Genetically Engineered Crops in the U.S.: Extent of Adoption and Impacts

Jorge Fernandez-Cornejo
Economic Research Service,
U.S. Department of Agriculture

Presented in the Workshop "Measuring Biotechnology Outputs and Impacts" at the OECD in Paris, France. December 11, 2006

Outline

- Objective
- GE Crops Available and in Development
- The Extent of Adoption
- The Survey Data
- Adoption, Net Returns, and Household Income
- Market Benefits
- Adoption, Pesticide Use, and Conservation Tillage
- Conclusions

Objective

To summarize the experience of the first 10 years of adoption of genetically engineered (GE) crops by U.S. farmers.

Biotech crops currently available and in development in the U.S.

	Input traits				Output traits	
Crop	Herbicide tolerance	Insect resistance	Viral/fungal resistance	Agronomic properties[1]	Product quality[2]	Nutraceuticals; pharmaceuticals; industrial[3]
Corn	C	C	D	D	D	D
Soybeans	C	D		D	D	
Cotton	C	C		D	D	
Potatoes		W	D	D	D	D
Wheat	C		D			
Other field crops	C D	D	D	D	D	D
Tomato, squash, melon			D	D	W D	D
Other vegetables	D				D	
Papaya			C			
Fruit trees			D		D	
Other trees				D	D	
Flowers					D	

C = Currently available; D = In various stages of development and testing. W = Withdrawn from the market.
Sources: Virginia Polytechnic Institute and State University; USDA, APHIS; Colorado State; Shoemaker et al.; Pew.

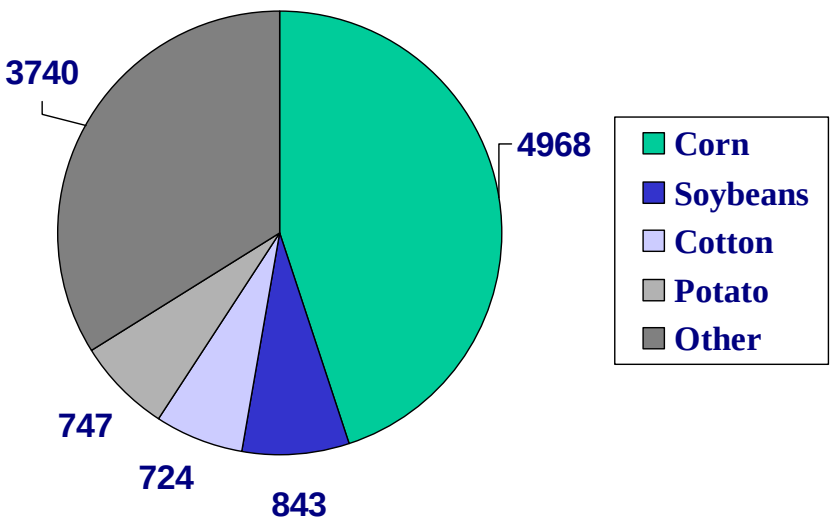
1. Resistance to cold, drought, frost, salinity; more efficient use of nitrogen; increased yield.

2 Increased protein, carbohydrate, fatty acid, micronutrient, oil; modified starch content; enhanced flavor, etc

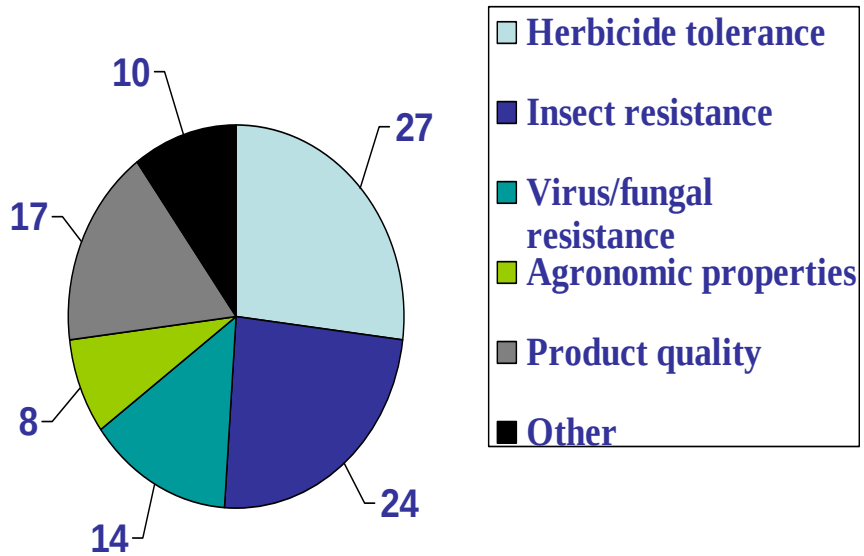
3. Increased vitamin, iron, beta-carotene content; antibodies, vaccines;

