Globalization, GMOs and Food Security

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New Delhi

Last two decades world scenario:

Increase in population

Industrialization

Food consumption

Shrinkage of space for cultivation

Economic prosperity

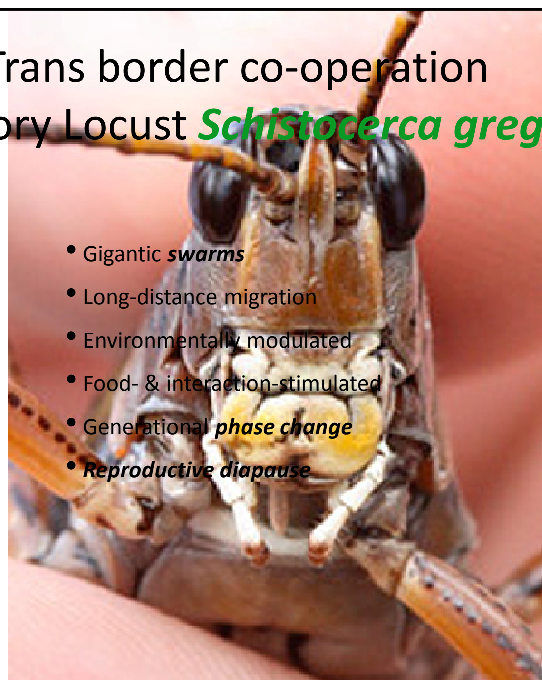
Two major Biotechnological interventions

Insect Control

Weed control

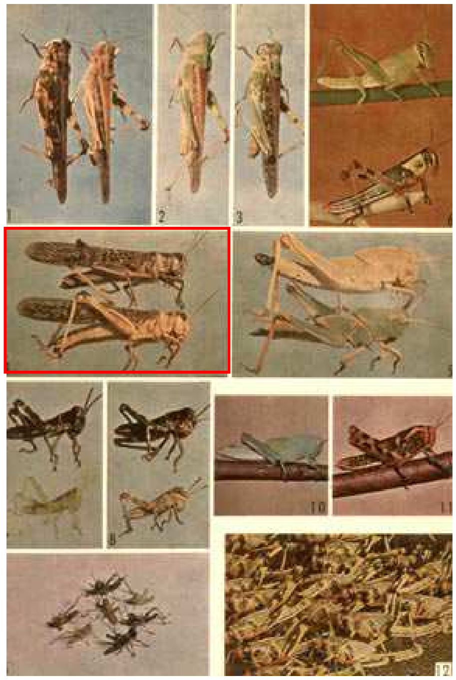
Trans border co-operation

Migratory Locust ***Schistocerca gregaria***



- Gigantic ***swarms***
- Long-distance migration
- Environmentally modulated
- Food- & interaction-stimulated
- Generational ***phase change***
- ***Reproductive diapause***

http://fiveprime.org/hivemind/Tags/locust (Len Abrams)



Some migratory locust swarms may contain hundreds of billions of insects, weighing thousands of tons.

Protecting crop plants against insect predation

Genetic Varieties

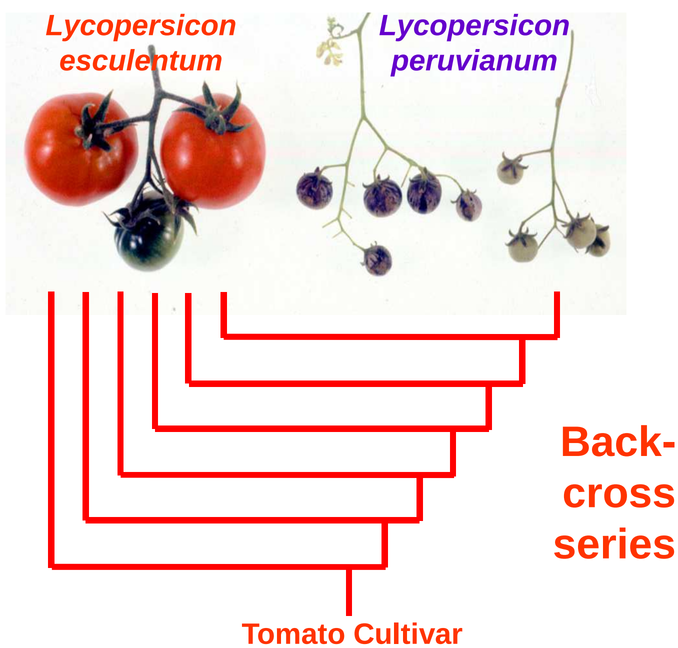
Chemical insecticides

Biological insecticides

The creation of corn by plant breeding

The corn that Columbus received was created by the Native Americans some 8,000 years ago by domestication of a wild plant called teosinte. They used genetic engineering in a quite remarkable way to produce a more productive variety.

