Current status of GE crops worldwide

a. What crops have been commercialized?
b. What are the potential and current positive and negative impacts (benefits/risks)

Cholani Weebadde
Michigan State University

Global food production – facing challenges

- **Challenge:** By 2050 we need to double food production to feed the projected 9.2 billion people using less resources (fossil fuel, water & nitrogen) and alleviate poverty, hunger & malnutrition (7 billion people in 2011; just 12 years after 6 billion)
- **How:** Need to increase crop productivity by integrating best of conventional crop technology & best practices of crop biotechnology applications including novel traits

High productivity paths to Agriculture

- Green revolution and "industrial" farming
  - Traditional farming – Pre 1980s (where we were)
    - Excessive use of water, fertilizer, pesticides, diesel fuel and excessive tilling of soil
  - Precision farming – Post 1980s (where we are…)
    - New irrigation technologies, more precise use of fertilizer, controlled use of pesticides, reduced tillage to save diesel fuel
- Biotech crops fit into Precision farming: Seeds with novel traits to make crops better adapted to biotic and abiotic stresses

Bt Corn protect against corn borer damage

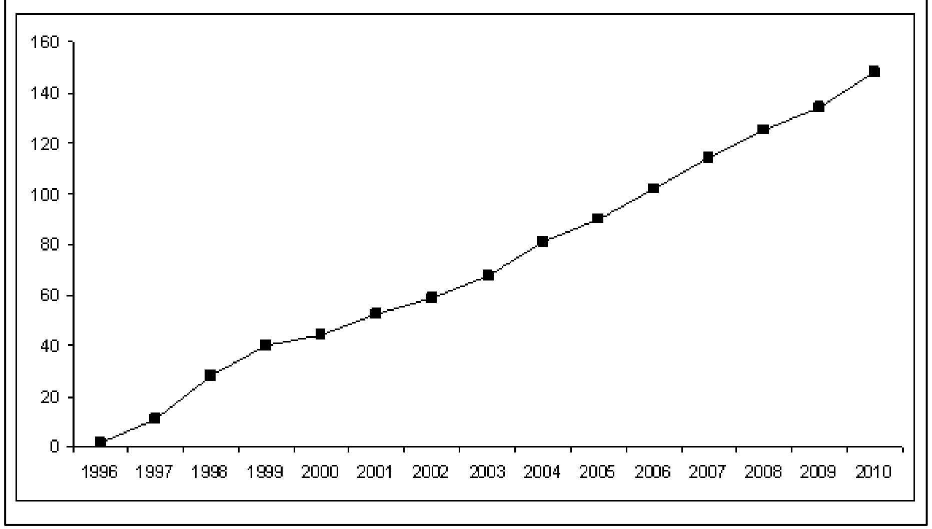
Source: Robert Paarlberg

Current Status of GE crops

- **2010 REPORT FROM EU COMMISSION DIRECTORATE-GENERAL FOR RESEARCH**
  - *"The main conclusion to be drawn from the efforts of more than 130 research projects, covering a period of more than 25 years of research, and involving more than 500 independent research groups, is that biotechnology, and in particular GMOs, are not per se more risky than, for example, conventional plant breeding technologies."*

A record 94-fold increase in hectarage of GE crops between 1996 (1.7 million) and 2011 (160 million), makes biotech crops the fastest adopted crop technology in the history of modern agriculture

Figure 1: Global Area of Biotech Crops, 1996 to 2010 (Million Hectares)
Source: Clive James, 2010.



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

Source: Clive James, 2011.

16 Years after commercialization of Biotech crops…

2011 (2010/2009)

160 (148/134) million hectares

43% (45%/45%) in the US

50% (48%/46%) in developing countries

16.7 (14.4/14) million farmers (over 90% from small, resource poor farmers)

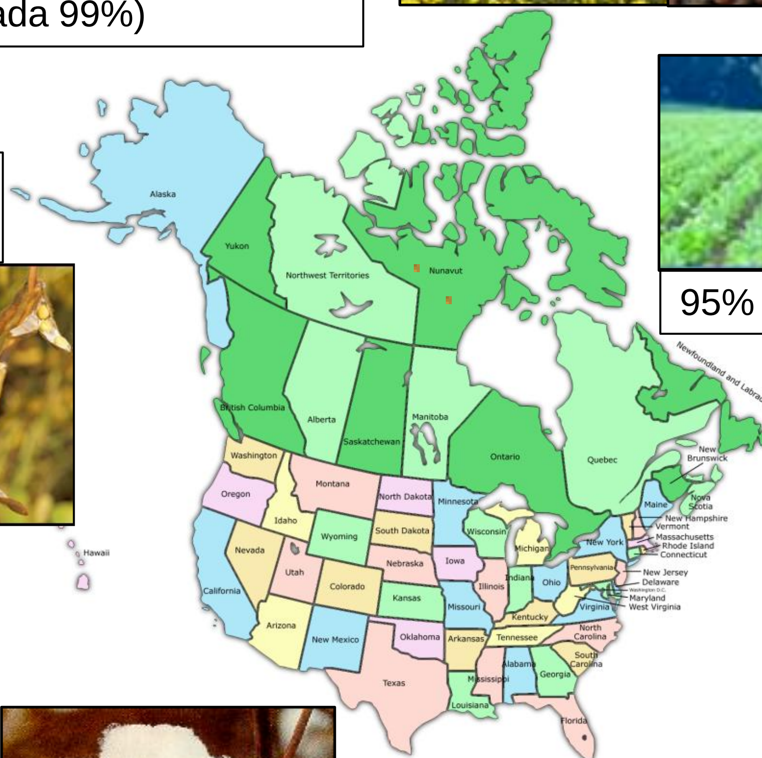
29 (29/25) countries (19 Developing and 10 industrial)

Source: Clive James, 2011

GE crops in North America

80% - 85% US **maize**
Of this, 75% double/triple stacked IR and HT (US & Canada 99%)

86% - 93% HT Canola in Canada (US 95% & Canada 83%)



95% HT Sugar beet in US and Canada

HT **Soybean** (US 92% & Canada 73%)

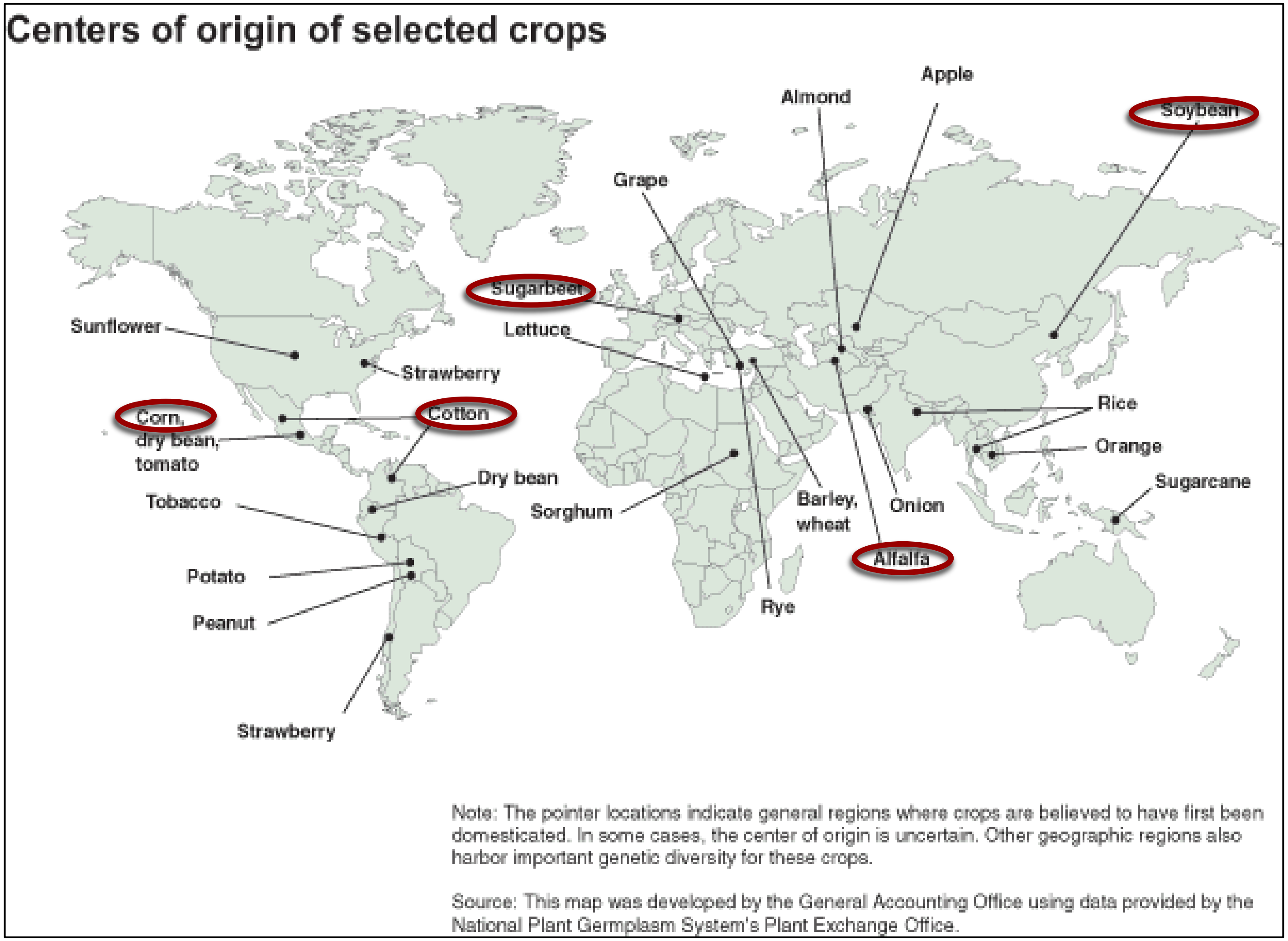
VR Squash

VR Papaya – saves the industry in the US

90% US IR **Cotton**
Of this, 75% double stacked

HT Alfalfa

Crop/Trait/Location considerations



US and Canada are not the crop origins for the 3 major GE crops that are commercialized. For others, situation varies according to species.

Canola (**Can**adian **o**il; **l**ow **a**cid) is produced from *B. napus. Multiple origins – mainly in Europe. Recent introduction to Canada and US. Concern: readily hybridize with other weedy Brassica species*

Yellow Squash –*American origin (not a known weed; less concerned)*

Papaya – *Exact origin not known – believed to be a native of tropical America perhaps Southern Mexico and neighboring central America (not a known weed; less concerned)*

GE crops in South America

Mexico, Costa Rica, Colombia, Brazil 20%, Argentina 87%

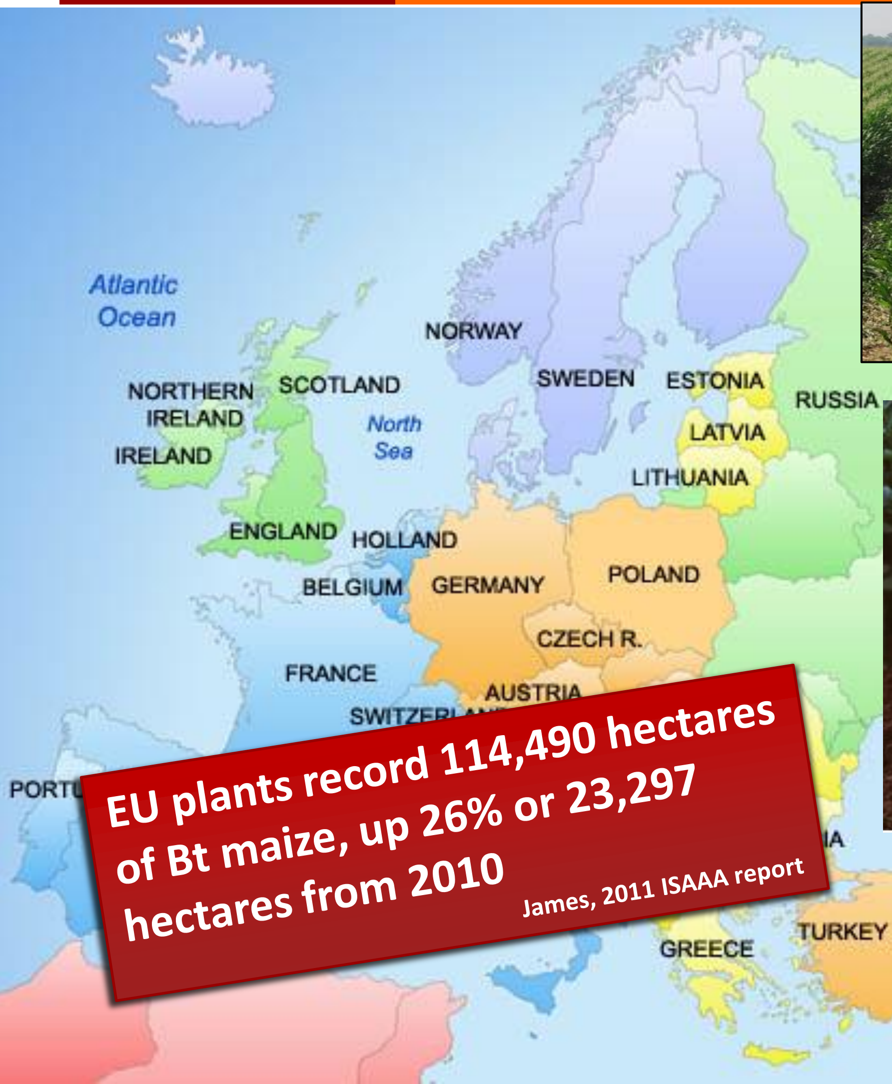
Chile, Honduras, Brazil 11%, Uruguay 62%, Argentina 85%

Chile

Mexico, Costa Rica, Bolivia, Chile, Brazil 62%, Paraguay 90%, Uruguay 99%, Argentina 99%

10 countries in South America grew Biotech crops in 2011

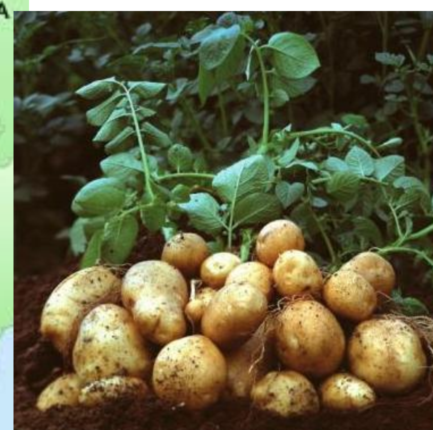
GE crops in Europe



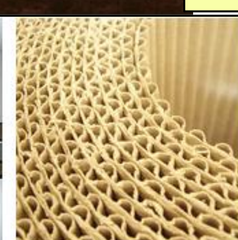
EU plants record 114,490 hectares of Bt maize, up 26% or 23,297 hectares from 2010

James, 2011 ISAAA report

Spain, Czech Republic, Portugal, Romania, Poland, Slovakia



Amflora - a starch potato tailor-made for industrial use that produces pure amylopectin. The European Commission approved Amflora for <u>commercial application only</u> in Europe.



Sweeden, Germany, Czech Republic

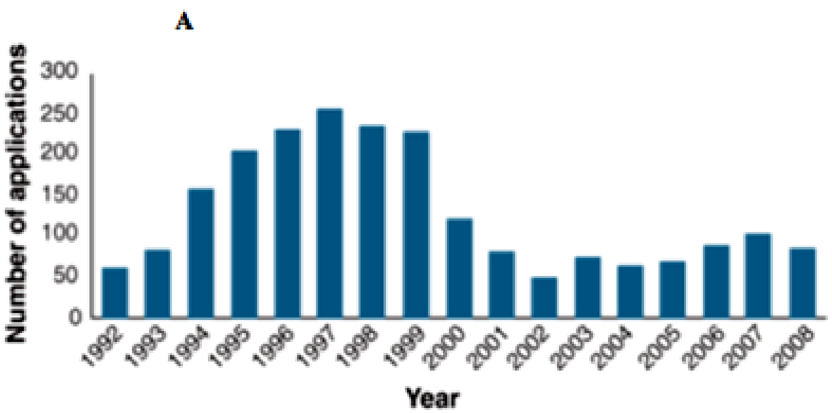
Number of notifications for Confined Field Trial (CFT) applicatons in Europe

Country / Year	1992-2000	2001-2008	Total (1992-2008)
Austria	3	-	**3**
Belgium	116	19	**135**
Czech Republic	2	13	**15**
Denmark	41	10	**51**
Finland	24	3	**27**
France	502	96	**598**
Germany	127	69	**196**
Greece	19	-	**19**
Hungary	-	29	**29**
Iceland	-	1	**1**
Ireland	4	2	**6**
Italy	275	20	**295**
Lithuania	-	2	**2**
Netherlands	118	61	**179**
Poland	-	10	**10**
Portugal	12	13	**25**
Romania	-	23	**23**
Slovak Republic	-	5	**5**
Spain	182	255	**437**
Sweden	63	39	**102**
United Kingdom	218	30	**248**
EU Total	**1706**	**700**	**2406**[1]
USA	6111	7609	**13702**[2]
Canada	-	1707[3]	

- We think Europe is anti-GE right?
- There are a number of countries that have or are conducting Confined Field Trials for GE crops in the EU… **Why?**
- If they need the technology one day, they wouldn't have to start from scratch and see too many countries ahead of them. Science moves forward

(Source for European data: 2001-2008, http://bgmo.jrc.ec.europa.eu/deliberate/dbcountries.asp and 1992-**2008 http://www.gmo-compass.org/eng/agri_biotechnology/field_trials/229.summary_gmo_field_trials_eu_member_states.html ; USA data, http://www.isb.vt.edu/cfdocs/fieldtests1.cfm , and Canadian data, http://www.inspection.gc.ca/english/plaveg/bio/confine.shtml#sum)**

Confined Field Trials approved: EU vs. North America (US and Canada)



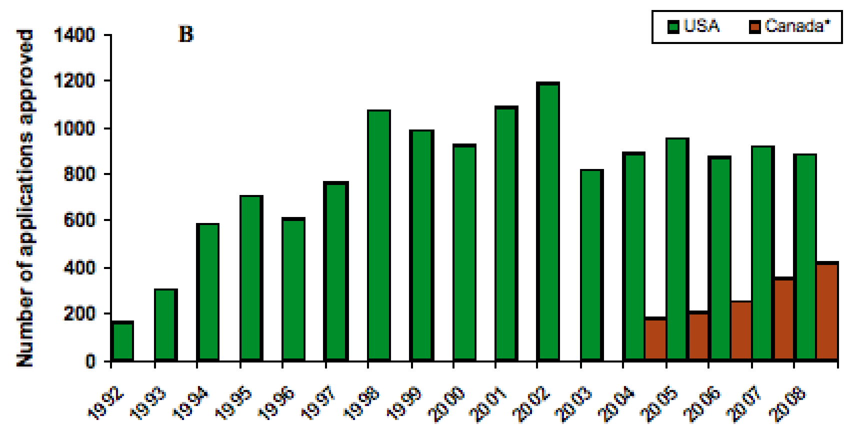


Figure 1. Number of applications approved for confined field trials (CFTs) of genetically modified crops: A) in European Union and B) North America. *CFTs of plants with novel traits (PNT) planted in Canada from 2004 to 2008; data for 1992 to 2003 is not provided. The decline in number of CFTs in EU starting in 2000 was due to "mad cow" livestock infection, and reports of food product contamination by Starlink corn.

http://www.nepadbiosafety.net/abne/wp-content/uploads/2010/10/diagram.pdf

What's happening in Europe?

- **"A change of heart in Europe – a strongly-worded open letter from 41 Swedish scientists in support of biotech/GM crops – a petition endorsed by UK scientists; Member of African Biotechnology Stakeholders Forum criticizes EU of *"hypocrisy and arrogance" in relation to GM crops"***

- "In October 2011, 41 leading Swedish biological scientists, in a strongly-worded open letter to politicians and environmentalists, spoke-out about the need to revise European legislation to allow society to benefit from GM crops using science-based assessments of the technology. A contingent of scientists from the United Kingdom endorsed the Swedish petition."

Read more….. ISAAA 2011 report

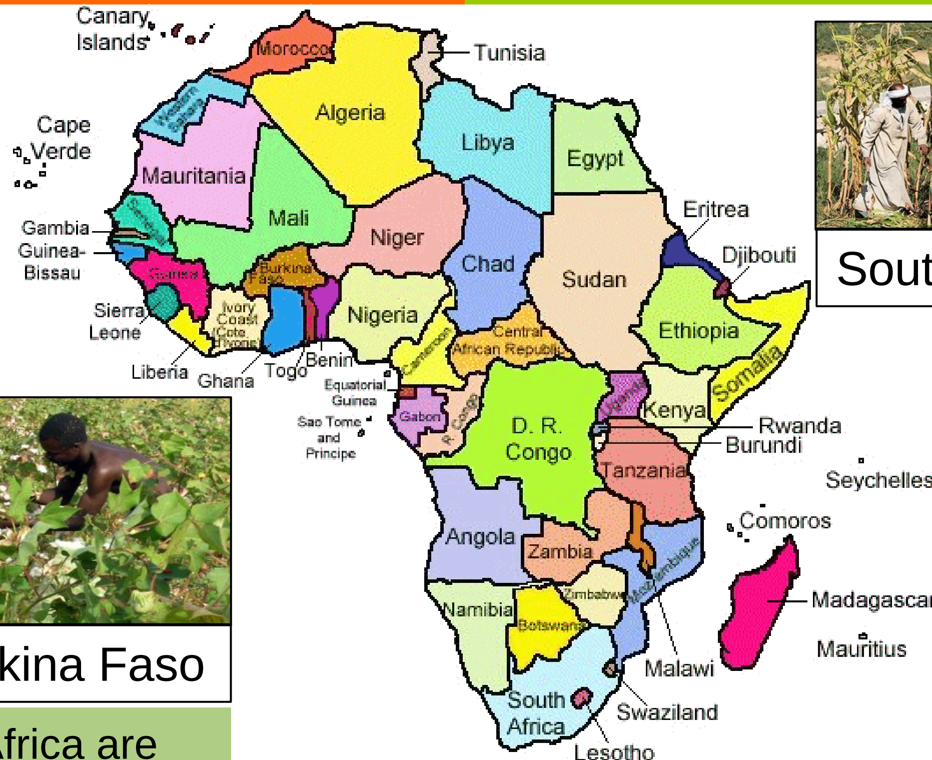
Africa speaks out in frustration….

- **Dr. Felix M'mboyi, A Kenyan national and a member of the African Biotechnology Stakeholders Forum, accused the European Union of *"hypocrisy and arrogance"*** *and called for "development bodies within Europe to let African farmers make full use of GM crops to boost yields and feed a world population expected to reach 7 billion by the end of the year."*

- *Dr. M'mboyi, stated that "**The affluent west has the luxury of choice in the type of technology they use to grow food crops**, yet their influence and sensitivities are denying many in the developing world access to such technologies which could lead to a more plentiful supply of food. This kind of hypocrisy and arrogance comes with the luxury of a full stomach."*

Read more….. ISAAA 2011 report

GE crops in Africa



South Africa 69%, Egypt

South Africa 84%, Burkina Faso

90% of Cotton in South Africa are GE with 75% of them with double stacked traits

South Africa 80%

http://www.nepadbiosafety.net/

NEPAD - African Biosafety Network of Expertise (ABNE) Headquarters in Burkina Faso

GE crops in Asia



Cotton

India, Pakistan, Myanmar

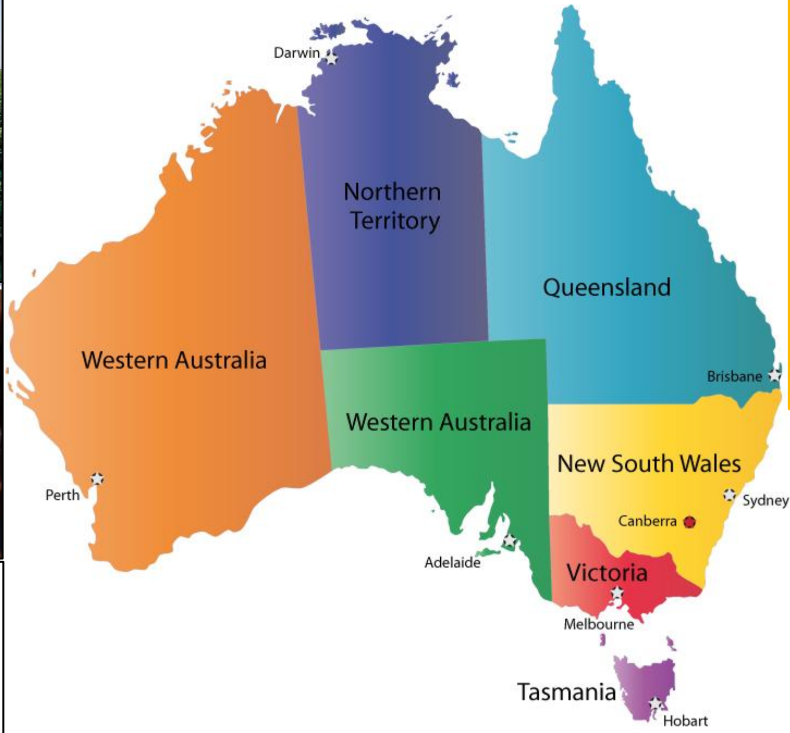
Japan


The Philippines

China 64% Cotton

GE crops in Australia

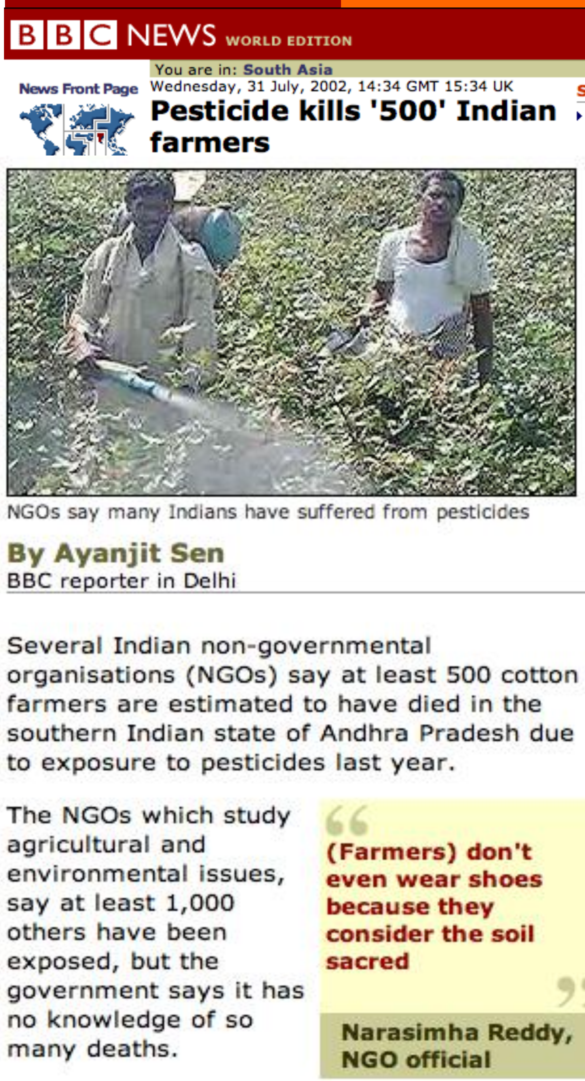
Approx. 90% cotton in Australia are GE with 88% of it representing double stacked traits



"Australia planted its largest ever hectarage of cotton of which 99.5% was biotech"

James, 2011 ISAAA report

Reasons for wider adoption of GE crops


BBC NEWS WORLD EDITION

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News Front Page

Wednesday, 31 July, 2002, 14:34 GMT 15:34 UK

Pesticide kills '500' Indian farmers

NGOs say many Indians have suffered from pesticides

By Ayanjit Sen
BBC reporter in Delhi

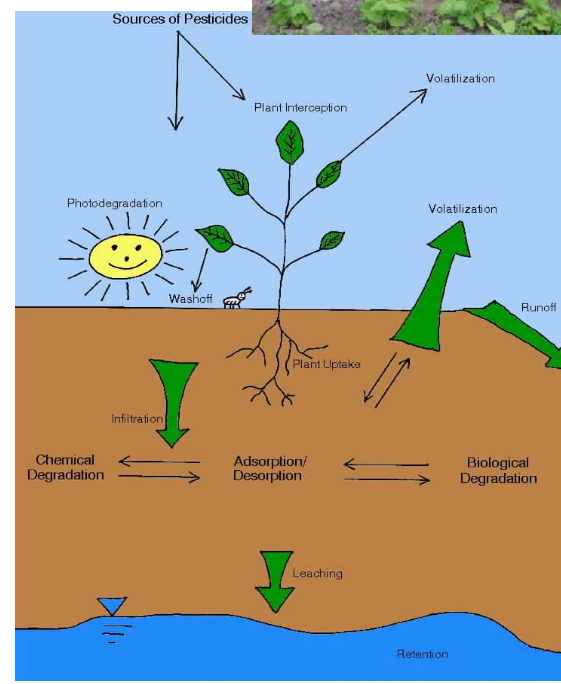
Several Indian non-governmental organisations (NGOs) say at least 500 cotton farmers are estimated to have died in the southern Indian state of Andhra Pradesh due to exposure to pesticides last year.

The NGOs which study agricultural and environmental issues, say at least 1,000 others have been exposed, but the government says it has no knowledge of so many deaths.

"(Farmers) don't even wear shoes because they consider the soil sacred"

Narasimha Reddy, NGO official

- Generally, GE crops have had fewer adverse effects on the environment than non-GE crops produced conventionally.
- Use of toxic pesticides is lower in GE fields than non-GE, non-organic fields (less toxic to non-target organisms or persists less in soil and waterways).



Why farmers like GE crops - USA

If you consider insect and herbicide tolerant crops;

- Protect against crop losses from diseases and weeds
- Higher returns per hectare
- Reduced pesticide use and **costs**
- Ease of production with large farms (less time spent on the tractor spraying pesticides or cultivating fields)

Why farmers like Bt as an insecticide - US

Mammalian Toxicity, rats

Comparison of LD 50 value for insecticides

cyhalothrin 79-144 mg/kg

carbosulphan 90-250 mg/kg

cypermethrin 250-2000 mg/kg

Bt kurstaki > 5,000-24,000 mg/kg

When comparing Bt to other insecticides, Bt is sometimes referred to as **"practically non-toxic"** – Why?

-Human gut has low pH

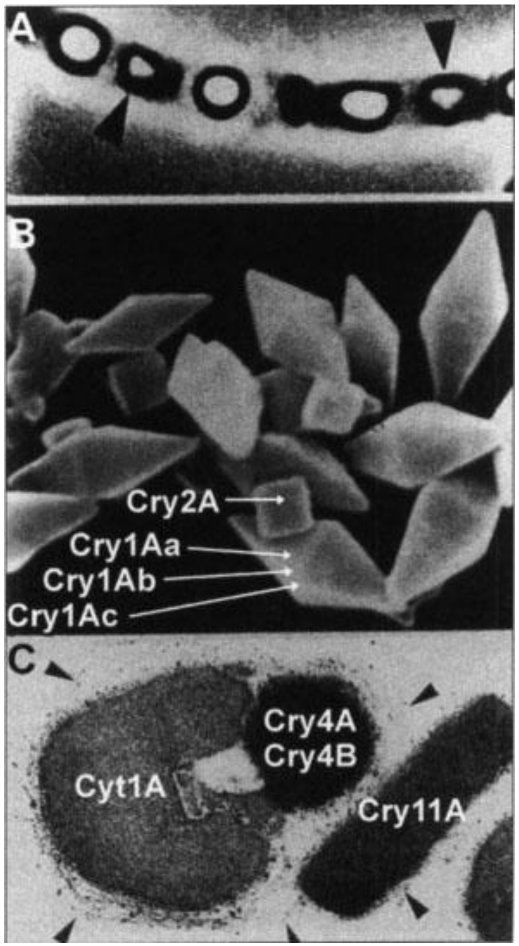
-Humans don't have the gut receptors

Source: Chris DiFonzo

Scientific basis of

Bt Insect Resistant Biotech Crops

Bt and its importance



- Bt – ***Bacillus thuringiensis***
- **Common soil bacterium**
- **Produces crystal (Cry) proteins during sporulation**
- **Different strains of Bt produce different Cry proteins that are toxic to a variety of insects**
- **Led to development of Bt insecticides against insect pests**

TABLE 1. Insect spectrum of major Bt toxin types

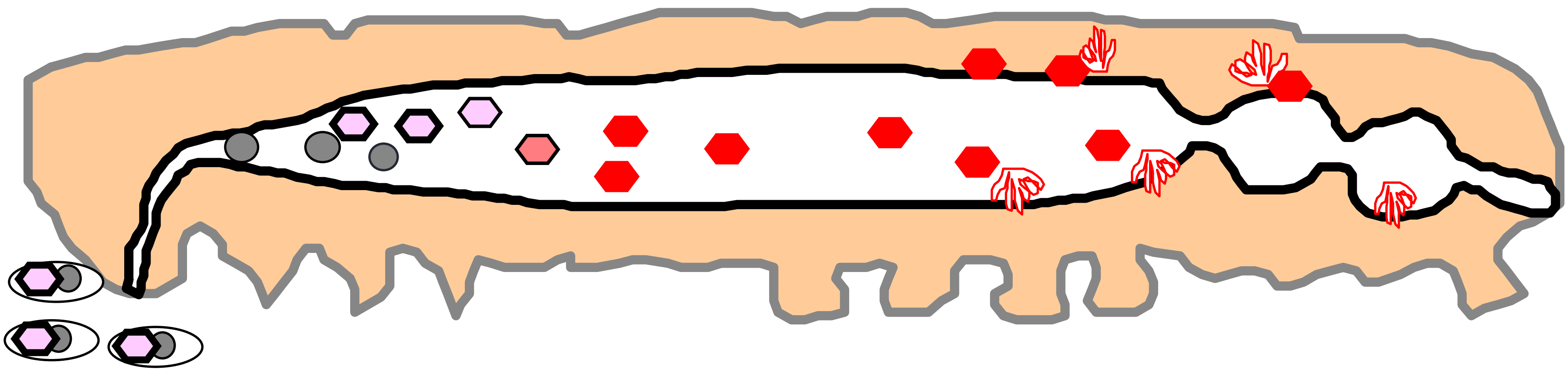
Toxin types	Primary target spectrum
Cry1	Lepidoptera (caterpillars)
Cry2	Lepidoptera
Cry3	Coleoptera (beetles)
Cry4	Diptera (mainly, mosquitoes & blackflies)
Cyt1	Diptera (mainly, mosquitoes & blackflies)

Bt insecticides generally contain a mixture of several proteins

Example: Dipel = Bt kurstaki (Btk)

Cry1Aa, Cry1Ab, Cry1Ac, Cry 2Aa, + Cry2Ab

How Bt works as an insecticide…..



Ingestion of spores, crystal proteins (= protoxins)

Activation of toxin:
- crystals solubilized under high pH
- protein cleaved by gut proteases

Toxin binding to gut receptors:
- paralyzes gut
- insects stops feeding
- gut membrane leaks
- bacteria multiply in body
- septicemia

Practically non toxic to humans
- **Human gut low pH**
- **No gut receptors**

Source: Chris DiFonzo

Why Bt sprays are not economical for large fields - US

Bt is a common insecticidal spray used in organic agriculture, on sensitive habitats, and home gardens

But, it has limitations…..

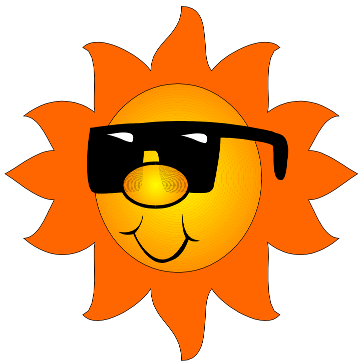
Insect larvae are the most susceptible to Bt

1. Timing is crucial (have to spray at larval stage and spores must be eaten by larvae)
2. Need to scout large fields to time applications right
3. Bt gets exposed to UV and breaks down fast (within hours) – have to apply repeatedly

- Spraying large fields requires hiring of equipment (coverage)
- Repeated applications add cost
- Spraying Bt on large farms is not cost effective compared to pesticides

Why farmers like Bt Crops - US

- Bt Crops developed to address limitations of Bt insecticides
  - **Coverage** – 100% since all plant parts make the insecticide
  - **Timing** – Insecticide is made all the time
  - **Breakdown** – Insecticide is within the plant in high dose (not exposed to UV)
  - **Cost** – Is part of the cost of seed (no additional costs required for application)



Benefits of Bt corn – Control from European corn borer

Benefit: Less damage from European corn borer. Less pesticides needed for control

Added benefit: Insect damage attracts secondary infections with fungi that produce mycotoxins toxic to humans

Bt crops do not have this issue

Benefits of Bt corn – Control from Corn root worm

Makes machine harvesting difficult!! – yield loss

Untreated Corn
- severe feeding
- lodging, goosenecking

Soil insecticides used: Broad spectrum, difficult to apply, depends on soil moisture

Untreated	Soil insecticide	Herculex RW

Yieldgard RW
- trace feeding

Bt seed – no calibration, handling of pesticide, targeted for the pest

Percent reduction of pesticide use in Bt Cotton compared to conventional (adapted from Fitt et al. 2004)

Country	Number of sprays	Average pesticide use (%)	Reference
Argentina	- 48	- 49	Qaim *et al.* 2003
USA	- 28		Williams 2003
Australia	- 56	- 43 - 92 [1)]	Fitt 2003
India	- 42	- 70	Pyke 2004
China	- 59 - 66	- 70 - 80 - 61	Pray *et al.* 2002 Huang *et al.* 2003 Lu *et al.* 2002
South Africa (small scale)		- 25	Ismael *et al.* 2002
South Africa (large scale)		- 56	Kirsten *et al.* 2002
Mexico	- 54		Traxler *et al.* 2001

[1)] Bollgard II

BollgardII – (Cry1Ac/Cry2Ab2) - 92% reduction

Additional resistance to secondary pests of cotton

Sanvido et.al, Oct 2006

Percent reduction of pesticide use in Bt Cotton compared to conventional (adapted from Fitt et al. 2004) Cont'd

- Cotton – highly susceptible to several serious insect pests (primary & secondary);
  - budworm-bollworm complex with considerable damage
- Control of secondary pest may require different genes

  BollguardII has Cry1Ac/Cry2Ab2
- Second gene is affective against secondary pests

  (soybean and cabbage looper, saltmarsh caterpillar, beet and fall armyworm)
- One gene – 43% reduction
- Two genes – 92% reduction

Economic benefits from Bt Cotton - Worldwide

Performance advantage of GE-insect resistant cot… …entional cotton (expressed as percentage increase or decre…

	Argenti…				Africa
Seed costs					%
Pesticide cos…					-58%
Yield				1%	65%
Reven…				9%	65%
Profit		0%	69%	12%	299%
Notes:	…on …al farmers	variable with location			

"Bt cotton increased the income of farmers significantly by up to US$250 per hectare and also halved the number of insecticide sprays, thus reducing farmer exposure to pesticides"

James, ISAAA report 2011

Farmers who adopted transgenic varieties experienced higher yields (from lower pest damage), higher revenue, and reduced pesticide costs. These factors more than compensated for increased seed costs.

Raney, 2006. Curr. Opin. Biotechnol. 17:1-5.

Economic benefits of Bt cotton - India

Performance advantage of IR (Bt) vs. non-IR cotton

	Chemical Costs	Profits
Maharashtra	- 44 %	56%
Karnataka	- 49%	172%
Tamil Nadu	- 73%	229%
Andra Pradesh	- 19%	-40%
National Average	- 41%	59%

Drought

No adopted germplasm

(Raney, Current opinion in Biotech, 2006)

Economic benefits of Bt cotton - India

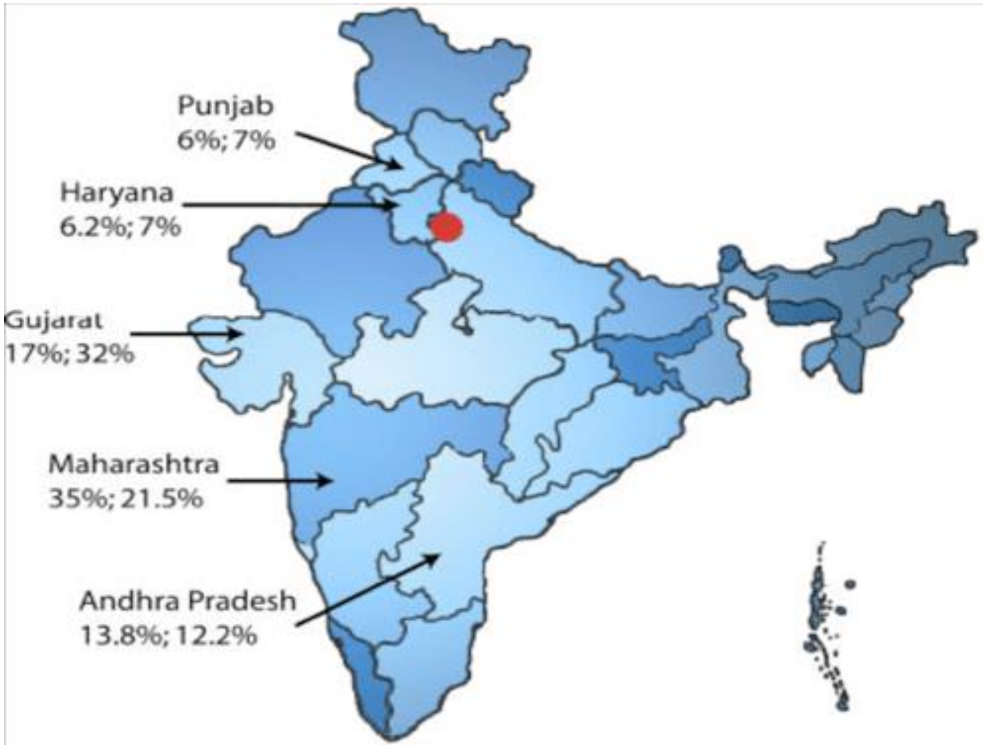
Effects of Bt cotton on insecticide use in regions of the Maharashtra State, India, 2002-2003

	Number of bollworm pest sprays		
	Non-Bt	Bt	change
Vidharba region	2.97	1.95	-34%
Marathwada region	2.74	1.08	-61%
Khandesh region	3.91	1.24	-68%

7793 fields 2002; 1577 fields, 2003

(Morse et al., Crop Protection, 2005)

Summary Economic benefits of Bt cotton - India

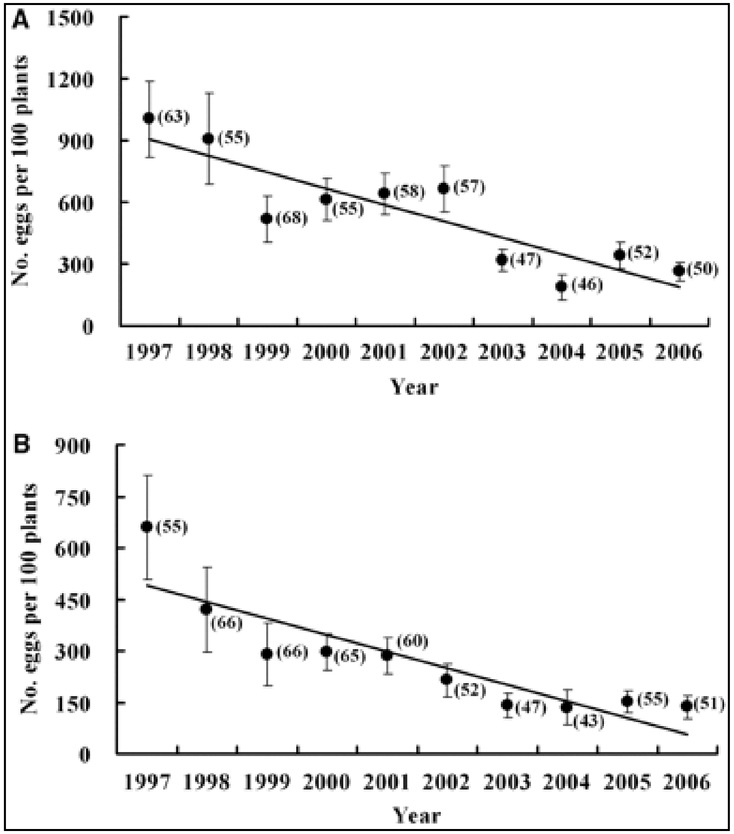


Bt cotton has transformed cotton production in India!!!

James, 2011 ISAAA report

- Celebrated a decade of successful cultivation of Bt Cotton
- Bt cotton is the most productive and profitable crop in the country
  - number two exporter of cotton globally
  - second largest cotton producer in the world

Impact of Bt Cotton on Pest control - China



Study area:
6 provinces
3 million hectares cotton
22 million hectares other crops

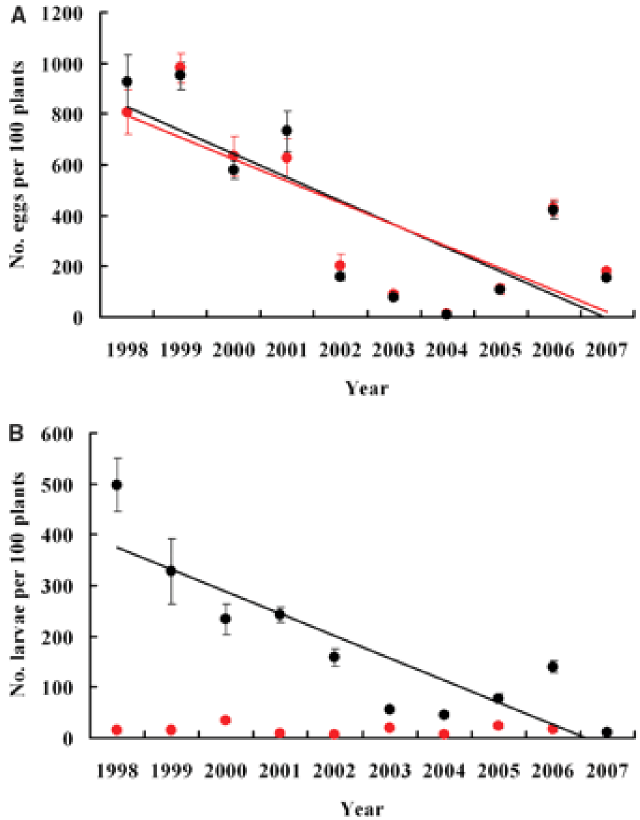
Pest pressure from cotton bollworm on Bt cotton plants decreased in direct proportion to use of Bt cotton over the past decade

Decline did not correlate several other factors that might influence insect populations such as temperature or rainfall

Wu et al., Sept. 19, 2008, Science

Fig. 1. Egg densities of *H. armigera* from 1997 to 2006 on cotton in northern China. (**A**) Relation between egg density of the second generation ( ) and planting year of Bt cotton. Linear model of egg density (black line), $y = 157{,}076.05 - 78.21x$, $F = 32.16$, df = 1,549, $P < 0.0001$, $R^2 = 0.06$. (**B**) Relation between egg density of the third generation ( ) and planting year of Bt cotton. Linear model of egg density (black line), $y = 94{,}644.36 - 47.15x$, $F = 26.42$, df = 1,558, $P < 0.0001$, $R^2 = 0.05$. Data are means ± SEM.
Values in parentheses are the numbers of sampling sites for each year.

Impact of Bt Cotton on Pest control - China



Pest pressure from cotton bollworm on cotton plants also decreased in non-Bt cotton fields (black dots)

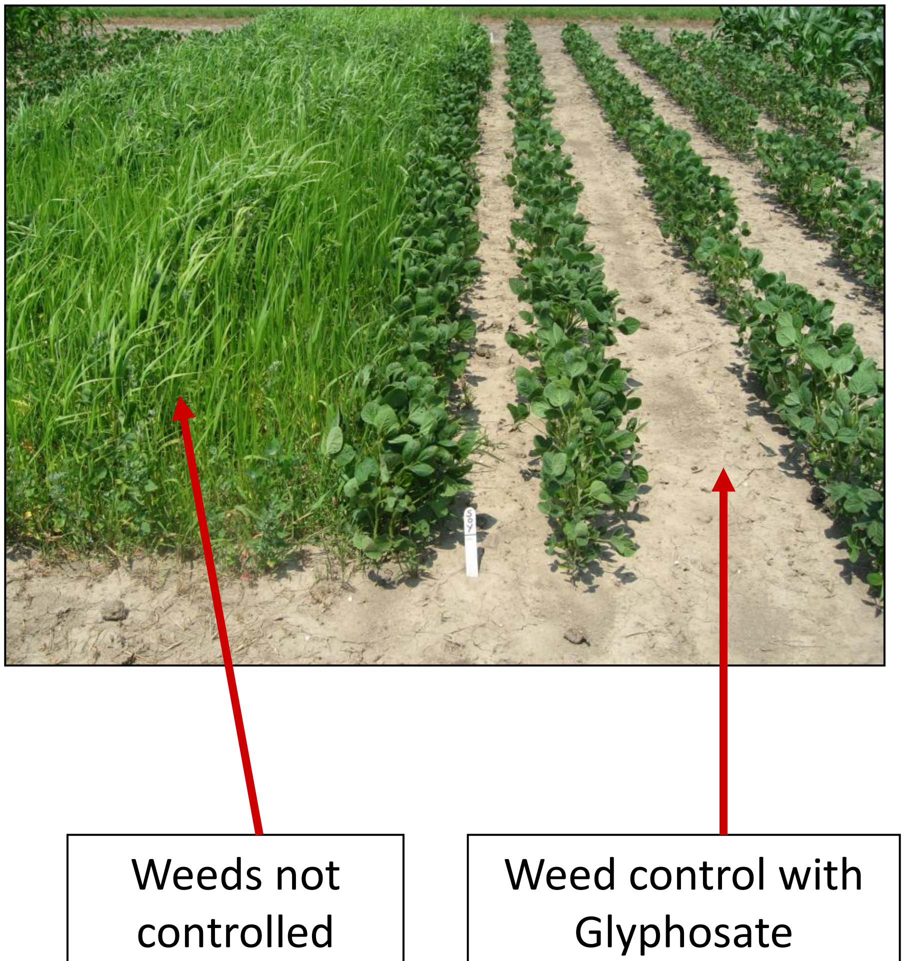
The eggs from Bt plants did not develop into larvae, those on non-Bt plants did, indicating effectiveness of the Bt in reducing subsequent generations

>>> non-Bt cotton also benefitted and required less pest control

indirect (unexpected) advantage

Fig. 3. Egg and larval densities of *H. armigera* on cotton at Langfang site, Hebei Province, China, from 1998 to 2007. (**A**) Relation between egg density on Bt cotton(red circles) and non-Bt cotton (black circles) and planting year of Bt cotton. Linear model on Bt cotton (black line), y = 185,476.90 – 92.42x, F = 69.05, df = 1,58, P < 0.0001, R^2 = 0.54. Linear model on non-Bt cotton (red line), y = 171,365.94 – 85.37x, F = 62.59, df = 1,58, P < 0.0001, R^2 = 0.52. (**B**) Relation between larval density on Bt cotton (red circles) and non-Bt cotton (black circles) and survey years. Linear model on non-Bt cotton (black line), y = 87,107.86 – 43.41x, F = 97.56, df = 1,58, P < 0.0001, R^2 = 0.63. Data are means ± SEM. There are six samples for each point in the graphs.

Why farmers like Round-up Ready crops?



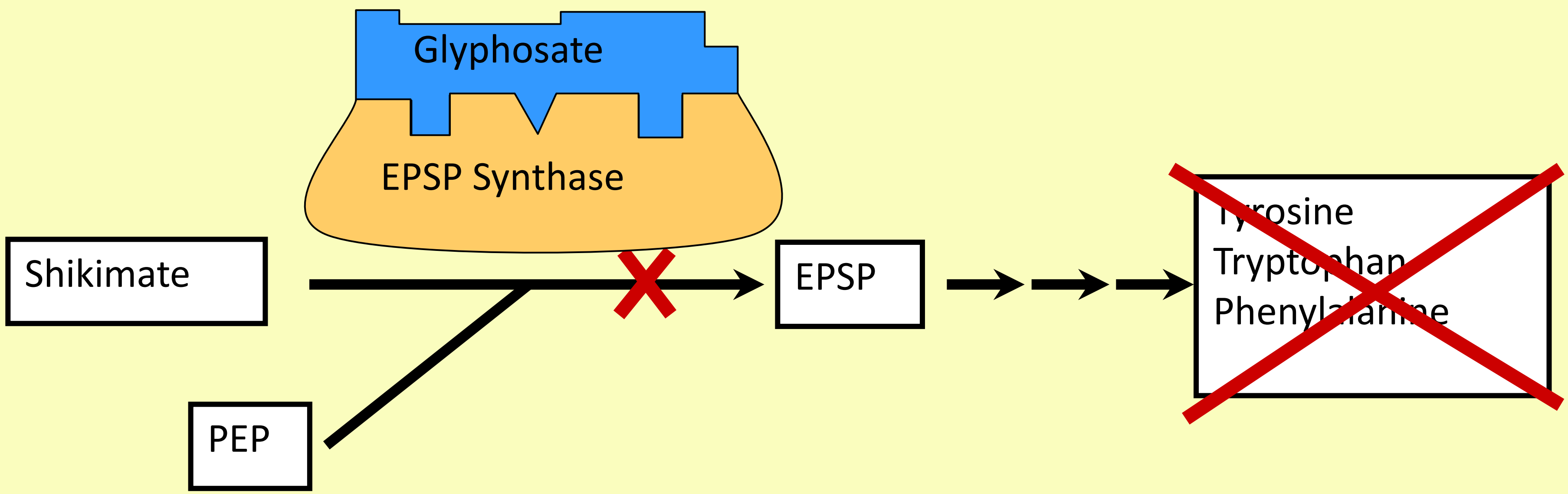
- Weeds are a major production constraint for crops
- A vast amount of toxic herbicides are used for weed control
- Once herbicides are sprayed, need to wait for herbicide to degrade before planting the crop to avoid damage

Scientific basis of

Round-up Ready/Glyphosate Herbicide Tolerant Biotech Crops

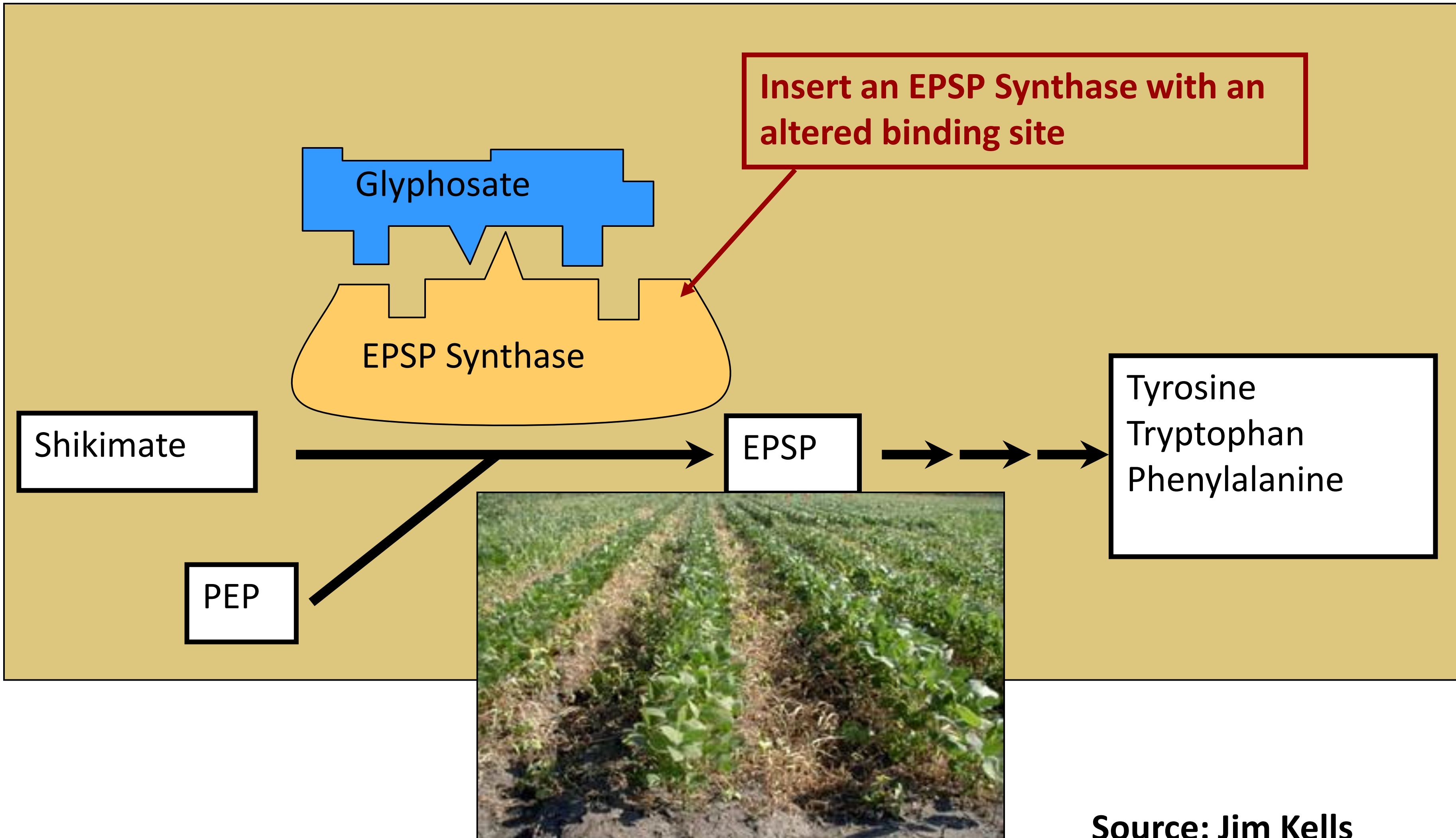
Glyphosate mode of action

Glyphosate (herbicide) blocks action of EPSP Synthase – 3 essential amino acids not made



Source: Jim Kells

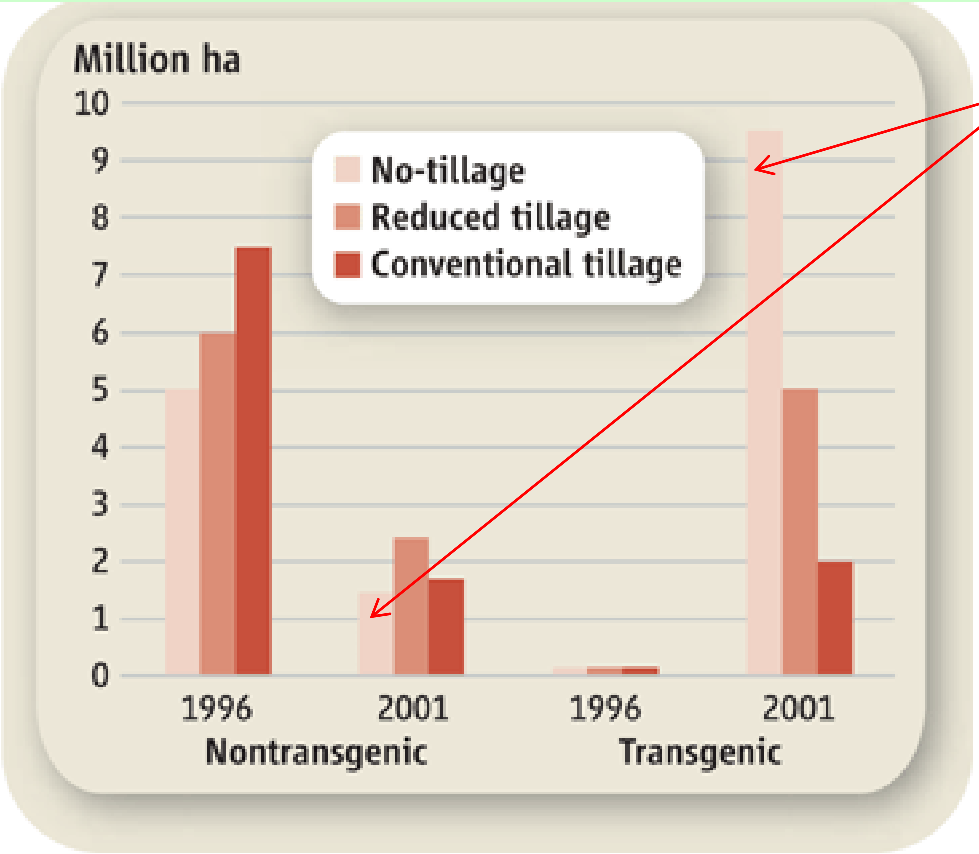
Mode of action: Glyphosate tolerant crops



Source: Jim Kells

HT crops – Use of conservation tillage for cotton and soybean

Weed control through tillage practices – tilling allows weeds to germinate on which herbicides are used for control. Depending on the half life of the herbicide used, crop can be planted.



Adoption of HT-crops made it easier to use no-till strategies

No-till and reduced till (88%) greatly exceed conventional for herbicide tolerant GE crops

HT crops – impact on tillage practices

- **Use of Round Up Ready crops was correlated with increase in reduced tillage or no-till practices**
- **Environmental considerations: tillage exposes soil to wind and water erosion which can carry both soil and agricultural chemicals.**
- **reduced tillage can**
  - **reduce erosion, groundwater contamination, and conserve nutrients and organic matter**
  - **increase soil insect and microbial populations**
  - **reduce soil compaction resulting from passages across the field**

- indirect (unexpected) advantage

Economic benefits from HT Soybean in Argentina

Table 3. Argentina second-crop soybeans.

Year	Second-crop area (million ha)	Increase in income linked to GM HT system (million $)	Additional production (million tonnes)
1996	0.45	Negligible	Negligible
1997	0.65	173.8	0.258
1998	0.8	475.2	0.807
1999	1.4	657.4	2.2
2000	1.6	891.0	2.6
2001	2.4	1,081.6	4.9
2002	2.7	1,446.5	5.8
2003	2.8	1,623.5	6.4
2004	3.0	1,701.1	5.7

Note. Additional gross margin based on $99/ha 1997–2001, 116/ha in 2002, $123/ha in 2003, and $121/ha in 2004 (source: Grupo CEO).

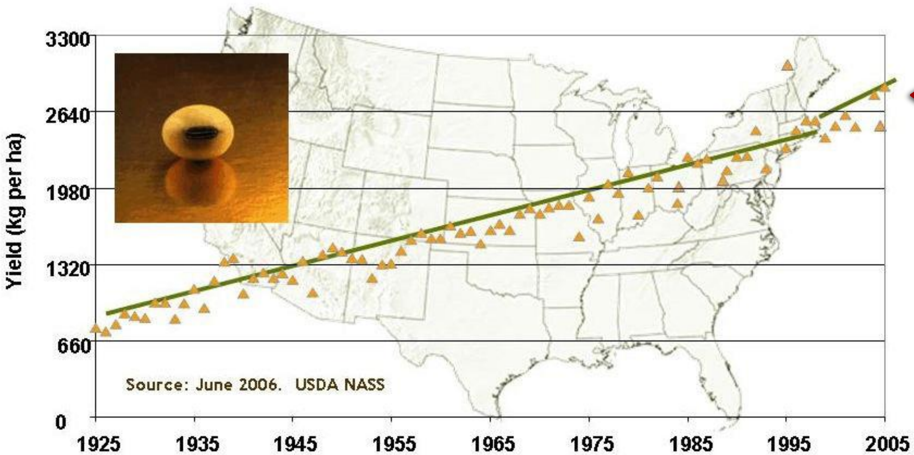
No tillage system

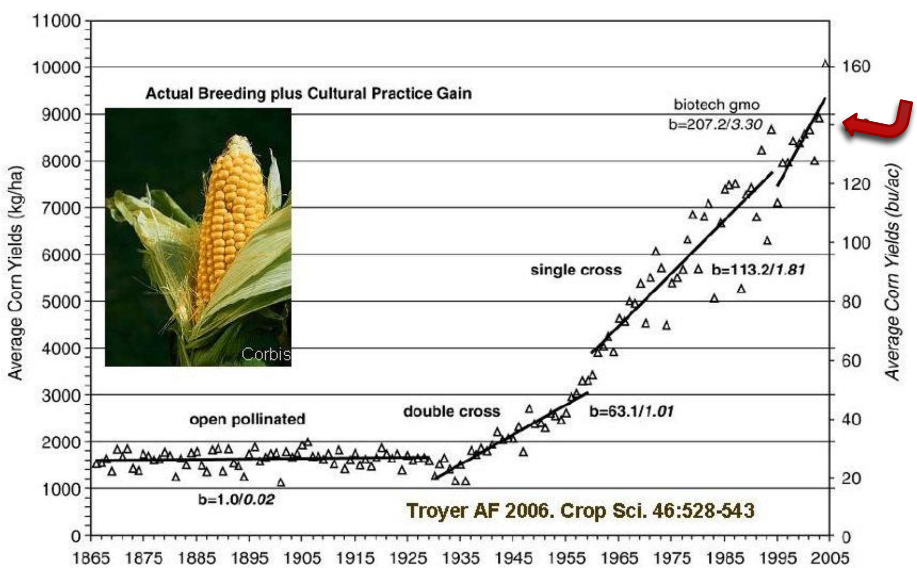
-Ease of management

-Additional time for planting, growing and harvesting a second crop (after a wheat crop)

Brookes and Barfoot, 2005

Yield benefits from corn and soybean - USA





Rate of yield increase faster in the biotech era

- **1. Biotech crops have significantly helped increase productivity and income**
- Eg. US corn and soybean yields have been increasing at a steady rate as a result of improved genetics and cultural practices. GE crops make it easy to control insect and weed pests as resistance comes as part of the cost of seed – bringing economic benefits to the farmer

Overall benefits - USA

- **2. Biotech crops allow no-till agriculture, and helps in erosion prevention and soil loss, energy consumption, and other parameters. Summary for GE and non-GE crops show benefit to environment – lets compare Corn, Soybean and Cotton with non GE Wheat.**

	Corn	Cotton	Soybean	Wheat
Yield per acre (% increase)	41	31	29	19
% decrease in land per bushel (corn, soybean or wheat) or lb (cotton)	37	25	26	17
% decrease in soil loss per bushel or lb	69	34	49	50
% decrease in energy use per bushel or lb	37	66	65	9
% change in greenhouse gas emissions per bushel or lb	-30	-33	-38	+15

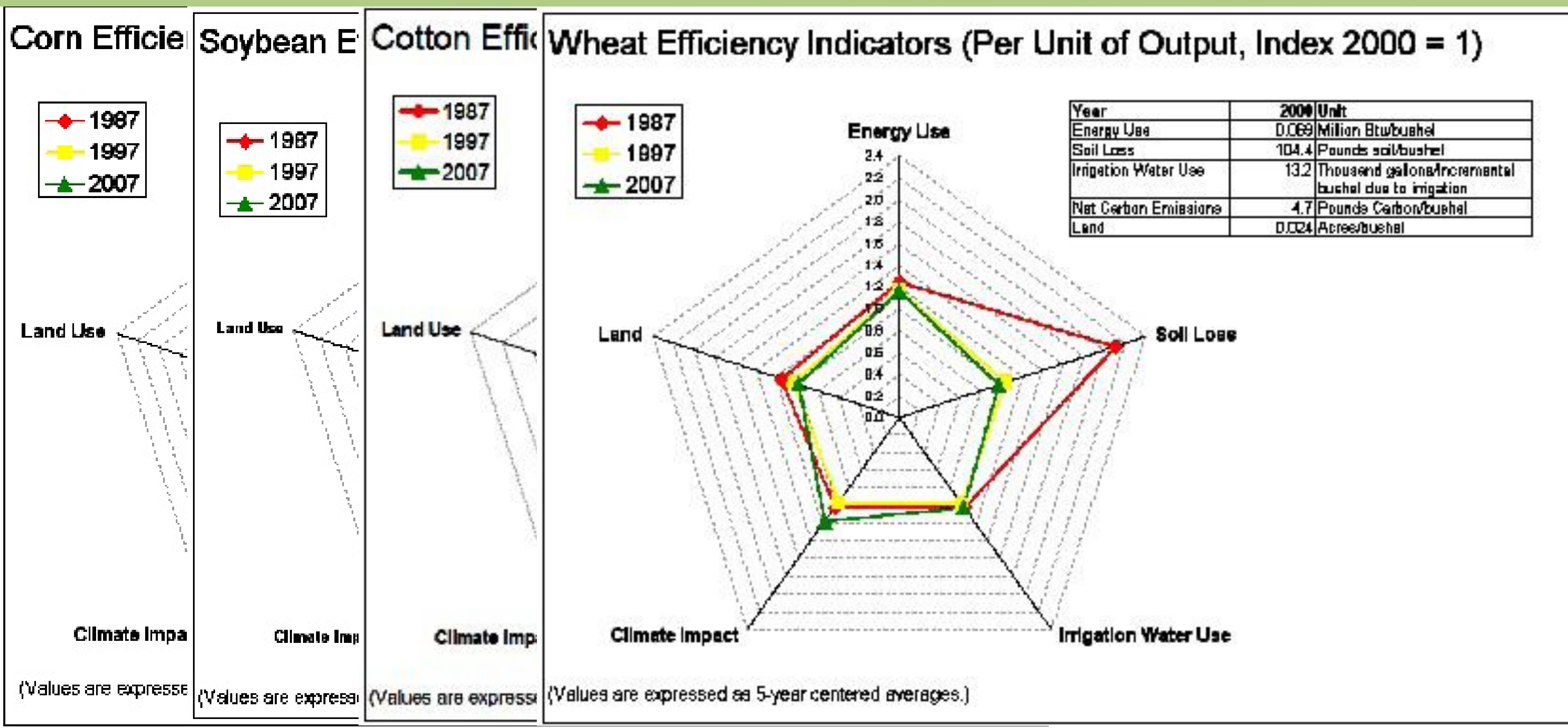
Corn, Cotton and Soybean largely GE by 2007 whereas wheat was not. In general, the yield increases and sustainability indicators have been greater for GE crops than non-GE.

http://keystone.org/spp/env-sustain_ag.html

Overall benefits - USA

- **2.Cont'd – lets compare Corn, Soybean and Cotton with non GE Wheat.**

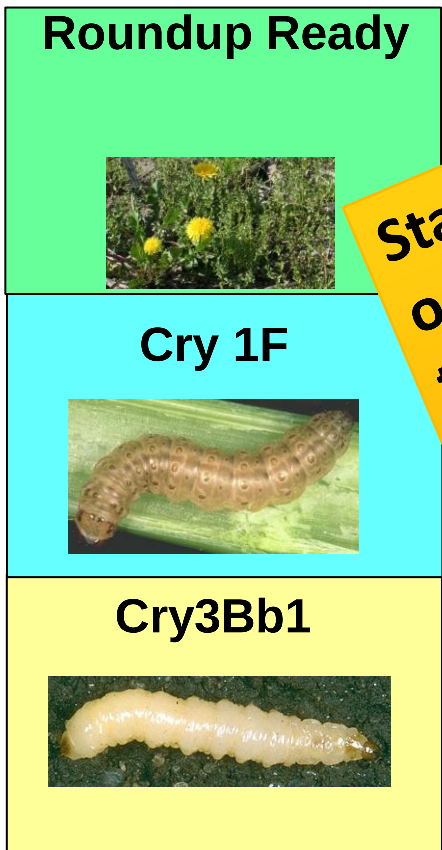
A comprehensive study on the effect of current agronomic practices on sustainability released by the Keystone Center. Full report available online at http://keystone.org/spp/env-sustain_ag.html



Making GE crops better….

Gene stacking

Multiple targets

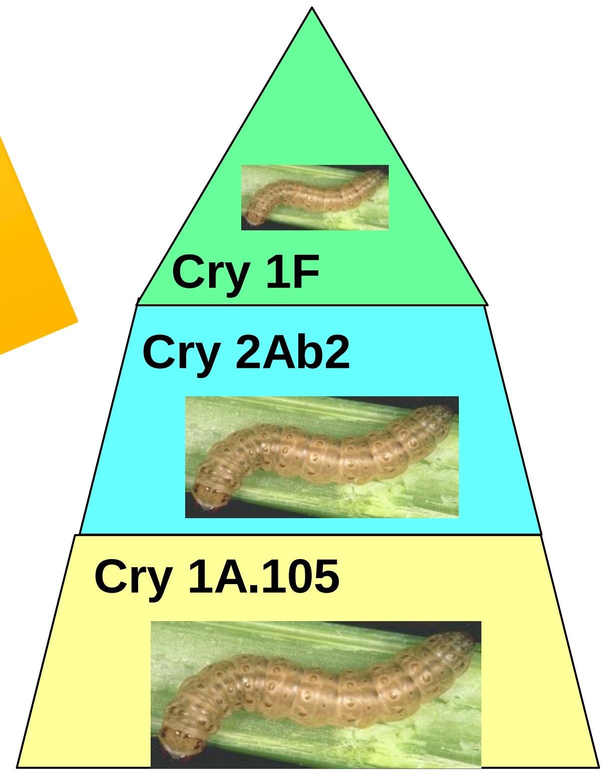


Stacked traits occupied ~25% of the global 160 million hectares!

James, 2011 ISAAA report

Gene pyramiding

Same target, reduced refuge



Source: Chris DiFonso

What stacked traits are available?

Competing companies with different genes and stacked traits – often confusing to farmers…. Too many to select from!

YieldGard VT

Agrisure® GT/CB/LL

HERCULEX™ I Insect Protection HX

Agrisure® GT

HERCULEX® RW Rootworm Protection HX

YieldGard Corn Borer™

HERCULEX® XTRA Insect Protection HX

YieldGard VT Triple™

Agrisure® CB/LL

YieldGard Rootworm™

Source: Chris DiFonso

New kid on the block – SMARTSTAX!

- **U.S./Canadian approval, 20 July 2009**

	Monsanto	Dow AgroSci
Herbicide Tolerance	Roundup Ready	Liberty Link
Corn Borer	Cry 1A.105 Cry 2Ab2	Cry 1F
Rootworm	Cry3Bb1	Cry 34 Ab1 Cry 35 Ab1

First 'gene pyramid' in corn – 5% refuge

Source: Chris DiFonso

Issues faced with GE crops

1. **Pests developing resistance to GE crops**

   eg. Weeds developing resistance to Glyphosate

   eg. Insects developing resistance to Bt crops

2. **Secondary pests becoming more prominent due to targeted control of the primary pest**

3. **Effects on non-target organisms**

These issues are not new or unique to GE crops. Many weeds and insects have evolved resistance to pesticides in the past requiring more toxic pesticides for their control.

Emergence of weeds resistant to Glyphosate

REASON: INCREASED SELECTION PRESSURE!!!

Data on the use of Glyphosate

HT Soybean

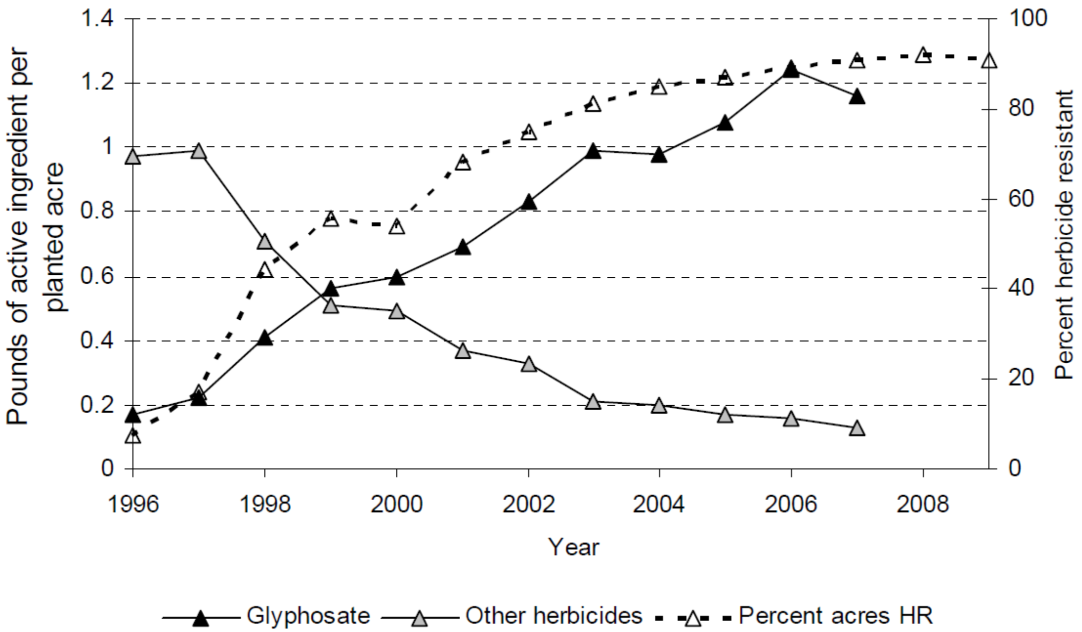


FIGURE S-1 Application of herbicide to soybean and percentage of acres of HR soybean.
NOTE: The strong correlation between the rising percentage of herbicide-resistant (HR) soybean acres planted over time, the increased applications of glyphosate, and the decreased use of other herbicides suggests but does not confirm causation between these variables.
SOURCES: USDA-NASS, 2001; 2003, 2005, 2007, 2009a, b; Fernandez-Cornejo et al., 2009.

- **Finding: When adopting GE herbicide-tolerant (HT) crops, farmers mainly substituted the herbicide glyphosate for more toxic herbicides**
- **The predominant reliance on glyphosate is now reducing the effectiveness of this weed-management tool**

Source: NRC report

Emergence of insects resistant to Bt

- **Emergence of insect resistance to Bt crops has been low so far and of little economic or agronomic consequence**
- **Two pest species have evolved resistance to Bt crops in the United States**

Bt Corn

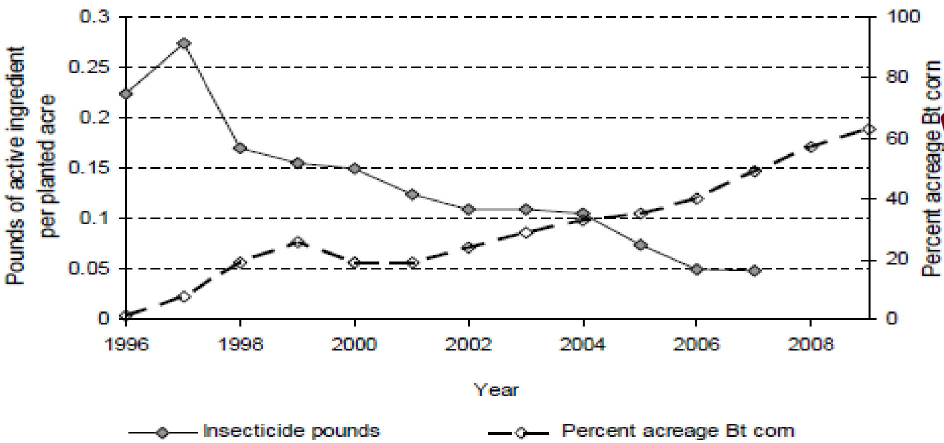
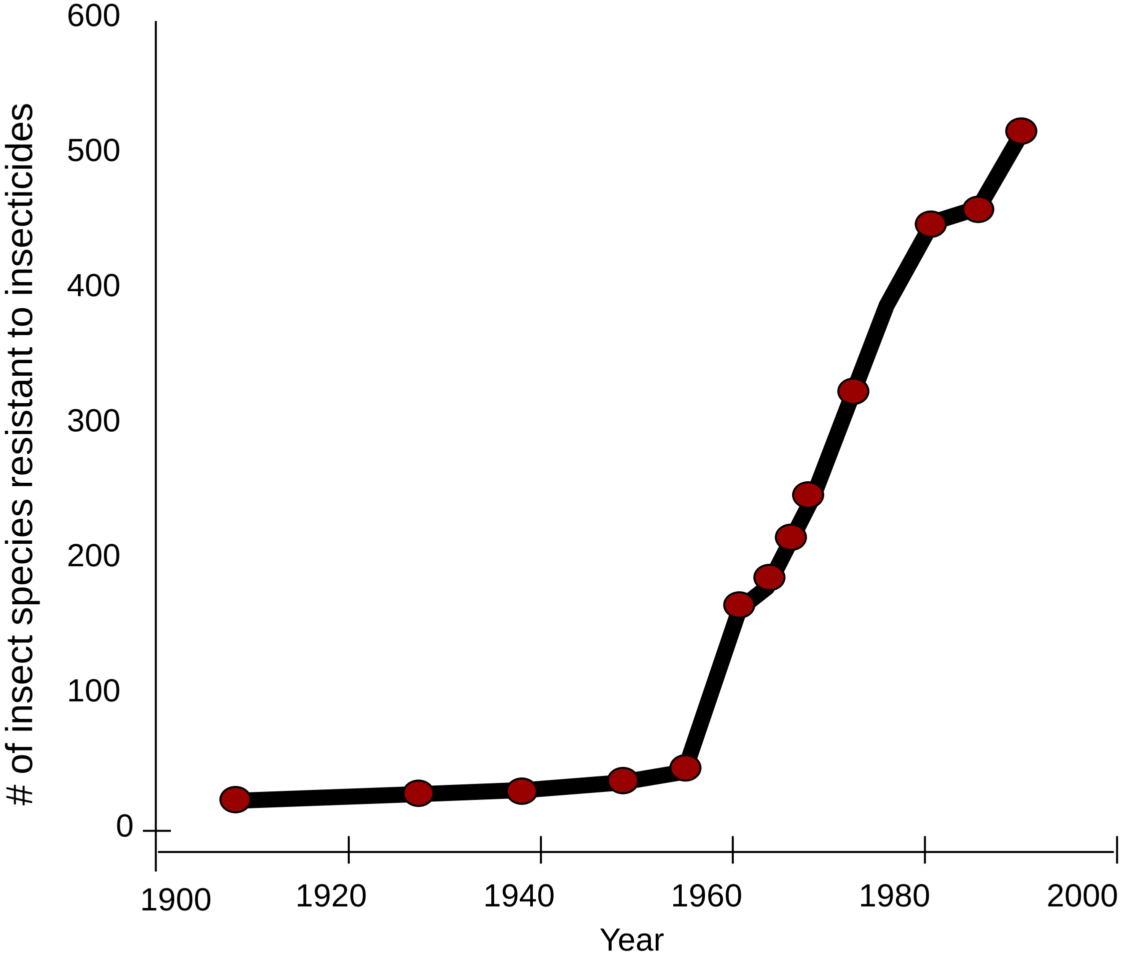


FIGURE S-4 Pounds of insecticide applied per planted acre and percent acres of Bt corn, respectively.
NOTE: The strong correlation between the rising percentage of Bt corn acres planted over time and the decrease in insecticide pounds per planted acre suggests but does not confirm causation between these variables.
SOURCES: USDA-NASS, 2001; 2003, 2005, 2007, 2009a, b; Fernandez-Cornejo et al., 2009.

REASON: INCREASED SELECTION PRESSURE!!

Resistance to Bt has been shown in the laboratory and in the field



European corn borer

Diamondback moth

Issues faced with GE crops

2. Secondary pests becoming more prominent due to targeted control of the primary pest

Published online 13 May 2010 | Nature | doi:10.1038/news.201 42

News

GM crop use makes minor or problem

Pesticide use rising as Chinese fa transgenic crop.

Jane Qiu

Numbers of mirid bugs eviously only minor pests in -fold since 1997, they found e region," says Wu. "Their ri the scale of *Bt* cotton cul

Rise

The ris ese farmers back to pesticides — they are two-thirds as much as they did before *Bt* cotton s mirids develop resistance to the pesticides, hat farmers will soon spray as much as they ever did.

Not unexpected - Bt crops specifically target the primary pest. Other means have to be used to control secondary pests

Mirid bugs have filled the gap created by killing other pests of cotton.

Science/AAAS

Why would we want to have GE crops?

- Climate change is going to adversely affect agriculture and human well-being especially in the developing word by:
  - Yield declines in most important crops – South Asia predicted to be most hardly hit
  - Increasing prices for most important agricultural crops and prodcuts
- Agricultural sector needs to have tools for speeding up the development of new and improved crops to deal with constraints related to climate change
- **Genetic engineering is one such biotechnology tool available for the plant breeder to improve crops**

Thank you!

Questions?