GE crops developed and tested as measured by the total number of permits for field testing approved by USDA's APHIS, 1987-2004

By Crop (number)



By phenotype category (Percent)



Source: Virginia Polytechnic Institute and State University, 2005.

Bt Crops

- Bt crops carry the gene from the soil bacterium *Bacilus Thuringiensis.*

- Crops containing the Bt gene by certain insects are able to produce proteins that are toxic when ingested:

  - Bt corn protects against the European corn borer (and/or the corn rootworm.

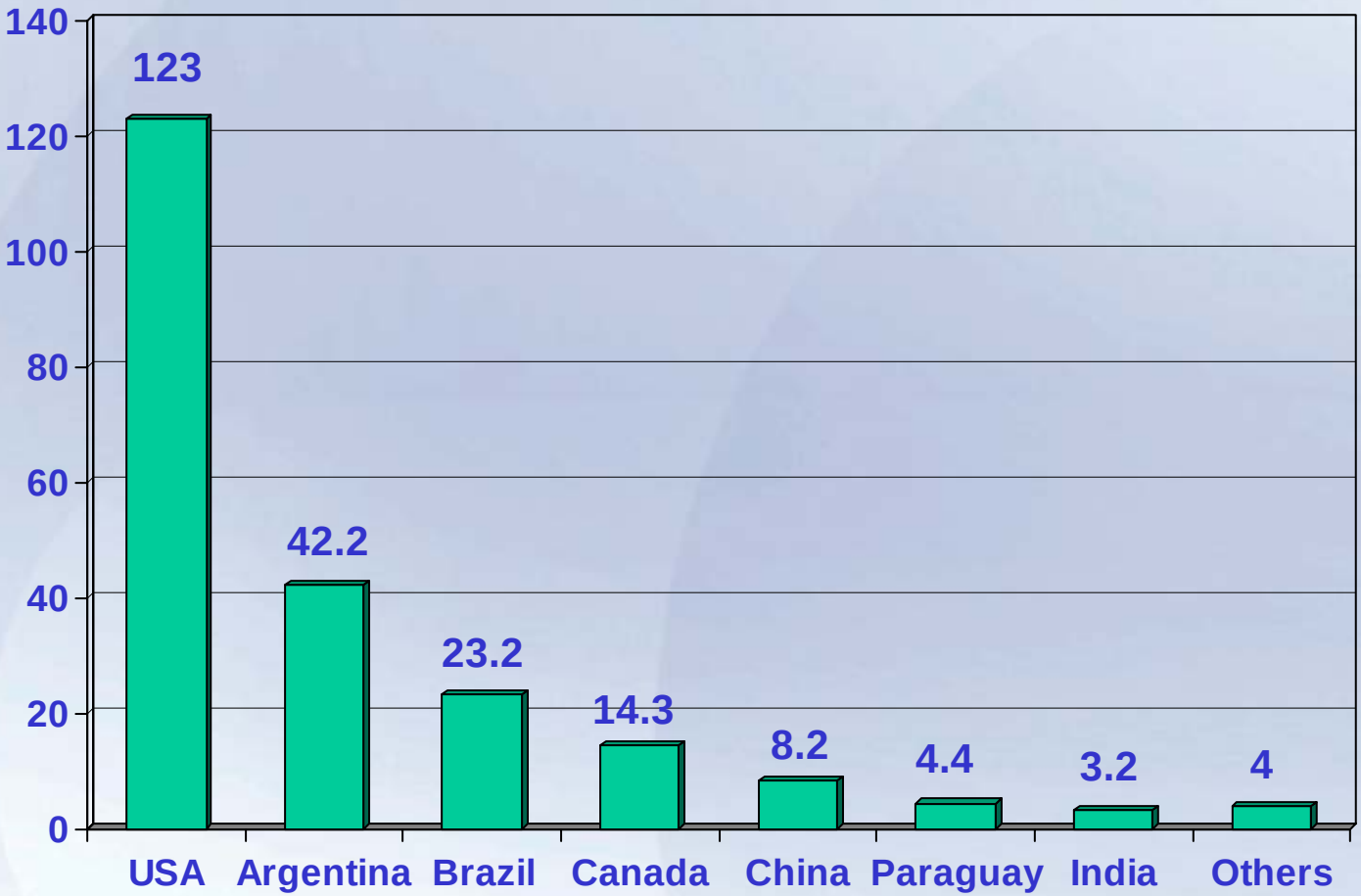
  - Bt cotton protects against the tobacco budworm, the bollworm, and the pink bollworm.

Herbicide Tolerant Crops

- Herbicide-tolerant (HT) crops contain traits that allow them to survive certain herbicides that previously would have destroyed the crop along with the targeted weeds, allowing farmers to use more effective herbicides.

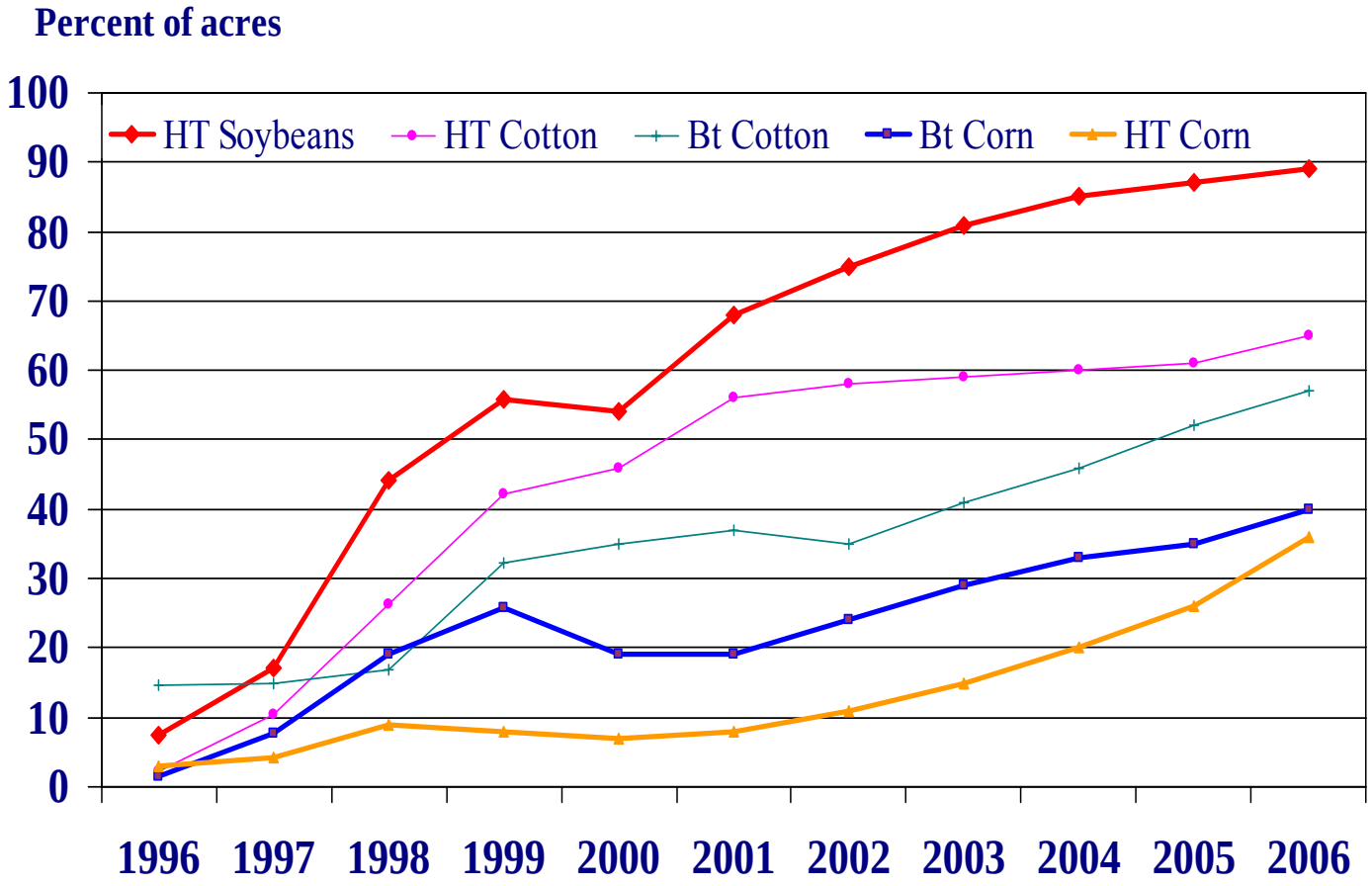
World Adoption of GE Crops

Area planted in million acres, 2005



Source for US: NASS data; source for other countries: ISAAA

Adoption of genetically engineered crops has grown steadily in the U.S.



Notes: 1. Data for each crop category include varieties with both HT and Bt (stacked) traits
2. Bt to control corn rootworm introduced commercially in 2003.

Source: USDA/NASS data

Why are U.S. farmers adopting GE crops?

According to USDA surveys, the main reasons stated by U.S. farmers for adopting GE crops are:

1. To increase yields
2. To save management time and make other practices easier.
3. To decrease pesticide input costs

Farm Level Effects of Adoption

Comparison of means between adopters and nonadopters ignores:

♦ Other differences between adopters and nonadopters that influence yields and pesticide use like:

- Input and output prices
- Weather/Infestation levels
- Farm size
- Other production practices

♦ Simultaneity and self-selection

Modeling Adoption Impacts - Theoretical Issues

1. Farmers' adoption and pesticide use decisions may be simultaneous.

2. Farmers are not assigned randomly to the two groups (adopters and nonadopters) but they make the adoption choices themselves. Therefore, adopters and nonadopters may be systematically different. Differences may manifest themselves in farm performance and could be confounded with differences due to adoption. This self-selectivity may bias the results, unless corrected.

A Theoretical Modeling Framework

To account for simultaneity and self-selectivity we use a two-stage econometric model:

- The first stage consists of the *decision model* --for the adoption of GE crops as well as other practices. The adoption decision model is estimated by probit analysis.

- The second stage is the *impact model* that provides estimates of the impact of using GE crops on pesticide use, yields and farm profits after controlling for other factors.

The Data Used for the Impact Studies

- U.S. farm-level data are obtained from the Agricultural Resource Management Survey (ARMS) developed by the Economic Research Service (ERS) and the National Agricultural Statistics Service (NASS) of USDA and carried out by NASS.

- ARMS is the major source of information on production practices, acreage planted and harvested, resource use, and financial conditions among U.S. farms, as well as the characteristics and economic well-being of farm households. ARMS is carried out annually at the national level and is representative of U.S. diverse farm and farm households.

- Most biotech studies are based on 1997-2001 survey data

Data Products from the ARMS Program

- Phase 1:Screening sample

-Phase 2: Field level sample includes:

- input use
- production practices
- costs and returns

-Phase 3: Farm level sample includes:

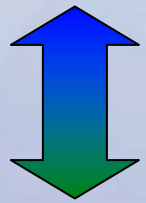
- income and expenses
- assets and debt
- business and operator characteristics
- farm household characteristics

-Link between phase 2 and phase 3 data

Complex Design of the ARMS

Phase II provides in-depth perspective chemical use, production practices, and input costs

Production Practices and Costs Report (commodity)



Phase II & III linked so that production practice data are combined with economic data

Costs and Returns Report

Enterprise Specific Reports

Phase III versions combined for a larger sample to support income & structural analyses for both businesses and households

Association of yield and net returns with adoption of GE crops

	Yield	Net returns
HT cotton	↑	↑
Bt cotton	↑	↑
HT corn	Small↑	↑
Bt corn	↑	**Depends on infestation1/**
HT soybeans	Small↑	ns

Notes:
ns: Not significant
1/ In low infestation years, some farms may have negative returns if Bt corn is used on fields where the value of protection against the ECB is lower than the Bt seed premium. (This "over-adoption" may be due mainly to poor forecast of ECB infestation levels).

HT soybean adoption and net returns

- Despite the rapid adoption of HT soybeans by U.S. farmers, there was no significant difference between the net returns to using HT versus conventional soybeans.

- This result suggests that other factors may be driving adoption, such as the simplicity and flexibility (less management time) of the HT program.

Adoption HT soybeans and off-farm income

- An important alternative use of time is off-farm work by farmers and their spouses (off-farm income is now higher than net income earned from farming).
- Recent ERS research using 2000 U.S. data shows that adoption of HT soybeans is associated with a significantly higher off-farm household income as well as total farm household income.
- This result suggests that farmers who adopt HT soybeans save management time, allowing them to obtain a higher income from off-farm activities.

Market Effects of GE Crop Adoption

Market effects of GE crop adoption – Methodology

(1) Estimate the technology-induced supply shift for each commodity-producing region using data on adoption rates, crop yields, and savings in pest control costs net of technology fees and seed premiums;

(2) Calculate the impacts of the new technologies on world and regional prices;

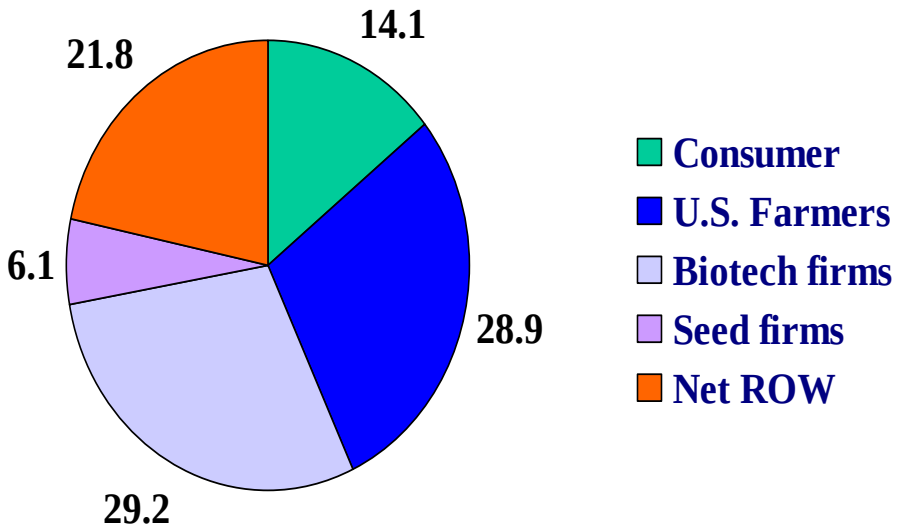
(3) Estimate changes in producer and consumer surpluses in the United States and ROW are then estimated.

(4) Finally, estimate monopoly profits accruing to the biotechnology developers and seed firms. Profits are estimated based on data on adoption rates, technology fees, and seed premiums.

Market effects of GE crop adoption: Results

- Factors influencing benefits are crop yields, prices, payments to technology providers and seed firms, other costs, and the effect of adoption on world prices.
- Benefits range: $200 million to $300 million in 1997.
- The market benefits and their distribution among farmers, biotech/seed firms, and consumers depend on the crop, the technology, and the year.

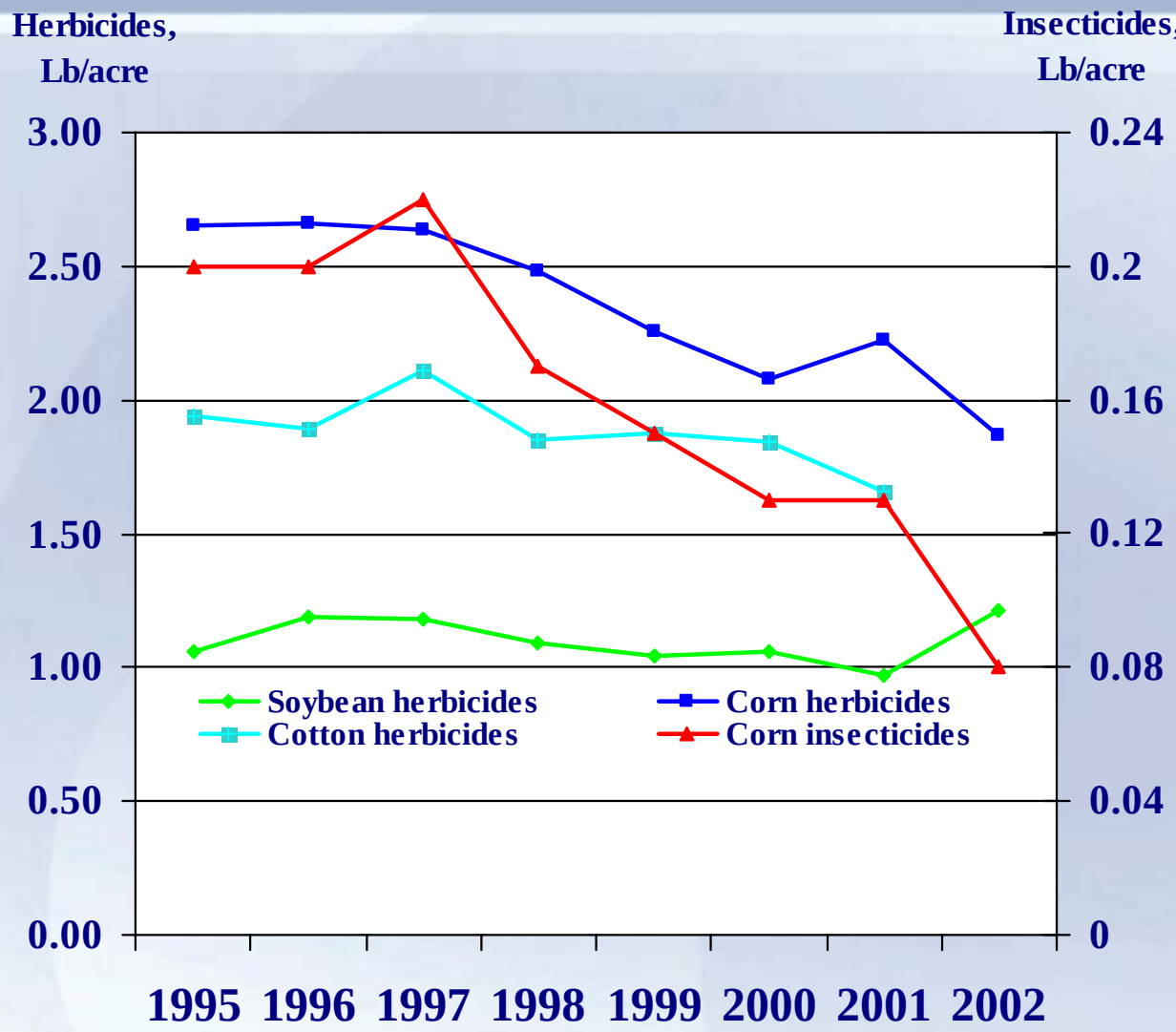
Stakeholders' shares of the estimated total world benefit from adopting Bt cotton, 1997



Source: ERS estimates (Price et al., 2003)

Adoption, pesticide use, and conservation tillage: A summary

Pesticide use in major field crops trended downwards



Source: USDA/NASS surveys

Controlling for other factors, lower pesticide use was associated with adoption of GE crops:

- In terms of pesticide acre-treatments: Reduction of 19.1 million, a 6.2 percent decrease (1997/98 data).
- In terms of total amount of pesticide active ingredients: about 2.5 million pounds.
- Adoption of HT soybeans was associated with a slight increase in herbicide use, but it allowed farmers to use more benign herbicides (glyphosate has lower toxicity and persistence than the herbicides that it replaces).

Pesticide Toxicity and Persistence

- Adoption of herbicide-tolerant soybeans allowed farmers to use more benign herbicides (glyphosate).

Glyphosate:

- Has low *toxicity* to mammals, birds, and fish (less than 1/3 of that of the herbicides that it replaces).
- Binds to the soil rapidly, preventing leaching.
- Is biodegraded by soil bacteria (*persistence* is 1/2 that of the herbicides that it replaces).

Effects of genetically engineered crops on pesticide use - Summary of primary studies

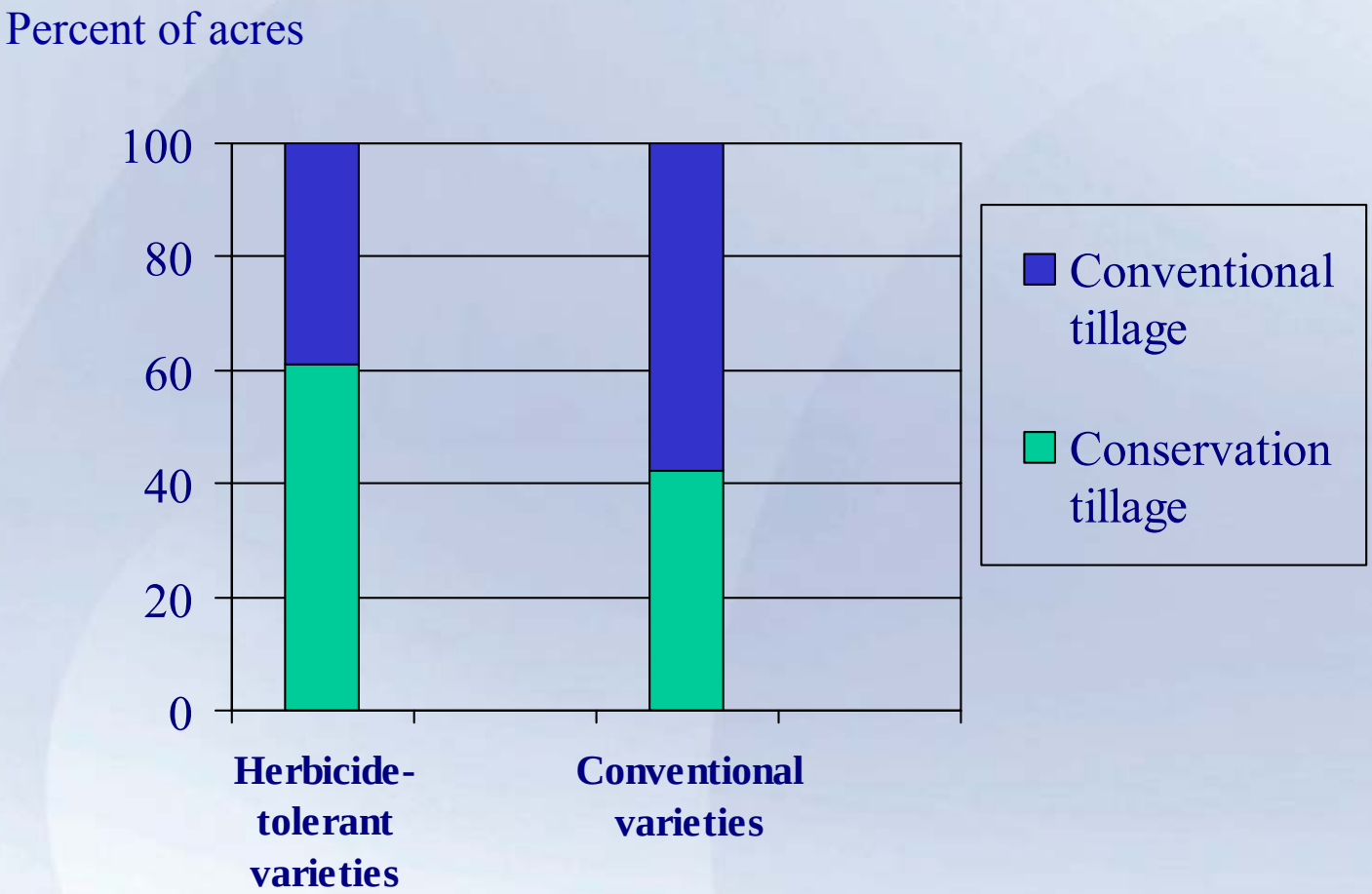
Crop/Researchers Date of publication	Data source	Effect on Pesticide use
Herbicide-tolerant soybeans		
Roberts et al., 1998	Experiments	Decrease
Marra et al., 1998	Survey	Decrease
Fernandez-Cornejo et al., 2002	Survey	Small incr.
Herbicide-tolerant cotton		
Culpepper and York, 1998	Experiments	Decrease
Fernandez-Cornejo et al., 2000	Survey	Same
Herbicide-tolerant corn		
Fernandez-Cornejo and Klotz-Ingram, 1998	Survey	Decrease
Bt cotton		
Stark, 1997	Survey	Decrease
Marra et al., 1998	Survey	Decrease
Fernandez-Cornejo et al., 2000	Survey	Decrease
Bt corn		
Rice and Pilcher, 1998	Survey	Decrease
Marra et al., 1998	Survey	Decrease
Pilcher et al., 2002	Survey	Decrease
Fernandez-Cornejo & Li, 2005	Survey	Decrease

Conservation Tillage

- Conservation tillage (CT) includes any tillage that leaves at least 30 % of the soil surface covered with crop residue). CT reduces soil erosion by wind and water, increases water retention, and reduces soil degradation and water and chemical runoff. However, weed control is a major concern among farmers adopting CT.

- Farmers using CT are more likely to adopt herbicide-tolerant crops.

Adoption of conservation tillage is associated with adoption of herbicide-tolerant crops.



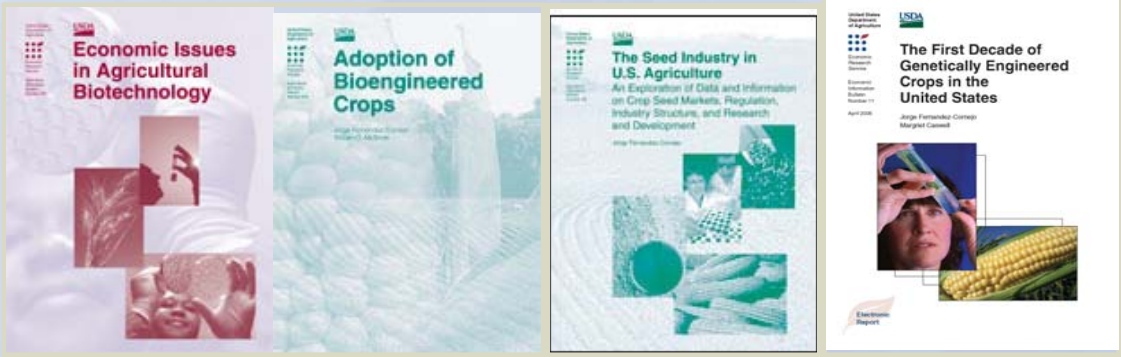
Source: ARMS data

Conclusions

- The adoption of GE crops in the U.S. has been rapid since these crops first became available to U.S. farmers in 1996. HT soybeans reached close to 90 percent adoption after 10 years.
- In general there were tangible benefits to farmers adopting GE crops, but not all are captured in traditional measures of profits.
- The adoption of GE crops is associated with a reduction in aggregate pesticide use. In addition, the pesticides used are more environmentally benign
- Adoption of conservation tillage is associated with adoption of herbicide-tolerant crops. But direction of causality not clear.

Thank you!

For more information:



http://www.ers.usda.gov/publications/aib762/
http://www.ers.usda.gov/publications/aib786/
http://www.ers.usda.gov/publications/aer810/
http://www.ers.usda.gov/publications/tb1906/tb1906.pdf
http://www.ers.usda.gov/publications/EIB11/

Data:

1. ARMS: http://www.ers.usda.gov/data/arms/

2, Other adoption data: http://www.ers.usda.gov/Data/BiotechCrops/