Genteic variability in tomato

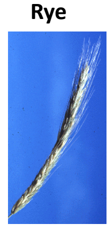


Interspecific Cross

Wheat

X

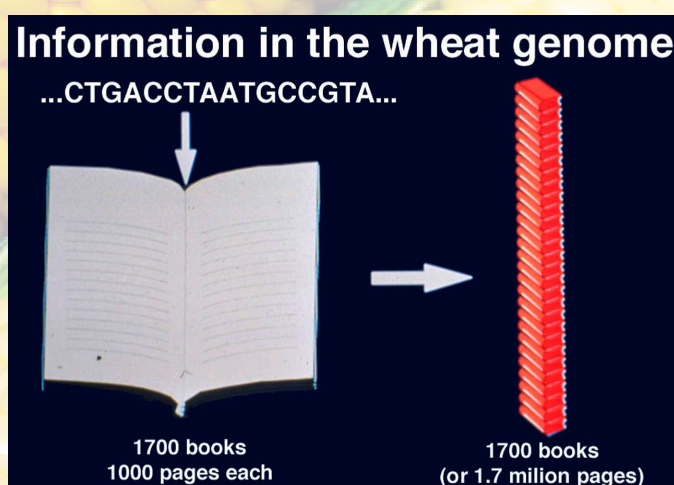
Rye

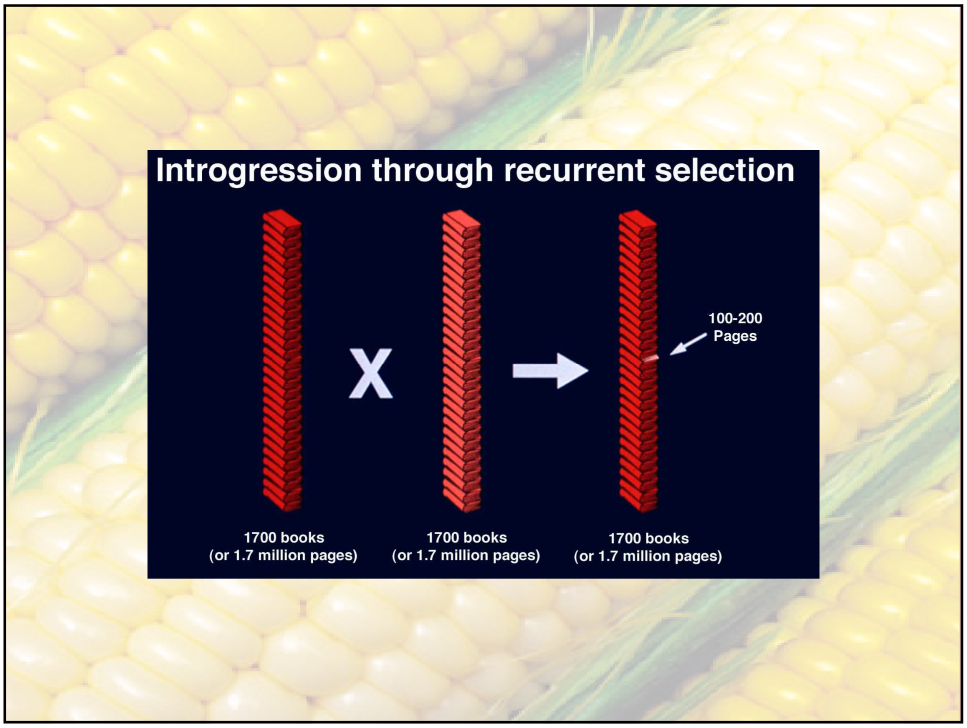


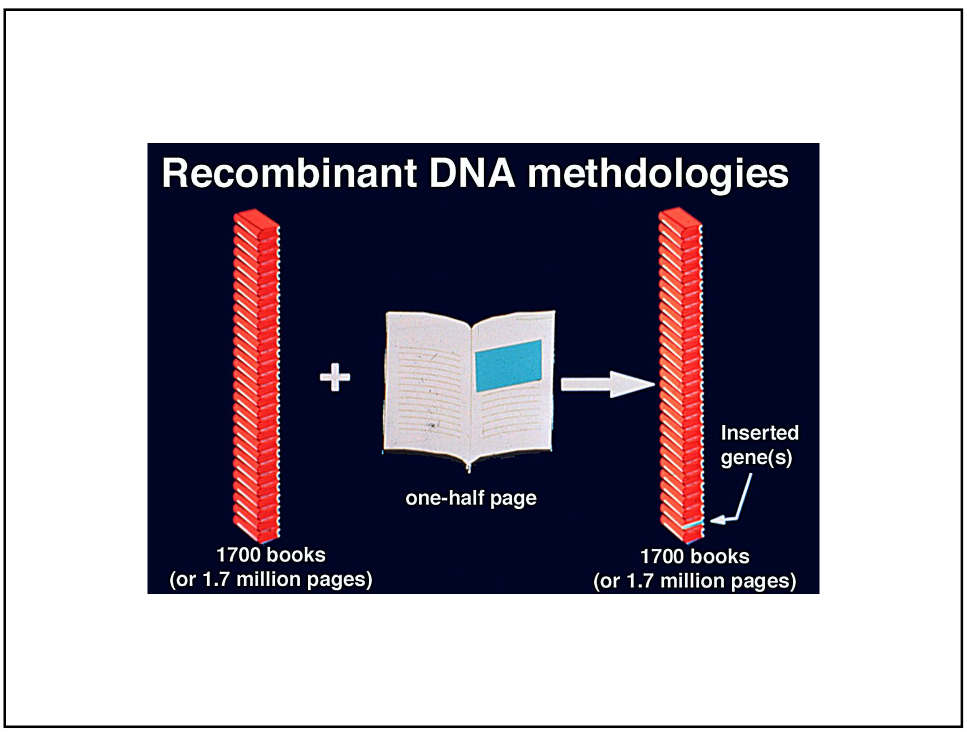
Triticale

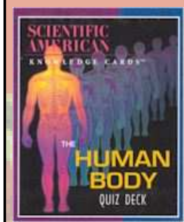
New species, but
NOT biotechnology
products

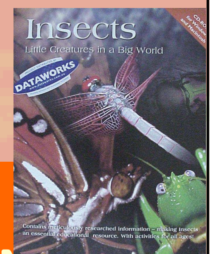
Creation of brocoflower by plant breeding




Introgression through recurrent selection
X
100-200
Pages
1700 books
(or 1.7 million pages)
1700 books
(or 1.7 million pages)
1700 books
(or 1.7 million pages)

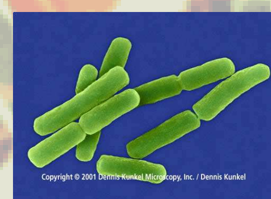

Recombinant DNA methdologies
+
one-half page
Inserted
gene(s)
1700 books
(or 1.7 million pages)
1700 books
(or 1.7 million pages)

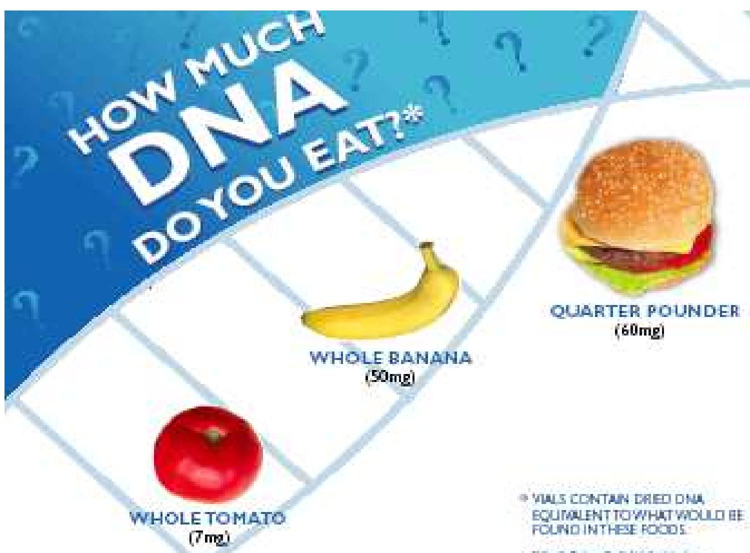




DNA IS EVERYWHERE

Present day tools permit to move DNA from any source





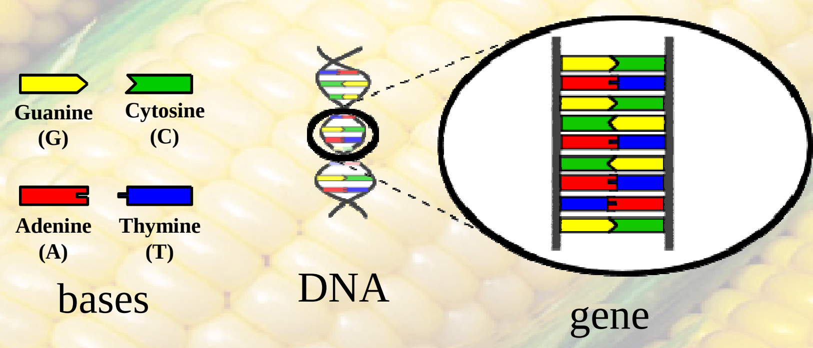
We eat DNA every day

The Crop Agriculture Technology Timeline graph

2,000 BC	Cultivation
19thC	Selective Cross breeding
Early 20th C	Mutagensis and selection
Mid 20th C	Cell culture
1930s	Somaclonal variation
1940s	Embryo rescue
1950s	Polyembryogenesis
1970s	Anther culture
1980	Recombinant DNA
1980s	Marker assisted selection
1990s	Genomics
2000	Bioinformatics

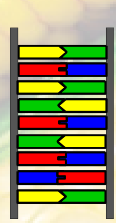
DNA and Genes Can be mobilised by new tools

- ***Genes*** = the coding system for instructions
- ***A gene*** = is a segment of **DNA**



Genes and Proteins

transcription



→ mRNA → protein ········→ trait

translation

Gene
(a piece of DNA)

How are Transgenic Plants Produced?

Commonly Used Methods:

- *Agrobacterium tumefaciens*
- Gene Gun / Biolistics
- Electroporation

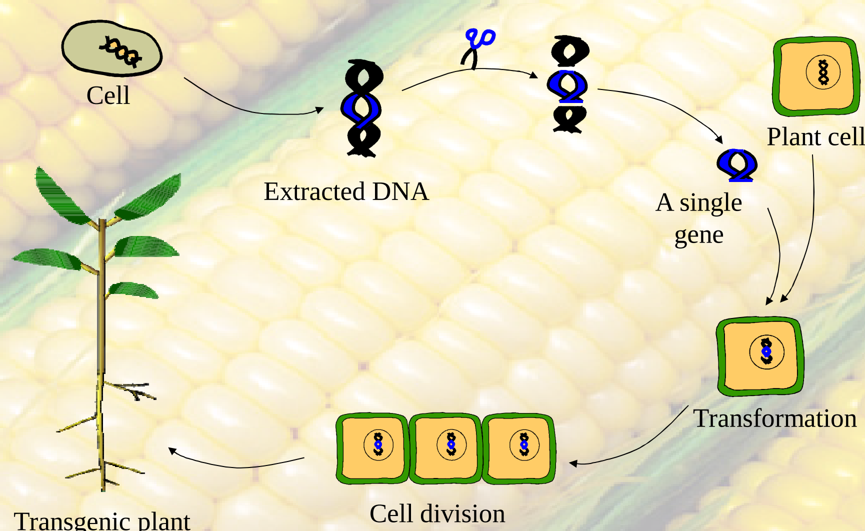
Genetic Engineering

- *The process of manipulating and transferring instructions carried by genes from one cell to another*

Why change gene instructions?

- **to produce needed chemicals**
- **to carry out useful processes**
- **to give an organism desired characteristics**

Plant Genetic Engineering Process

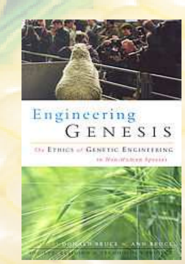


Discovery and application of Restriction enzymes

As biological scissors permitting exchange of DNA fron diverse sources

What Is Biotechnology?

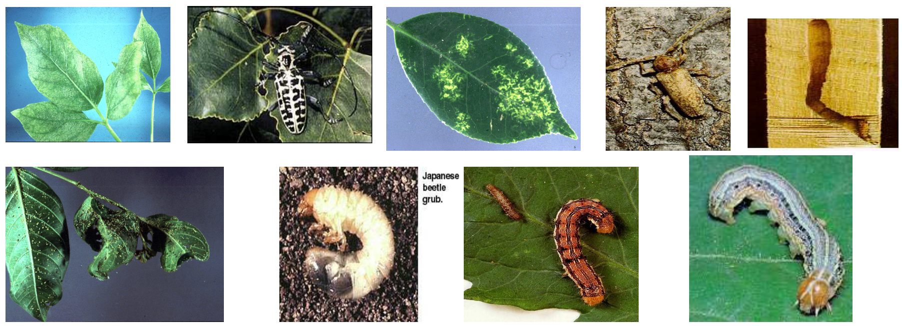
- *Harnessing the natural biological processes of living systems for the benefit of mankind*
  - Biotechnology in the past
    - making bread and cheese, brewing beer
    - crossbreeding plants



- Modern biotechnology
  - genetic engineering

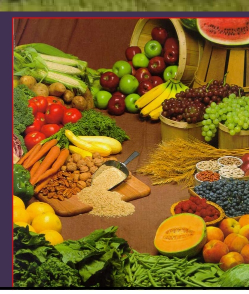
Application of Genetic Engineering in crop protection
case study 1: Insect control

Insects cause severe damage to crop and reduce productivity



WHY ARE LARGE AMOUNTS OF PESTICIDES USED IN AGRICULTURE?

1. Pesticides were used as a form of "CROP INSURANCE". This was the ORIGINAL PHILOSOPHY behind pesticide usage.
2. Cosmetic appeal



What is a biopesticide

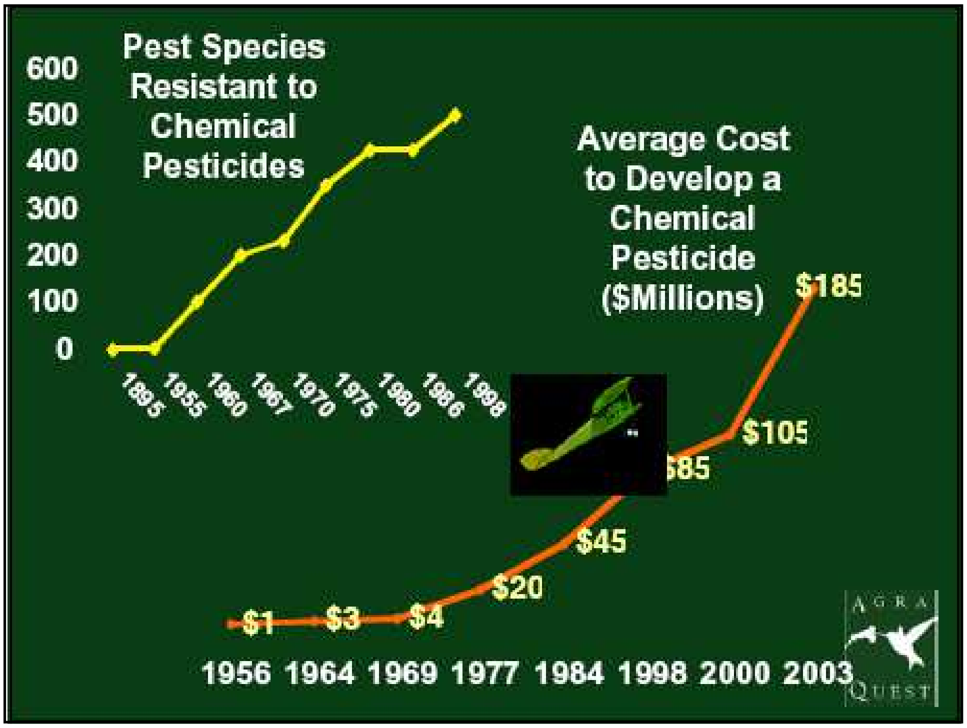
Biopesticides are certain types of pesticides derived from natural materials such as animals, plants, bacteria and certain minerals

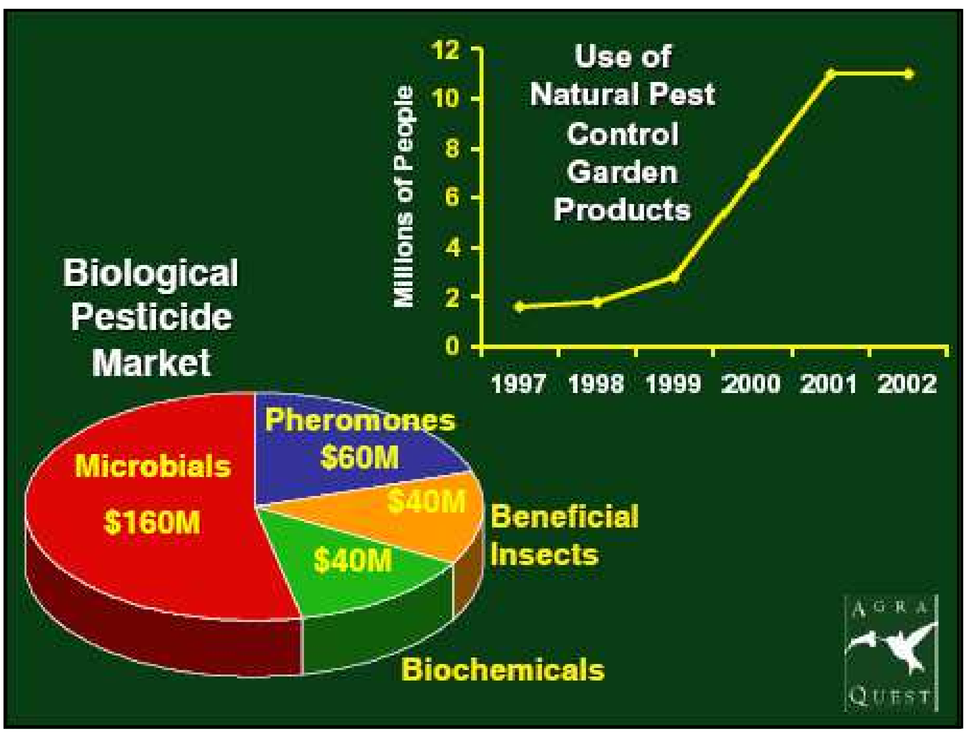
Three categories of biopesticides

- Microbial pesticides – bacteria, fungi, viruses or Protozoa
- Plant-incorporated Protectants (PIPs): incorporation of genes with pesticidal properties into plants
- Biochemical pesticides: naturally occurring to control pests by non-toxic means, e.g. pheromones

Early Pest Controls

- Sumerians controlled insects with sulfur 5,000 years ago.
- Chinese describe mercury and arsenic to control pests 2,500 years ago.
- People have used organic compounds and biological controls for a long time.
- Romans burned fields and rotated crops to reduce crop disease.
- Use of predatory insects.


Pest Species Resistant to Chemical Pesticides
600
500
400
300
200
100
0
1895 1955 1960 1967 1970 1975 1980 1986 1998
Average Cost to Develop a Chemical Pesticide ($Millions)
$185
$105
$85
$45
$20
$1 $3 $4
1956 1964 1969 1977 1984 1998 2000 2003


Use of Natural Pest Control Garden Products
Millions of People
12
10
8
6
4
2
0
1997 1998 1999 2000 2001 2002
Biological Pesticide Market
Pheromones $60M
Microbials $160M
$40M
Beneficial Insects
$40M
Biochemicals

Pesticides

PESTICIDES IN DIFFERENT MEDIA

Water
- Pesticides in drinking water: tap, well

Food
- Crops routinely sprayed:
  - fruits, vegetables, grains
- Bioaccumulation in animals and products
  - fish, meat, eggs, dairy

WHO

22

Newspaper headings

Bangladesh fish a health hazard – not fit to eat

India accuses Pepsi/Coke of pesticide contamination in bottled waters

Pakistani farmers complain of adulterated pesticides being sold

Saudi Arabia announces 2000 camels died from pesticide residue in feed

Yemen sends 1000s of pesticide-infected persons to Saudi Arabia for treatment

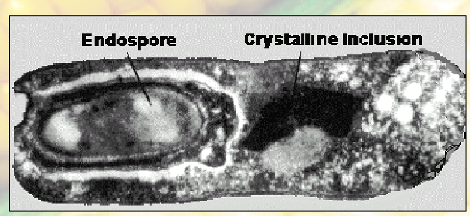
Australia & EU reject food imports with pesticide residue, most recently from China

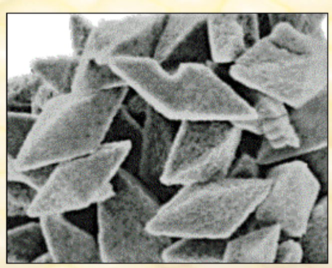
Bacillus thuringiensis (Bt)

- A bacterium that kills insects.
- First discovered in 1911 as a pathogen of flour moths.
- First used as a commercial insecticide in France in 1938.
- Used in the USA in the 1950s.
- Replaced by more effective insecticides in the 1960s.
- With resistance to synthetic pesticides, Bt research funded in the 1980s.
- Organic farmers use Bt as insecticide.
- Bt strains produce a complex mixture of toxins that kill certain types of insects.
- Initially, Bt was available only for control of lepidoptera, but other Bt strains are active against larvae of coleoptera (beetles), diptera (small flies, mosquitoes), and insect vectors of some tropical diseases.

Courtesy USDA

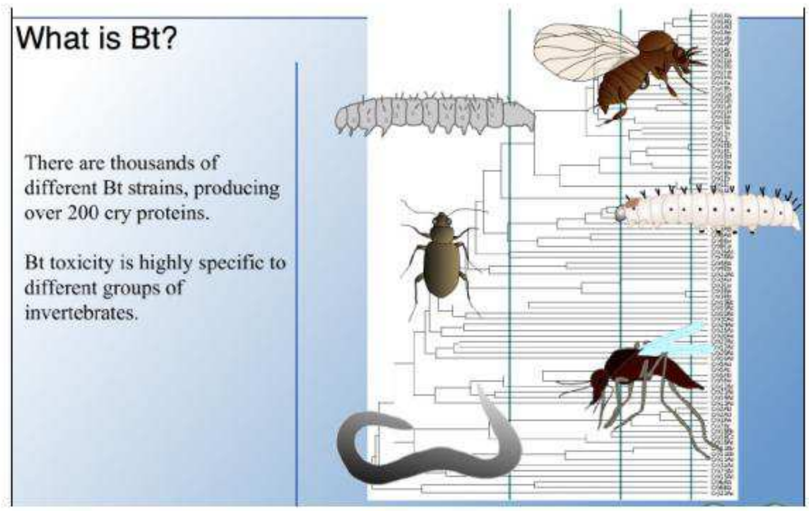
Spores and Crystals of *Bacillus thuringiensis*





Structural and Functional diversity
140 different proteins and encoding genes described
Targets and specificity established for a few proteins

Insect Resistance Group:
Diversity of Bt protein targets



Ecological niches of *Bacillus thuringiensis* strains

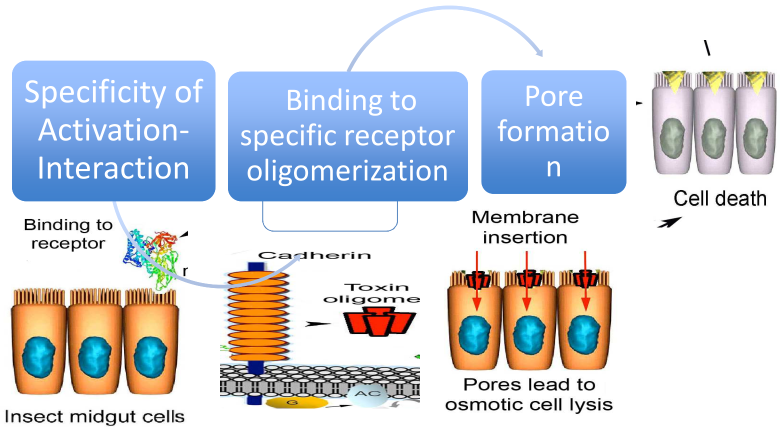
Soil

Leaf surface

Grain dust

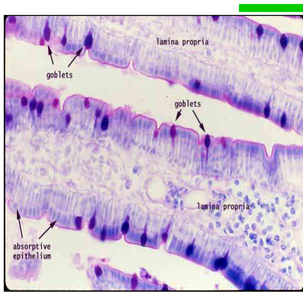
Insect cadavers

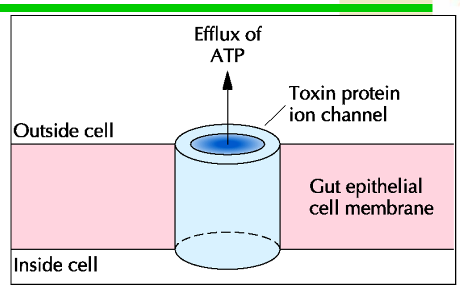
Events in Cry1Ac interaction upon ingestion



Insect Resistance Group:

Activation and Insertion of Bt Toxin into Insect Gut Epithelial Cell





15 min. after Channel Formation:

- **Metabolism ceases**
- **Insects stop feeding**
- **Dehydration**
- **Death**

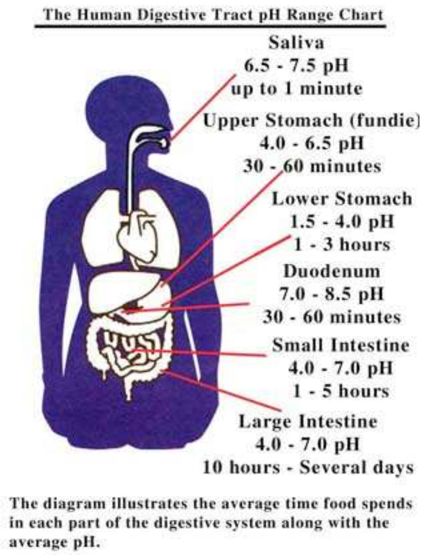
Difficult pests to control Only biopesticide works!   Cry3A protein

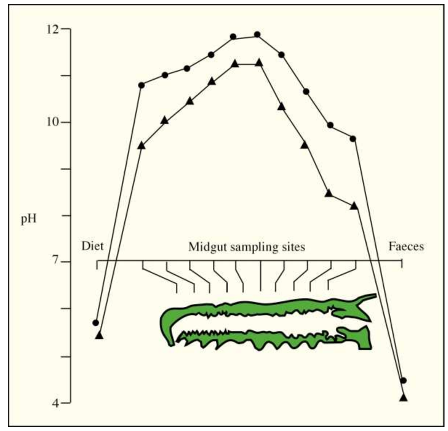
Most resilient pest - colorado potato beetle *Leptinotarsa decemlineata is a strong candidate for this award, having managed in the space of about 50 years to develop resistance to 52 different compounds belonging to all major insecticide classes (including cyanide).*

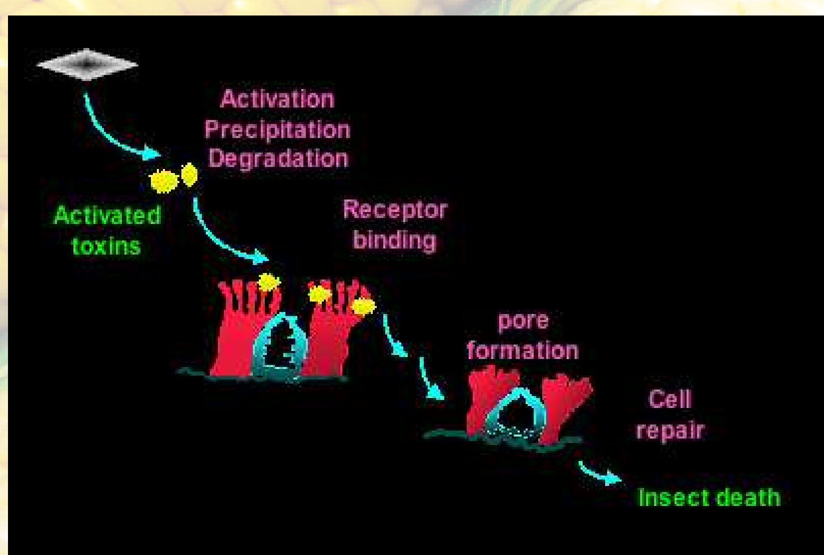
Beetle

therefore has effectively beaten the chemists.Wherever possible, biocontrol (control by natural enemies) should be part of the strategy because the predator-parasite can more easily keep up in this arms race, one which humans have so palpably lost.

Has monster been created?


The Human Digestive Tract pH Range Chart
Saliva
6.5 - 7.5 pH
up to 1 minute
Upper Stomach (fundie)
4.0 - 6.5 pH
30 - 60 minutes
Lower Stomach
1.5 - 4.0 pH
1 - 3 hours
Duodenum
7.0 - 8.5 pH
30 - 60 minutes
Small Intestine
4.0 - 7.0 pH
1 - 5 hours
Large Intestine
4.0 - 7.0 pH
10 hours - Several days
The diagram illustrates the average time food spends in each part of the digestive system along with the average pH.


12
10
7
4
pH
Diet
Midgut sampling sites
Faeces


Activation
Precipitation
Degradation
Activated
toxins
Receptor
binding
pore
formation
Cell
repair
Insect death

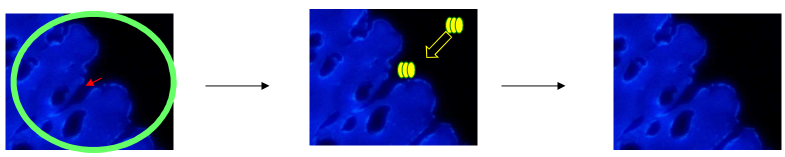
Identification of receptor
Generating knockdowns in larvae

Cell Lysis and Death

Receptor for Cry at epithelial tissue

Toxin interacts with receptor

Cells Treated with siRNA of APN receptor



NO Receptor for Cry at epithelial tissue

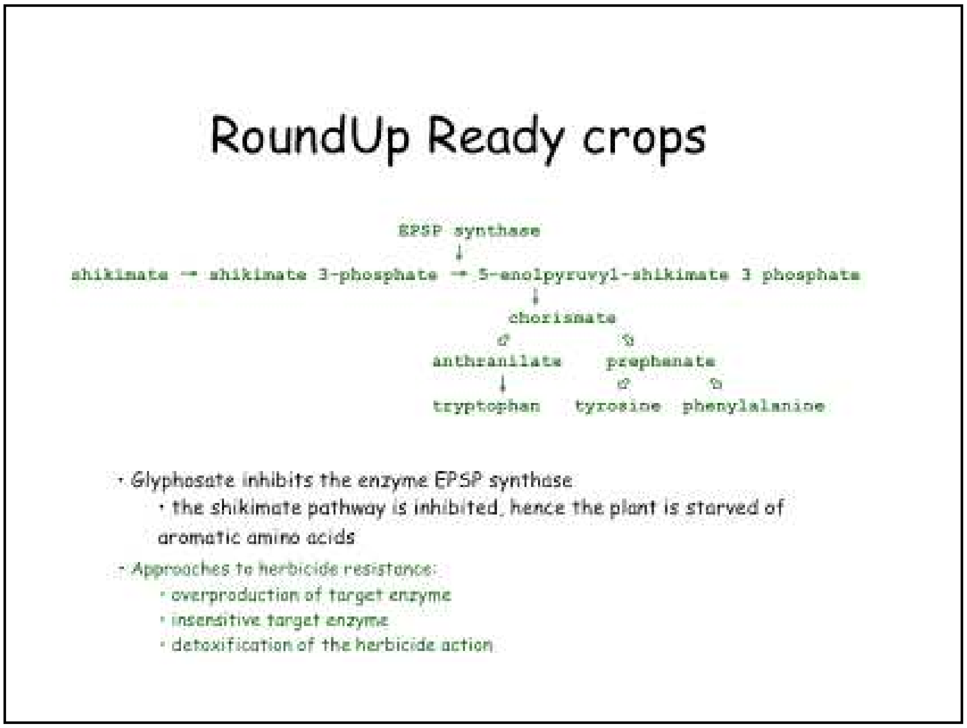
NO binding of Toxin

NO Cell Lysis

Application of Genetic Engineering in crop protection case study 2: Weed control

Weed control is essential to modern crop production practices. If not controlled, weeds can:

- Inhibit crop stand establishment
- Compete with the crop for:
- water and nutrients in the soil
- sunlight, thus limiting photosynthetic activity of the crop
- Harbor pests and pathogens



Tolerance to Glyphosate

Insert a gene encoding an EPSPS with reduced affinity for glyphosate

- *aro A*: *Salmonella typhimurium*
- *Epsps*: *Petunia hybrida*
- *CP4 Epsps*: *Agrobacterium* CP4 strain

Insert a gene which breaks down glyphosate

- *gox*: encodes glyphosate oxidoreductase (GOX); isolated from *Achromobacter* sp. strain LBAA

Roundup Ready™ Soybeans

Broad spectrumHerbicide glyphosate
EPSP synthase inhibitor

Current Products

- Canola
  - Herbicide resistant
    - Better for the environment
  - Altered fatty-acid composition
    - A value-added food

http://www.ens.lycos.com/ens/pics11/ canolaprods.jpg

Current Products

- Tomato
  - Flavr Savr Tomato
    - Delayed softening
    - Consumers get a better tasting tomato
    - Failed
  - Virus resistant tomato
    - Resistant to pests
    - Decreases the amount of pesticide applied to crops

Transgenic tomato plants show resistance (left) while non-transformed plants are susceptible to cucumber mosaic virus under field conditions (right)
http://www.apsnet.org/online/feature/BioTechnology/Images/2.4.jpg

Can GMO's have health benefits?

- Some plants have been altered to increase the nutritional value
- Pharmaceuticals, Plantibodies, and Edible Vaccines

What will biotechnology deliver?

- **By genetically modifying plants we can:**
  - Reduce pesticide use
  - Conserve fuel and water
  - Preserve non-pest insect populations
  - Increase food production per hectare of farmland
  - Enable crops to grow in sub-optimal conditions
  - Increase the nutritional value of food

Other Cool Plant Biotech Products

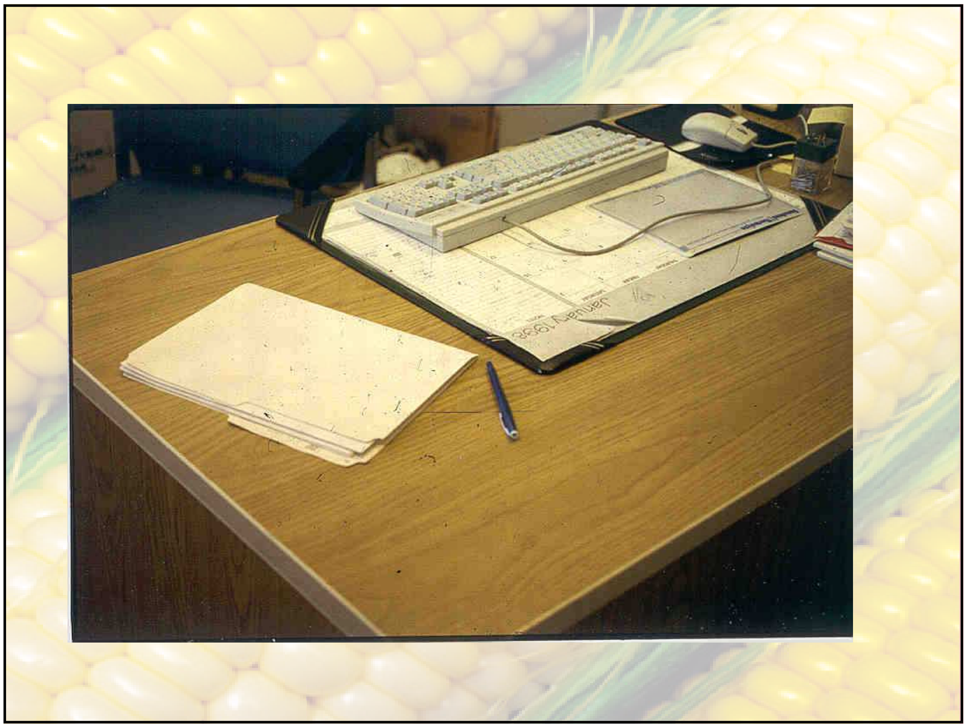
- Blue Carnations and Roses
  - Nature can not make these
- Non-allergenic peanut

- Decaffeinated coffee
  - Less processing

What does it take to bring a GM crop to market?

Variety release requirements: Conventional cultivars

- Agronomic performance
- Proximate analysis
- Antinutritive factors



Variety release requirements: Transgenic cultivars

- Agronomic performance
- Proximate analysis
- Antinutritive factors
- *Plus:*

Plus:

- Molecular characterization of inserted DNA,
- Southern and restriction analyses
- PCR for several fragments,
- Various enzyme assays (ALS, NOS, NPT-II)
- Copy number of inserts
- Size of each fragment,
- Source of each fragment
- Utility of each fragment
- How fragments were recombined
- How construct was delivered into flax
- Biological activity of inserted DNA (genes)
- Quantitative analyses of novel proteins (western analyses)
- Temporal activity of inserted genes
- spatial activity of inserted genes
- complete amino acid analysis
- detailed amino acid analysis for valine, leucine and isoleucine
- Toxicity (feeding trials were not warranted)
- Allergenicity (feeding trials were not warranted)
- Biological analysis:
- Pathogenicity to other organisms
- dormancy,
- outcrossing
- potential for horizontal gene transfer
- seed production
- flowering time,
- flower morphology
- analysis of relatives
- stability of inserted genes over seed generations
- survivability in natural environment
- survivability in agricultural environment in presence of herbicide
- survivability in agricultural environment in absence of herbicide
- Interaction with other organisms- alterations to traditional relationships
- