food and National Council on Science and Technology (CONACYT); responsible for environmental aspects of biotechnology is Ministry of the Environment and Natural Resources

Agricultural biotechnology research institutions include: Instituto Nacional de Investigaciones Forestales Agricolas y Pecuarias (INIFAP) Centro de Investigación Científica de Yucatán Colegio de Postgraduados Instituto Politécnico Nacional (IPN) Universidad Nacional Autónoma de México (UNAM); / Centre of Biotechnology Universidad Autónoma Agraria Antonio Narro (UAAAN) Instituto Tecnológico Agropecuario

ALSO SEE:

Mexican governments invests $300 million United States annually in agro-biotechnology R&D (August 2002) Mexico has 800 biotechnologists, 100 specializing in GMO's
Savia and Cinvestav private sector leaders

CIMMYT transgenic wheat for tolerance to drought, low temperatures, and salinity (March 2004)

Mexico first planted biotech cotton commercially in 1996, the same year as the United States. By 2000, biotech cotton accounted for 261,300 hectares, one-third of Mexico's growing area. see Traxler, G. and S. Godoy-Avila. "Transgenic Cotton in Mexico." AgBioForum. 2004 7(1&2):57-62.

Paraguay

Population: 6.2 million	GDP: $28 billion	Government: $934 million
Land area: 397,000 sq. ka.	(slightly smaller than California)	
Arable land: 7.6%	Crop land: 0.23%	Climate: tropical to semiarid
Crops: cotton, sugarcane, soybean, maize, wheat, tobacco		
Agriculture is 25% of GDP and 45% of labor force		*CIA World Factbook*

Soybeans with herbicide tolerant traits are reportedly 50% of the cultivated soybean area of Paraguay, even though the formal approval to grow GM soy was only just granted for the 2004/05 crop season.

See: "Paraguay gives green light for GMO soy". Reuters News. October 20, 2004

Peru

Population: 28.4 million GDP: $139 billion Government: $10.4 billion
Land area: 1.3 million sq. ka. (slightly smaller than Alaska)
Arable land: 2.9% Crop land: 0.38% Climate: tropical-desert-temperate
Crops: coffee, cotton, sugarcane, rice, wheat, potatoes, corn, plantains, coca
Agriculture is 10% of GDP and (n.a.) % of labor force *CIA World Factbook*

FAO Biotechnologies in Developing Countries database shows:

Field studies

- Potato - Lepidoptera resistance, specifically potato tuber moth

Laboratory Trials

- Potato - resistance to late blight fungi, virus resistance, reduction of natural toxicants
- Sweet potato - improvement of flour quality, and virus resistance

Responsibility for biotechnology research in agriculture is with Ministry of Agriculture and the National Council on Science and Technology (CONCYTEC); responsible for environmental aspects of biotechnology is the National Council of the Environment

Agricultural biotechnology research institutions include: Instituto Nacional de Investigación Agraria (INIA) / Universidad Nacional Agraria La Molina / Universidad Nacional de San Antonio Abad del Cusco

Uruguay

Population: 3.4 million GDP: $27 billion Government: $3.7 billion
Land area: 173,620 sq. ka. (slightly smaller than the state of Washington)
Arable land: 7.2% Crop land: 0.27% Climate: warm; freezing unknown
Crops: rice, wheat, corn, barley
Agriculture is 6% of GDP and 14 % of labor force *CIA World Factbook*

James (2003) - Bt corn for first time, 60,000 hectares soy in 2003/04.

AGBIOS database of government regulatory approvals - [for environmental release, food and feed]

Soybean

- Monsanto (line GTS 40-3-2) glyphosate herbicide tolerance approved for environmental/food/feed in 1997.

FAO Biotechnologies in Developing Countries database shows:

No field studies or laboratory trials

Responsibility for biotechnology research in agriculture is with Ministry of Cattle, Agriculture and Fisheries and National Council for Inovation, Science and Technology (DINACYT/CONICYT) under the authority of the Ministry of Education and Culture; responsible for environmental aspects of biotechnology is Ministry of Housing, Regional Planning and Environment

Agricultural biotechnology research institutions include: Instituto Nacional de Investigación Agropecuaria (INIA); INIA Unidad de Biotecnología Universidad de la República; Facultad de Veterinaria; Facultad de Agronomía Secretariado Uruguayo de la Lana

ALSO SEE:

"Agricultural R&D in Uruguay: Policies, Investments, and Institutional Profile", IFPRI, September 2000, http://www.ifpri.org/themes/grp01/grp01_uruguay.pdf

Venezuela

Population: 24.6 million GDP: $132 billion Government: $21.5 billion
Land area: 882,050 sq. ka. (slightly more than twice the size of California)
Arable land: 3.0% Crop land: 0.96% Climate: tropical; moderate in highlands
Crops: corn, sorghum, sugarcane, rice, bananas, vegetables, coffee
Agriculture is 5% of GDP and 13 % of labor force *CIA World Factbook*

FAO Biotechnologies in Developing Countries database shows:

Field studies

- cassava - high yield

Laboratory Trials

- banana - resistance to bacteria
- coffee - virus resistance
- mango - unspecified objective
- papaya - unspecified objective
- rice - unspecified objective
- sugar cane - unspecified objective

Responsibility for biotechnology research in agriculture is with Ministry of Science and Technology and the National Council of Scientific and Technological Research; responsible for environmental aspects of biotechnology is the Ministry of Environment and Renewable Natural Resources

Agricultural biotechnology research institutions include: Instituto Nacional de Investigaciones Agrícolas de Venezuela (INIA) /Instituto Venezolano de Investigaciones Científicas (IVIC) Universidad Nacional Experimental Francisco de Miranda (UNEFM) Universidad Central de Venezuela; Facultad de Agronomía; Fac. de Ciencias Veterinarias Central-Western University of Venezuela; Decanato de Ciencias Veterinarias; Decanato de Agronomía

Asia / Pacific

- Australia
- Bangladesh
- China
- India
- Indonesia
- Japan
- Malaysia
- New Zealand
- Pakistan
- Philippines
- South Korea
- Thailand

Australia

Population: 19.7 million GDP: $526 billion Government: $87 billion
Land area: 7.6 million sq. ka. (slightly smaller than the US contiguous 48 states)
Arable land: 6.9% Crop land: 0.03% Climate: semiarid; temperate; tropical
Crops: corn, wheat, barley, sugarcane, fruits
Agriculture is 3% of GDP and 5% of labor force *CIA World Factbook*

James (2003) - 100,000 hectare biotech in 2003/04, 59% of total cotton area, Bt cotton area limit
GM ha decline from drought, about 100k ha grown 03, 59% total cotton area, 03/04 limits Bt cotton

AGBIOS database of government regulatory approvals -

Cotton: [for environmental release, food and feed, some import only]

- Monsanto Bollgard resistant to lepidopteran pests including, but not limited to, cotton bollworm, pink bollworm, and tobacco budworm (lines MON531 only, not also lines MON757/MON1076). environmental release and food/feed consumption approvals in 1996
- Monsanto Bollgard II resistant to lepidopteran pests including, but not limited to, cotton bollworm, pink bollworm, and tobacco budworm (lines MON15985 environmental release and food only approvals in 2002. Production limited to New South Wales and southern Queensland
- Monsanto Roundup-Ready glyphosate herbicide tolerance (line MON1445 and MON1698) approved for environmental release and food consumption in 2002
- Calgene (line BXN) Oxynil herbicide tolerance, including bromoxynil and ioxynil, approved for food and/or feed use in 2002

Maize: [for environmental release, food and feed, some import only]

- Monsanto (line MON863) resistance to corn root worm (Coleopteran, Diabrotica sp.). Approval for food use 2003
- Monsanto Roundup-Ready (line NK603) glyphosate herbicide tolerance. Food use approval 2002
- Monsanto Roundup-Ready (line GA21) glyphosate herbicide tolerance, environmental release approval 1998
- Monsanto Yieldgard (line MON810) resistance to European corn borer (Ostrinia nubilalis). Full approval in 1998.
- Syngenta NaturGard KnockOut (line SYN-176) resistance to European corn borer (Ostrinia nubilalis) and phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium, approved for environmental release in 1996, and food/feed approvals in 1998
- Syngenta (line SYN-BT11) phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium, environmental release and food/feed use in 2001
- Bayer Liberty-Link (lines T14, T25) Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium, approved for environmental release and food/feed use in 1998.
- DeKalb Bt Xtra (line TBD-418) resistance to European corn borer (Ostrinia nubilalis) and phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. environmental release approval 1998

Soybean**:** [for environmental release, food and feed, some import only]

- Monsanto Roundup-Ready (line GTS 40-3-2) glyphosate herbicide tolerance full approval 1996.
- DuPont Canada Agricultural Products (line G94-1, G94-19, G168) modified seed fatty acid content, specifically high oleic acid expression, food use approval in 2000

Canola (Argentine): [for environmental release, food and feed, some import only]

- Bayer (line MS8xRF3) glufosinate ammonium herbicide tolerance and restored fertility, approved for food and feed use in 2002 and environmental release in 2003.
- Bayer (line T45) phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. approved for food and feed use in 2002 and environmental release in 2003.
- Aventis (line OXY-235) Oxynil herbicide tolerance, including bromoxynil and ioxynil, food approval in 2002.
- Aventis (line PGS1) glufosinate ammonium herbicide tolerance and restored fertility, approved for food and feed use in 2002 and environmental release in 2003.
- Aventis (line PGS2) glufosinate ammonium herbicide tolerance and restored fertility, approved for food and feed use in 2002 and environmental release in 2003.
- Monsanto Westar Roundup Ready (line GT73, RT73) glyphosate herbicide tolerance, approved for food in 2000 and environmental release in 2003.

Potato [food and feed, import only]

- Monsanto Russet Burbank NewLeaf Plus (line RBMT21-29, et.) Resistant to Colorado potato beetle (Leptinotarsa decemlineata, Say), and resistant to potato leafroll luteovirus (PLRV). Approved for food/feed consumption 2001.
- Monsanto Atlantic and Superior NewLeaf (line ATBT04, et.) Resistance to Colorado potato beetle (Leptinotarsa decemlineata, Say). Approved for food/feed consumption 2001.
- Monsanto NewLeaf (lines RBMT15 and SEMT15) Resistance to Colorado potato beetle (Leptinotarsa decemlineata, Say); resistance to potato virus Y (PVY). Approved for food/feed consumption 2001.

Sugar Beet: [food and feed, import only]

- Monsanto (Novartis) InVigor (line GTSB77) glyphosate herbicide tolerance, approved for food/feed use in 2002.

CSIRO - Commonwealth Scientific & Industrial Research Organization

Field studies

- apple - antibiotic resistance
- barley - herbicide tolerance, starch breakdown
- canola - fungal resistance, herbicide tolerance, insensitivity to daylight hours, lowered anti-nutritional characteristics, modify plant structure, reduce seed pod scattering
- cotton - herbicide tolerance, insect resistance, tolerance to water logging
- field peas - insect resistance, nutritional quality
- grapevine - reduce fruit color
- Indian mustard - herbicide tolerance
- lettuce - antibacterial tolerance, virus tolerance

- lupins - color bioassay selection, herbicide tolerance, nutritional value, seed tolerance
- oilseed poppy - increased alkaloid production
- papaya - antibiotic resistance, fruit quality
- pineapple - biochemical alteration, control of flowering
- subterranean clover - herbicide tolerance, improved nutritional quality
- sugarcane - increase sugar content, altered juice color, resistance to leaf scald disease
- tomato - herbicide tolerance
- wheat - ampicillin resistance, herbicide tolerance
- white clover - virus resistance

ALSO SEE:

"Beyond Canola - Research Roundup", Biotech Bulletin 3, Agrifood Awareness Australia Limited, October 2003

CSIRO 93 - cotton (insect resistant and herbicide tolerant)

AFAA - Agrifood Awareness Australia

Bangladesh

Population: 141.3 million GDP: $259 billion Government: $4.9 billion
Land area: 133,910 sq. ka. (slightly smaller than Iowa)
Arable land: 60.7% Crop land: 2.6% Climate: tropical monsoon
Crops: rice, jute, tea, wheat, sugarcane, potatoes, tobacco, pulses, oilseeds, spices, fruit
Agriculture is 24% of GDP and 63% of labor force *CIA World Factbook*

FAO Biotechnologies in Developing Countries database shows:

Laboratory Trials

- lentil - unspecified objective
- mungbean - increase yield
- papaya - papaya mosaic virus resistance
- peanut - unspecified objective
- rice - salt tolerance
- tobacco - unspecified objective

Responsibility for biotechnology research in agriculture is with Ministry of Agriculture, Ministry of Food (MOF), Ministry of Livestock and Fisheries, Bangladesh Agricultural Research Council (BARC) and Ministry of Science and Technology; responsible for environmental aspects the Ministry for Environment and Forests

Agricultural biotechnology research institutions include: Bangladesh Rice Research Institute (BRRI) Bangladesh Agricultural Research Institute (BARI) National Institute of Biotechnology / Bangladesh Forest Research Institute (BFRI) Bangladesh Fisheries Research Institute (FRI) / Bangladesh Agricultural University / University of Business, Agriculture and Technology (IUBAT)

China

Population: 1.28 billion GDP: $6 trillion Government: $225 billion
Land area: 9.3 million sq. ka. (slightly smaller than the US)
Arable land: 13.3% Crop land: 1.3% Climate: diverse; tropical / arctic
Crops: corn, rice, wheat, potatoes, sorghum, peanuts, tea, millet, barley, cotton, oilseed
Agriculture is 15% of GDP and 50% of labor force *CIA World Factbook*

James - China increased Bt cotton area fifth consecutive year in 2003/04 to 2.8 million hectare, or an adoption rate of 68% biotech; increased Bt cotton acres for 5th consecutive year, 02: 2.1 mha, 03: 2.8 mha, 6 m small farmers

China planted 5.1 million hectare in cotton and produced 22.4 million bales in 2003/04. The earlier analysis showed market value of China biotech cotton crop was $3.9 billion in 2003/04.

AGBIOS database of government regulatory approvals - [for environmental release, food and feed]

Cotton:

- Monsanto Bt, resistance to lepidopteran pests including, but not limited to, cotton bollworm, pink bollworm, tobacco budworm, approved 1997

FAO Biotechnologies in Developing Countries database shows:

Commercial approval:

- cotton - lepidopteran resistant
- green pepper - virus resistance
- tomato- CMV virus resistance, prolong fruit ripening

Field studies

- chili - resistance to CMV and TMV virus
- cabbage - resistance to Turnip Mosaic Virus
- maize - high lysine protein content, and Lepidoptera (corn borer) resistance
- cotton - resistance to Verticilium and Fusarium
- groundnut - resistance to Striped virus
- melon - CMV virus resistance
- papaya - PRSV virus resistance
- potato -- wilt bacterium resistance, PVY virus resistance, PVY and wilt resistance combined
- rice- lepidopteran resistant (stem and yellow borers), salt tolerance, blight and RDV resistance
- soybean- lepidopteran resistant (soybean moth)
- tobacco - TMV virus resistance
- sweet pepper - CMV virus resistance
- tomato - frost tolerance

Laboratory Trials

- barley - unspecified objective
- carrot - mycobacterium (foreign) protein
- maize - salt tolerance
- canola - unspecified objective
- papaya - delay growth and fruit ripening
- sorghum- salt tolerance
- wheat - bacterial wilt resistance (BYDV)
- sugar beet - aluminum tolerance

Responsibility for biotechnology research in agriculture is with Ministry for Agriculture; also responsible are Ministry of Fisheries, the Ministry of Forestry and Ministry of Science and Technology, which also has an overview on patent legislation; Ministry of Land and Resources responsible for environmental aspects of biotechnology

Agricultural biotechnology research institutions include: Chinese Academy of Agricultural Science / China National Rice Research Institute / Chinese Academy of Forestry / Chinese Academy of Sciences / Zhejiang Agricultural University / China Agricultural University

India

Population: 1.05 billion GDP: $2.7 trillion Government: $48 billion
Land area: 3.0 million sq. ka. (slightly more than one-third the size of the US)
Arable land: 54% Crop land: 2.7% Climate: varies tropical to temperate
Crops: rice, wheat, oilseed, cotton, jute, tea, sugarcane, potatoes
Agriculture is 25% of GDP and 60% of labor force *CIA World Factbook*

James (2003) - first year of Bt cotton in 2002/03, 100,000 hectare in 2003/04

AGBIOS database of government regulatory approvals - [for environmental release only]

Cotton:

- Monsanto (line MON531/757/1076) in 2002 for resistance to lepidopteran pests including, but not limited to, cotton bollworm, pink bollworm, tobacco budworm.

FAO Biotechnologies in Developing Countries database shows:

Field studies

- brassica (canola) - moisture stress
- cotton - Lepidoptera resistance
- tobacco - Lepidoptera resistance

Laboratory Trials

- cabbage - Lepidoptera resistance
- potato - starch composition, Lepidoptera (tuber moth) resistance, moisture stress
- rice - fungal (sheath blight) resistance
- tomato - delayed fruit ripening

Responsibility for biotechnology research in agriculture is with Ministry of Agriculture, Department of Agriculture Research and Education, Indian Council of Agricultural Research and Ministry of Science and Technology, Department of Biotechnology and Council of Scientific and Industrial Research; responsible for environmental aspects of biotechnology is Ministry of Environment and Forests

Agricultural biotechnology research institutions include: Indian Agricultural Research Institute / Central Agricultural Research Institute Central Tuber Crops Research Institute / Indian Institute of Science (IIS) Assam Agricultural University (AAU) / Punjab Agricultural University (PAU) / Kerala Agricultural University (KAU)

Indonesia

Population: 235 million GDP: $714 billion Government: $26 billion
Land area: 1.8 million sq. ka. (slightly less than three times the size of Texas)
Arable land: 9.9% Crop land: 7.2% Climate: tropical; moderate in highlands
Crops: rice, cassava (tapioca), peanuts, rubber, cocoa, coffee, palm oil, copra
Agriculture is 17% of GDP and 45% of labor force *CIA World Factbook*

FAO Biotechnologies in Developing Countries database shows:

Commercial approval:

- cotton - Lepidoptera resistance (Bt)

Field studies

- cotton - herbicide tolerant, Lepidoptera resistance
- maize - herbicide tolerant, Lepidoptera resistance
- soybean - herbicide tolerant

Laboratory Trials

- cacao - Lepidoptera resistance
- cassava - starch composition
- coffee - fungal resistant
- maize - Lepidoptera resistance
- oil palm - Lepidoptera resistance, lower saturated fatty acid
- peanut - virus resistant
- pepper - unspecified
- potato - Lepidoptera resistance, virus resistant
- rice - Lepidoptera resistance
- shallot - unspecified
- soybean - Lepidoptera resistance
- sugar cane - drought tolerant
- sweet potato - virus resistance
- tobacco - virus resistance
- tomato - unspecified

Responsibility for biotechnology research in agriculture is with Ministry of Agriculture and the State Ministry of Research and Technology; responsible for environmental aspects of biotechnology is the State Ministry of the Environment

Agricultural biotechnology research institutions include: Indonesian Agency for Agricultural Research and Development (IAARD) Indonesian Institute of Sciences Bogor Agricultural University / Padjadjaran University; Faculty of Agriculture Gadja Mada University

ALSO SEE: "Biotechnology Research and Policy Activities of ABSP in Indonesia, 1991-2002"
James - unconfirmed small area of Bt cotton in Sulawesi

Japan

Population: 127 million GDP: $3.7 trillion Government: $441 billion
Land area: 374,744 sq. ka. (slightly smaller than California)
Arable land: 12.1% Crop land: 1.0% Climate: varies tropical cool temperate
Crops: rice, sugar beets, vegetables, fruit
Agriculture is 1.4% of GDP and 5% of labor force *CIA World Factbook*

Status of transgenic crop plants in Japan, [94] **Agriculture, Forestry and Fisheries Research Council**

Crop - Trait - year of most recent activity

<u>Commercial approval</u>: **-** [for environmental release, food and feed, some import only]

- Canola - herbicide tolerant - commercial 2003
- Cotton - herbicide tolerant, insect resistant - commercial 2003
- Maize - herbicide tolerant, insect resistant - commercial 2003
- Potato - insect resistant, virus resistant - food import 2001
- Soybean - herbicide tolerant, high oleic acid - commercial 2003
- Sugarbeet - herbicide tolerant - feed import 2003

<u>Field studies</u>

- (Adzuki) bean - insect resistant - 1999
- Broccoli - herbicide tolerant, male sterile - 2001
- Cauliflower - herbicide tolerant, male sterile - 2001
- Cucumber - fungal resistant, virus resistant - 1999
- Melon - virus resistant - 1996
- Rice - herbicide tolerant, virus resistant, low allergen, low protein, cold resistant - 2003
- Tomato - delayed ripening, pectin-rich, virus resistant - 2000

<u>Laboratory Trials</u>

- Lettuce - ferritin-rich - 2000
- Papaya - virus resistant - 2000
- Strawberry - mildew resistant - 2000
- Tobacco - virus resistant, GUS enzyme - 2000
- Wheat - herbicide tolerant - 2001

Malaysia

Population: 23.1 million GDP: $198 billion Government: $20 billion
Land area: 328,550 sq. ka. (slightly larger than New Mexico)
Arable land: 5.5% Crop land: 17.6% Climate: tropical, monsoon
Crops: rubber, palm oil, cocoa, rice
Agriculture is 12% of GDP and 16% of labor force *CIA World Factbook*

FAO Biotechnologies in Developing Countries database shows:

Laboratory Trials

- banana - unspecified objective
- chili pepper - virus resistance
- eggplant - unspecified objective
- muskmelon - unspecified objective
- oil palm - biodegradable plastics
- papaya - PRSV virus resistance, extended shelf life
- pepper - CMV virus resistance
- pineapple - tolerance to blackheart
- rice - resistance to (sheath blight and tungro) fungi
- tobacco - unspecified objective
- wingbean - fungi resistance

Responsibility for biotechnology research in agriculture is with Ministry of Agriculture; responsible for environmental aspects of biotechnology is the Ministry of Science, Technology and the Environment (MOSTE)

Agricultural biotechnology research institutions include: Malaysian Agricultural Research and Development Institute (MARDI) / Forest Research Institute of Malaysia (FRIM) University Kebangsaan Malaysia (UKM); Faculty of Science and Technology, Centre for Gene Analysis and Technology (CGAT) / Malaysian Rubber Board (MRB) / Palm Oil Research Institute of Malaysia (PORIM)

New Zealand

Population: 4.9 million	GDP: $85 billion	Government: $32 billion
Land area: 269,000 sq. ka.	(about the size of Colorado)	
Arable land: 5.6%	Crop land: 7.0%	Climate: temperate
Crops: wheat, barley, potato, pulses, fruit, vegetable		
Agriculture is 4.8% of GDP and 10% of labor force		*CIA World Factbook*

New Zealand's Environmental Risk Management Authority (ERMA) reports two biotech field studies.

<u>Canola</u>

Field studies for herbicide tolerance were completed in 1998

<u>Onion</u>

Field studies for herbicide tolerance were approved in December 2003.

ALSO SEE: http://www.ermanz.govt.nz/

Pakistan

Population: 159 million GDP: $318 billion Government: $12 billion
Land area: 778,720 sq. ka. (slightly less than twice the size of California)
Arable land: 28% Crop land: 0.87% Climate: hot, temperate, arctic
Crops: cotton, wheat, rice, sugarcane, fruits, vegetables; milk, beef, mutton, eggs
Agriculture is 23% of GDP and 44% of labor force *CIA World Factbook*

FAO Biotechnologies in Developing Countries database shows:

Laboratory Trials

- cotton - Lepidoptera (diamond back moth) resistance
- rice - fungi resistance

Responsibility for biotechnology research in agriculture is with Ministry of Food, Agriculture and Livestock and Ministry of Scientific and Technological Research; responsible for environmental aspects of biotechnology is Ministry of Environment, Local Government and Rural Development

Agricultural biotechnology research institutions include: Pakistan Agricultural Research Council (PARC) National Institute for Biotechnology & Genetic Engineering Agricultural Biotechnology Research Institute National Agricultural Research Centre (NARC) / National Institute of Agricultural Biotechnology and Genetic Resources / Ayub Agricultural Research Institute (Punjab) / Central Cotton Research Institute

ALSO SEE:

"GM corn, wheat, cotton, vegetable seeds available on black market"

"Pakistan has developed at the laboratory level - cotton, sugar cane, soybean, and tomato - but can not be declared in the absence of biosafety laws"

"Biotechnology can improve mango production"

Philippines

Population: 84.6 million GDP: $380 billion Government: $11 billion
Land area: 298,170 sq. ka. (slightly larger than Arizona)
Arable land: 18.5% Crop land: 14.8% Climate: tropical marine; monsoon
Crops: rice, coconuts, corn, sugarcane, bananas, pineapples, mangoes
Agriculture is 15% of GDP and 45% of labor force *CIA World Factbook*

AGBIOS database of government regulatory approvals - [for environmental release, food and feed]

Maize

- Monsanto Bt, resistance to European corn borer (Ostrinia nubilalis), 2002

FAO Biotechnologies in Developing Countries database shows:

Field studies

- banana - BTV virus resistance
- maize - Lepidoptera resistance (Asiatic corn borer)

Laboratory Trials

- coconut - high lauric acid content
- mango - delay ripening
- papaya - delay ripening and resistance to PSRV virus
- rice - multiple resistance for fungi, insect, bacterial, and salt tolerance
- tobacco - delay leaf senescence, and increase yield
- tomato - delay fruit ripening

Responsibility for biotechnology research in agriculture is with Department of Agriculture, Department of Science and Technology, Council for Agriculture, Forestry and Natural Resources Research and Development and Council for Aquatic and Marine Research and Development; responsible for environmental aspects of biotechnology is Department of Environment and Natural Resources; Agriculture and Fisheries Modernization Act regulates biotechnology research policy

Agricultural biotechnology research institutions include: Philippine Rice Research Institute (PRRI) / Bureau of Agricultural Research (BAR) Philippine Coconut Authority (PCA) / University of the Philippines, Los Banos / University of the Philippines, Manila

ALSO SEE:

"Four big biotech firms seek license for agri products - soybean, cotton, corn, canola, potato, sugarbeet"

James (2003) - Philippines 20k ha Bt corn first time 2003

South Korea

Population: 48.3 million GDP: $941 billion Government: $118 billion
Land area: 98,190 sq. ka. (slightly larger than Indiana)
Arable land: 17.4% Crop land: 2.0% Climate: temperate
Crops: rice, root crops, barley, vegetables, fruit
Agriculture is 4.4% of GDP and 9.5% of labor force *CIA World Factbook*

AGBIOS database of government regulatory approvals - [food and feed import only]

<u>Maize</u>

- Monsanto, Glyphosate herbicide tolerance, 2002
- Resistance to European corn borer (Ostrinia nubilalis), 2002

<u>Soybean</u>

- Monsanto, Glyphosate herbicide tolerance, 2000

FAO Biotechnologies in Developing Countries database shows:

<u>Laboratory Trials</u>

- hot pepper - CMV and TMV virus resistance (Hungnong Seed Company)
- tobacco - PVY and TMV virus resistance (Korea Ginseng & Tobacco Research Institute)

No government or research institution details

Thailand

Population: 64.3 million GDP: $446 billion Government: $19 billion
Land area: 511,770 sq. ka. (slightly more than twice the size of Wyoming)
Arable land: 33% Crop land: 7% Climate: tropical, monsoon
Crops: rice, cassava (tapioca), rubber, corn, sugarcane, coconuts, soybeans
Agriculture is 11% of GDP and 54% of labor force *CIA World Factbook*

FAO Biotechnologies in Developing Countries database shows:

Field studies

- cotton - Lepidoptera (boll worm) resistance
- rice - salt tolerance, drought tolerance
- tomato - delay fruit ripening, TYLCV virus resistance
- pepper - CVBMV and PLCV virus resistance

Laboratory Trials

- cassava - unspecified objective
- papaya - PRV virus resistance
- yard long bean - resistance to aphid-borne mosaic virus

Responsibility for biotechnology research in agriculture is with Ministry of Agriculture and Cooperatives, Department of Agriculture and Ministry of Science and Technology, National Science and Technology Development Agency and National Research Council; responsible for environmental aspects of biotechnology is Ministry of Natural Resources and Environment

Agricultural biotechnology research institutions include: National Center for Genetic Engineering and Biotechnology, Biotec Central Research Unit Asian Institute of Technology Field Crops Research Institute Rice Research Institute of Thailand King Mongkuts Institute of Technology; Faculty of Agricultural Technology Khon Kaen University Chiang Mai University

ALSO SEE:

Thailand Biodiversity Center, papaya - PRSV virus resistance, fruit quality, rice, pineapple

Thailand Department of Agriculture

EUROPE

WEST EUROPE

- Austria
- Belgium
- Denmark
- Finland
- France
- Germany
- Greece
- Ireland
- Italy
- Netherlands
- Portugal
- Spain
- Sweden
- Switzerland
- United Kingdom

WEST EUROPE represents 15 countries

- 14 report deliberate field trials to Joint Research Centre (JRC) of European Commission.

- 13 are member of the original EU15, including Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Portugal, Spain, Sweden, United Kingdom.

- plus Switzerland which is not a EU15 country, nor is it included in JRC report, but does have biotech approvals

AGBIOS database of government regulatory approvals -

European Union

Canola Argentine [marketing only]

- Bayer Glufosinate ammonium herbicide tolerance and fertility restored, 1996.
- Bayer Phosphinothricin herbicide tolerance, specifically glufosinate ammonium, 1997/1998.
- Monsanto Glyphosate herbicide tolerance, 1997.

Chicory [for environmental release and marketing]

- Bejo Zaden Glufosinate ammonium herbicide tolerance and fertility restored, 1996

Maize [food and feed, marketing]

- Bayer Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium, 1998.
- Monsanto resistance to European corn borer (Ostrinia nubilalis), 1998
- Syngenta resistance to European corn borer (Ostrinia nubilalis); phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 1997/1998

Soybean [marketing]

- Monsanto Glyphosate herbicide tolerance, 1996.

Tobacco [marketing]

- Societe National d'Exploitation herbicide tolerance, including bromoxynil and ioxynil, 1994

Joint Research Centre, European Commission - Biotechnology & GMO's Information

Summary of JRC field test data - for complete list and details see "JRC" [95]
1849 (food or fiber, not tree or floral) field studies between 1991 and (August) 2004 in 15 countries
Rank ordered by number biotech field trials reported over the period

France (520 biotech field studies) - most recently (17 tests) in 2003, primary interest in maize, oilseed rape, sugar beet, and tobacco; also chicory, cotton, grape, lettuce, melon, potato, rice, sunflower

Italy (270 biotech field studies) - most recently (2 tests) in 2003, primary interest in maize, tomato, sugar beet; also chicory, eggplant, grape, kiwi, lettuce, melon, rape, olive, potato, raspberry, rice, soy, squash, strawberry, cherry, tobacco, watermelon, wheat

Spain (263 biotech field studies) - most recently (9 tests) in 2004, primary interest in maize, rice, cotton; also alfalfa, cantaloupe, maize, plum, melon, oilseed rape, orange, potato, rice, soy, squash, strawberry, sunflower, sugar beet, tobacco, tomato, wheat

Also see - (James, 2003) 6% of Maize crop is Bt variety, 32,000 hectare in 2003/04

United Kingdom (199 biotech field studies) - most recently (8 tests) in 2003, primary interest in oilseed rape, potato, sugar beet; also barley, chicory, maize, apple, pea, strawberry, tobacco, tomato, wheat

Also - (AGBIOS) [food and feed import only]

- Maize, Syngenta 1997 Resistance to European corn borer (Ostrinia nubilalis); phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 1998
- Soybean, Monsanto 1996 Glyphosate herbicide tolerance.

Germany (138 biotech field studies) - most recently (5 tests) in 2004, primary interest in potato, rape, sugar beet; also apple, grape, maize, pea, soy, spinach, tobacco, wheat

Also see - (James, 2003) Germany - token area of Bt maize in 2003/04

Netherlands (138 biotech field studies) - most recently (4 tests) in 2004, primary interest in potato, sugar beet, oilseed rape; also apple, cabbage, carrot, chicory, maize, ryegrass, sunflower, tomato

Also - (AGBIOS) [food and feed import only]

- Maize, Syngenta 1997 Resistance to European corn borer (Ostrinia nubilalis); phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium.

Belgium (129 biotech field studies) - most recently (1 test) in 2004, primary interest in oilseed rape, maize, sugar beet; also apple, alfalfa, cauliflower, chicory, Indian mustard, potato, wheat

Sweden (68 biotech field studies) - most recently (3 test) in 2004, primary interest in oilseed rape, potato, sugar beet; also apple, mustard

Denmark (38 biotech field studies) - most recently (1 test) in 2000, interest in sugar beet, potato, oilseed rape, maize

Greece (19 biotech field studies) - most recently (1 test) in 2004, interest in cotton, maize, sugar beet, tomato

Finland (16 biotech field studies) - most recently (1 test) in 2004, interest in barley, broccoli, cabbage, cauliflower, oilseed rape, potato, sugar beet, tobacco

Portugal (11 biotech field studies) - most recently (1 test) in 1999, interest in maize, potato, tomato

Ireland (5 biotech field studies) - most recently (1 test) in 2002, interest in sugar beet

Austria (3 biotech field studies) - most recently (1 test) in 1997, interest in potato and maize

Switzerland is another in the West Europe group. Not EU member and does not reported with JRC, but has granted regulatory approval for biotech maize and soybean.

Also - (AGBIOS) [food and feed import only]

- Maize, Monsanto 2000 Resistance to European corn borer (Ostrinia nubilalis).
- Syngenta 1997 Resistance to European corn borer (Ostrinia nubilalis); phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 1998
- Soybean, Monsanto 1996 Glyphosate herbicide tolerance.

EASTERN EUROPE

- Armenia
- Bosnia Herzegovina
- Bulgaria
- Croatia
- Czech Republic
- Georgia
- Hungary
- Moldova
- Romania
- Russia
- Serbia/Montenegro
- Slovenia
- Ukraine

EAST EUROPE includes 13 countries.

Czech Republic is the only member of the expanded EU25 (9 of 10 countries in expanded EU25 report no ag biotech interest - Estonia, Latvia, Lithuania, Poland, Slovakia, Hungary, Slovenia, Malta, Cyprus)

AGBIOS database of government regulatory approvals - [food and feed import only]

Soybean

- Monsanto Glyphosate herbicide tolerance 2001.

Three more countries are EU candidates, Turkey no reports of biotech activity, but Bulgaria and Romania do have biotech production in maize and soy.

Bulgaria

James (2003) - few thousand hectare herbicide tolerant maize
(FAO) confirms regulatory approval

Romania

James (2003)- 70,000 hectare of biotech soy in 2003/04. Following the analysis in Part I, at the world average price of $250 per metric ton, and 50% adoption rates, Romania generated $4.2 million in biotech soybean value.

"Biotech saves Romania", July 20, 2004, Ellinghuysen News: Herbicide tolerant soy has been grown in Romania since 1999. In 2003 between half and 60% of 185,000 acres were planted to biotech varieties.

Total soy yield was 33,500 metric tons. Biotech potato (for insect resistance) is approved, but not grown commercially

Russia

AGBIOS database of government regulatory approvals - [food only]

- Soybean, Monsanto, 1999, Glyphosate herbicide tolerance.

8 more countries from:

"Status of Agricultural Biotechnology and Biosafety in Selected Countries of the Balkans, the Caucasus and Moldova", July 2003, FAO

Armenia: (Caucasus)

- potato - lab or greenhouse study for starch composition
- tobacco - lab or greenhouse study for unspecified purpose

Bosnia Herzegovina: (Balkans)

- potato - lab or greenhouse study for fungi resistance

Croatia (Balkans):

- pea - lab or greenhouse study for heat stress
- wheat - lab or greenhouse study for drought tolerance

Georgia:

- potato - unconfirmed unregulated use

Moldova (Caucasus)

- pea - lab or greenhouse study for antibiotic resistance

Serbia and Montenegro

- maize - field trial for glyphosate tolerance

Slovenia

- laboratory experiment potatoes (fungus resistance),
- laboratory experiment flax (modified lignin and cellulose)

Ukraine

- maize - field trial herbicide tolerance and insect resistance
- canola - field trial herbicide tolerance and insect resistance
- sugar beet - field trial herbicide tolerance and insect resistance
- canola - field trial herbicide tolerance and insect resistance
- potato - field trial herbicide tolerance and insect resistance

NORTH AMERICA

- Canada
- United States

Canada

Population: 32.2 million GDP: $934 billion Government: $179 billion
Land area: 9.1 million sq. ka. (somewhat larger than the US)
Arable land: 4.9% Crop land: 0.02% Climate: varies temperate to arctic
Crops: wheat, barley, oilseed, tobacco, fruits, vegetables
Agriculture is 2.3% of GDP and 3% of labor force *CIA World Factbook*

James - 4.4 million hectare of biotech canola, maize, and soy in 2003/04
Canada 03 increases totaling 1 mha in all 3 crops, .5 mha soy
The earlier analysis showed combined market value of the three Canadian biotech crops was $2.0 billion in 2003/04.

1.1 million hectare of soybeans planted and 2.3 million metric tons produced, 50% was a biotech variety, estimated market value $284 million

1.2 million hectare of maize planted and 9.6 million metric tons produced, assumed 40% is biotech, estimated market value $384 million

4.7 million hectare of canola planted and 6.7 million metric tons produced, 68% biotech variety, estimated market value $1.29 billion

AGBIOS database of government regulatory approvals - [for environmental release, food and feed]

<u>Canola Argentine</u>
- Bayer Glufosinate ammonium herbicide tolerance and fertility restored. 1997
- Bayer Oxynil herbicide tolerance, including bromoxynil and ioxynil. 1995
- Bayer Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 1997
- Calgene Modified seed fatty acid content, specifically high laurate levels and myristic acid. 1996
- Monsanto Glyphosate herbicide tolerance. 1997
- Pioneer Imidazolinone herbicide tolerance, specifically imazethapyr. 1995
- Pioneer Modified seed fatty acid content, high oleic acid, low linolenic acid content. 1996

<u>Canola Polish</u>
- Bayer Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 1998
- Monsanto Glyphosate herbicide tolerance. 1997

<u>Cotton</u>
- Calgene Oxynil herbicide tolerance, including bromoxynil and ioxynil. 1996
- Monsanto Resistance to lepidopteran pests including, but not limited to, cotton bollworm, pink bollworm, tobacco budworm. 2003
- Monsanto Glyphosate herbicide tolerance. 1996

<u>Flax, Linseed</u>
- University of Saskatchewan Sulfonylurea herbicide tolerance, specifically triasulfuron and metsulfuron-methyl. 1998

Maize
- BASF Cyclohexanone herbicide tolerance, specifically sethoxydim. 1996
- Bayer Glufosinate ammonium herbicide tolerance and male sterility 1998
- Bayer Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 1997
- DeKalb Resistance to European corn borer (Ostrinia nubilalis); phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 1997
- DeKalb Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 1996
- Monsanto Resistance to corn root worm (Coleopteran, Diabrotica sp.) 2003
- Monsanto Resistance to European corn borer; glyphosate herbicide tolerance. 1997
- Monsanto Glyphosate herbicide tolerance. 1997
- Monsanto Resistance to European corn borer (Ostrinia nubilalis). 1997
- Monsanto Glyphosate herbicide tolerance. 1998/1999
- Monsanto 2001 Glyphosate herbicide tolerance.
- Mycogen Resistance to European corn borer (Ostrinia nubilalis); phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 2002
- Pioneer Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 1998
- Pioneer Resistance to European corn borer; glyphosate herbicide tolerance. 1996
- Pioneer Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 1996
- Syngenta Imidazolinone herbicide tolerance, specifically imazethapyr. 1997
- Resistance to European corn borer (Ostrinia nubilalis); phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 1996

Papaya
- Cornell University Resistance to viral infection, papaya ringspot virus (PRSV). 2003

Potato
- Monsanto Resistance to Colorado potato beetle (Leptinotarsa decemlineata, Say). 1995
- Monsanto Resistance to Colorado potato beetle; resistance to potato virus PVY. 1999
- Monsanto Resistance to Colorado potato beetle (Leptinotarsa decemlineata, Say). 1997
- Monsanto Resistance to Colorado potato beetle (Leptinotarsa decemlineata, Say); resistance to potato leafroll luteovirus (PLRV). 1999

Rice
- BASF Imidazolinone herbicide tolerance. 2002

Soybean
- Ag-food Canada Modified seed fatty acid content, specifically low linolenic acid2001
- Bayer Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 2000
- DuPont Modified seed fatty acid content, specifically high oleic acid expression. 2000
- Monsanto Glyphosate herbicide tolerance. 1995

Squash
- Asgrow-Seminis 1998 Resistance to viral infection, cucumber mosaic virus (CMV), watermelon mosaic virus (WMV) 2, zucchini yellow mosaic virus (ZYMV).
- Upjohn-Seminis 1998 Resistance to viral infection, watermelon mosaic virus (WMV) 2, zucchini yellow mosaic virus (ZYMV).

Sugar Beet

- Bayer Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 2001

Sunflower
- BASF Imidazolinone herbicide tolerance. 2003

Tomato
- Calgene Delayed softening through suppression of polygalacturonase (PG) enzyme activity. 1995
- DNA Plant Tech Increased shelf-life (delayed ripening) by reduced ethylene accumulation. 1995
- Monsanto Resistance to lepidopteran pests including, but not limited to, cotton bollworm, pink bollworm, tobacco budworm. 2000
- Zeneca Delayed softening through suppression of polygalacturonase (PG) enzyme activity. 1996

Canadian Food Inspection Agency, [96] Plant Products Directorate, Plant Biosafety Office

2003 Field Studies
- Alfalfa - stress tolerance, herbicide tolerance, antibiotic resistance, marker gene, altered falconoid patterns, alter morphology
- Brown mustard - herbicide tolerance
- Canola - herbicide tolerance, stress tolerance, modify oil or nutrition, male sterility, marker gene, enhance yield
- Corn - herbicide tolerance, insect resistance, stress tolerance, fungal resistance, marker gene
- Lentils - herbicide tolerance
- Potato - stress tolerance, antibiotic resistance, marker gene
- Safflower - herbicide tolerance, pharmaceutical/industrial enzyme
- Sugar beet - herbicide tolerance, antibiotic resistance, marker gene
- Tobacco - novel pharmaceutical, industrial protein, reduce nicotine, marker gene
- Wheat - herbicide tolerance, fungal resistance, enhance yield, marker gene

2002 Field Studies
- brown mustard - herbicide tolerance
- corn - fungal resistance, herbicide tolerance, insect resistance, nutritional change, marker gene
- canola - insect resistance, fungal resistance, stress tolerance, pod shatter resistance, herbicide tolerance, antibiotic resistance, male sterile, nutritional change, enhance yield, marker gene
- alfalfa - altered falconoid patterns, stress tolerance, herbicide tolerance, antibiotic resistance,
- tobacco - stress resistance, novel pharmaceutical, reduce nicotine, marker gene
- lentil - herbicide tolerance
- sunflower - herbicide tolerance
- wheat - enhance yield, herbicide tolerance, marker gene
- safflower - herbicide tolerance, industrial enzyme, novel pharmaceutical
- barley - fungal resistance
- sugar beet - herbicide tolerance, antibiotic resistance, marker gene
- flax - stress tolerance, antibiotic resistance, marker gene
- tomato - pathogen resistance, marker gene

2001 Field Studies

- potato - fungal resistance, marker gene, stress tolerance, antibiotic resistance
- barley - alter enzymatic activity, marker gene
- soybean - fungal resistance, antibiotic resistance
- corn - fungal resistance, herbicide resistance, antibiotic resistance, marker gene, modify oil composition, insect resistance
- canola - insect resistance, antibiotic resistance, marker gene, nutritional change, oil modification, fungal resistance, male sterility, alter metabolism, stress tolerance
- alfalfa - herbicide tolerance, antibiotic resistance, marker gene, genetic research, stress resistance
- brown mustard - male sterile, herbicide tolerance, marker gene, modify oil composition, stress tolerance
- lentils - herbicide tolerance
- wheat - herbicide tolerance, fungal resistance, marker gene
- grape vine - stress tolerance, antibiotic tolerance, marker gene
- safflower - herbicide tolerance, pharmaceutical protein
- sugar beet - herbicide tolerance, marker gene
- white clover - pharmaceutical protein, marker gene, stress tolerance, antibiotic resistance
- flax - antibiotic resistance, change oil content, stress tolerance
- tobacco - altered metabolism, marker gene

<u>2000 Field Studies</u>

- tobacco - pharmaceutical production, antibiotic resistance, marker gene, stress tolerance, herbicide tolerance
- potato - fungal resistance, marker gene, insect resistance, virus resistance, antibiotic resistance
- soybean - fungal resistance, antibiotic resistance
- corn - fungal resistance, herbicide tolerance, marker gene, modify oil composition, insect resistance
- canola - insect resistance, antibiotic resistance, herbicide tolerance, marker gene, enhance yield, fungal resistance, oil modification
- brown mustard - male sterility, herbicide tolerance, antibiotic resistance, oil modification, altered metabolism
- sugar beet - herbicide tolerance, antibiotic resistance, marker gene
- grape vine - stress tolerance, antibiotic resistance, marker gene
- lentils - herbicide tolerance
- wheat - herbicide tolerance, marker gene, fungal resistance
- barley - herbicide resistance
- flax - herbicide tolerance, pharmaceutical protein, oil modification
- safflower - herbicide tolerance, pharmaceutical protein
- alfalfa - stress tolerance, marker gene, antibiotic resistance, herbicide tolerance
- white clover - stress tolerance, antibiotic resistance

United States

Population: 290.3 million GDP: $10.5 trillion Government: $2 trillion
Land area: 9.1 million sq. ka.
About half the size of Russia; about three-tenths the size of Africa; about half the size of South America (or slightly larger than Brazil); slightly larger than China; about two and a half times the size of Western Europe
Arable land: 19.3% Crop land: 0.22% Climate: mostly temperate
Crops: wheat, corn, other grains, cotton
Agriculture is 2% of GDP and 2.4% of labor force

James - 42.8 million hectare of U.S. biotech soy, cotton, maize, and canola in 2003/04
U.S. gain 3.8 mha 03, increase soy and maize, decrease canola and cotton

Earlier analysis showed combined market value of four U.S. biotech crops was $27.5 billion in 2003/04.

29.2 million hectare of soybeans planted and 65.8 million metric tons produced, 81% were a biotech variety, estimated market value $13.3 billion

28.8 million hectare of maize planted and 256.9 million metric tons produced, 40% biotech varieties, estimated market value $10.3 billion

4.9 million hectare of cotton planted and 18.3 million bales produced, 73% biotech variety, estimated market value $3.8 billion

400,000 hectare of canola planted and 0.7 million metric tons produced, 73% biotech variety, estimated market value $138 million

AGBIOS database of government regulatory approvals - [for environmental release, food and feed]

<u>Canola Argentine</u>
- Bayer Glufosinate ammonium herbicide tolerance and fertility restored. 2002
- Bayer Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 2002
- Bayer Oxynil herbicide tolerance, including bromoxynil and ioxynil. 1999
- Calgene Modified seed fatty acid content, specifically high laurate levels and myristic acid. 1994
- Monsanto Glyphosate herbicide tolerance. 2003

<u>Chicory</u>
- Bejo Zaden Glufosinate ammonium herbicide tolerance and fertility restored. 1997

<u>Cotton</u>
- Bayer Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 2003
- Calgene Oxynil herbicide tolerance, including bromoxynil and ioxynil. 1994
- Calgene Resistance to lepidopteran insects; oxynil herbicide tolerance, bromoxynil. 1998
- DuPont Sulfonylurea herbicide tolerance, triasulfuron and metsulfuron-methyl. 1996
- Monsanto Glyphosate herbicide tolerance. 1995
- Monsanto Resistance to lepidopteran pests; cotton and pink bollworm, tobacco budworm. 2002

<u>Flax, Linseed</u>
- University of Saskatchewan Sulfonylurea herbicide tolerance, triasulfuron and metsulfuron-methyl. 1998

<u>Maize</u>
- Bayer Glufosinate ammonium herbicide tolerance and male sterility. 1996
- Bayer Resistance to European corn borer (Ostrinia nubilalis); phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 1998
- Bayer Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 1995
- Bayer Glufosinate ammonium herbicide tolerance and male sterility 1999
- DeKalb Phosphinothricin (PPT) herbicide tolerance, glufosinate ammonium. 1996
- DeKalb Resistance to European corn borer (Ostrinia nubilalis); phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 1997
- Monsanto Glyphosate herbicide tolerance. 2003
- Monsanto Resistance to corn root worm (Coleopteran, Diabrotica sp.) 2001
- Monsanto Resistance to European corn borer (Ostrinia nubilalis). 1996
- Monsanto Resistance to European corn borer; glyphosate herbicide tolerance. 1997
- Mycogen Resistance to European corn borer (Ostrinia nubilalis); phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 2001
- Pioneer Resistance to European corn borer; glyphosate herbicide tolerance. 1996
- Pioneer Glufosinate ammonium herbicide tolerance and fertility restored. 1998
- Syngenta Resistance to European corn borer (Ostrinia nubilalis); phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 1996

<u>Melon</u>
- Agritope Delayed ripening. 1996

<u>Papaya</u>
- Cornell University Resistance to viral infection, papaya ringspot virus (PRSV). 1997

<u>Potato</u>
- Monsanto Resistance to Colorado potato beetle (Leptinotarsa decemlineata, Say). 1994
- Monsanto Resistance to Colorado potato beetle; resistance to potato leafroll virus (PLRV). 1998
- Monsanto Resistance to Colorado potato beetle; resistance to potato virus PVY. 1998

<u>Rice</u>
- Aventis Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 1999

<u>Soybean</u>
- Bayer Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 1998
- DuPont Modified seed fatty acid content, specifically high oleic acid expression. 1997
- Monsanto Glyphosate herbicide tolerance. 1994

<u>Squash</u>
- Asgrow-Seminis Resistance to viral infection, cucumber mosaic virus (CMV), watermelon mosaic virus (WMV) 2, zucchini yellow mosaic virus (ZYMV). 1994
- Upjohn-Seminis Resistance to viral infection, watermelon mosaic virus (WMV) 2, zucchini yellow mosaic virus (ZYMV). 1994

Sugar Beet

- Bayer Phosphinothricin (PPT) herbicide tolerance, specifically glufosinate ammonium. 1998
- Monsanto-Novartis Glyphosate herbicide tolerance. 1998

Tobacco

- Vector Nicotine reduced. 2002

Tomato

- Agritope Delayed ripening. 1996
- Calgene Delayed softening 1992.
- DNA Plant Tech Increased shelf-life (delayed ripening). 1994
- Monsanto Delayed ripening. 1998
- Monsanto Resistance to lepidopteran pests; cotton and pink bollworm, tobacco budworm. 1998
- Zeneca Delayed softening through suppression of polygalacturonase (PG) enzyme activity. 1994

USDA APHIS dataset of biotech field release permits

Crop and Trait - developments since June 2003, end date for first CBI study

- corn - pharmaceutical proteins, herbicide tolerance, insect resistance, marker gene, drought tolerance, altered oil profile, lysine level, increase yield, increase germination, fungal resistance
- tobacco - reduced nicotine, protein production, virus (TMV and TSWV) resistance, herbicide tolerance, fungal (armillaria) resistance
- alfalfa - herbicide tolerance, increase secondary metabolite
- soybean - Lepidoptera resistance, herbicide tolerance, virus (BPMV) resistance, Hygromycin tolerant, altered lipid profile, fungal (Sclerotinia) resistance, increase yield
- tomato - altered metabolism, virus (PVY) resistance, insect resistance
- cotton - stress tolerance, fiber quality, insect resistance, herbicide tolerance
- potato - fungal (late blight and Phytophthora) resistance, virus (PVY, PVA,PLRV) resistance, reduce steroidal glycoalkaloids, reduced bruising, insect resistance
- peanut - fungal (Sclerotina) resistance, virus (TSWV) resistance
- banana - fungal resistance
- barley - protein production fungal resistance
- rice - increase yield, herbicide tolerance, marker gene, fungal resistance, male sterility
- sugar beet - herbicide tolerance
- sugarcane - herbicide resistance, virus (SCYLV) resistance
- onion - herbicide tolerance
- cucumber - salt tolerance
- apple - brown spot resistant
- lettuce - fungal (Sclerotinia) resistance
- papaya - virus (PRSV) resistance, bacterial (bunchy top) resistance
- pea - herbicide tolerance
- plum - fungal (Armillaria) resistance
- safflower - unspecified objective
- watermelon - parthenocarpy
- wheat - herbicide tolerant, fungal (fusarium) resistant, yield increase, drought tolerant
- canola - seed composition, oil profile, marker gene, male sterility

REFERENCES

[1] These value figures are based on end-of-season planting data for the U.S. in crop year 2003-2004. See Runge, C. Ford and Barry Ryan, 2003. "The Economic Status and Performance of Plant Biotechnology in 2003: Adoption, Research and Development in the United States." Washington, Center for Biotechnology Information. http://www.apec.umn.edu/faculty/frunge/plantbiotech.pdf

[2] James, C. 2003. Preview: Global Status of Commercial Transgenic Crops: 2003. *ISAAA Briefs* No. 30. ISAAA: Ithaca, NY.

[3] Calculations are based on area planted by country; estimated adoption rate; and world crop prices in 2003. Area planted figures are based on U.S. Department of Agriculture Statistics, cross-checked against Food and Agriculture Organization estimates. Adoption rates are based on James (op. cit. note 2) and industry reports. World crop prices are based on data from the Food and Agricultural Policy Research Institute (FAPRI, 2004) and USDA. Note that the growing season starts in the northern hemisphere in spring, with harvest in fall. That same fall, southern hemisphere farmers plant crops to be harvested in spring. The result is that global production data is generated every six months, which is gathered and documented about six months later. For example, final 2003 U.S. crop production and price data were released by USDA in June, 2004. James (2003, op. cit. note 2) calculates the global value of transgenic crops somewhat differently, by taking the sales price of seeds and adding any associated technology fees. Using this method, he concludes that in 2003, the global market value of biotech seeds and technology fees was $4.5 – 4.75 billion. This is equivalent to gross margins, whereas our estimate captures the market value of gross sales.

[4] James, 2003. Op cit, note 2.

[5] The status and performance of plant biotechnology in the United States was the subject of a 2003 assessment. See Runge, C. Ford and Barry Ryan. Op. cit. note 1.

[7] AGBIOS. GM database. 2004. http://www.agbios.com/main.php

[8] Food and Agriculture Organization (FAO), United Nations. 2004. http://www.fao.org/biotech/inventory_admin/dep/default.asp

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[11] U.N. Industrial Development Organization. 2003. BINAS Online. http://binas.unido.org/binas/regs.php

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[13] U.S. Central Intelligence Agency. *World Factbook*. January 2003. http://www.cia.gov/cia/publications/factbook/index.html

[14] "A National Biotechnology Strategy for South Africa." June 2001. http://www.st.gov.za/programmes/biodiversity/biotechstrategy.pdf. Also see: Thomson, J.A. "The Status of Plant Biotechnology in Africa." AgBioForum. 2004. 7(1&2):9-12.

[15] "Kenya prepares to grow genetically modified maize." *The Sunday Standard*. June 11, 2004.

[16] "Biotechnology Research and Policy Activities of ABSP in Kenya, 1991-2002." Agricultural Biotechnology Support Project, Michigan State University, 2002. www.iia.msu.edu/absp/kenya

[17] Thomson, J.A. op cit note 14.

[18] "Future of Plant Science in Zimbabwe." *Trends in Plant Science* 6(October, 2001):10.

[19] See "Future of Plant Science in Zimbabwe." *TRENDS in Plant Science* 6(10)(October, 2001) and the *WISARD Directory* (op cit, note 10).

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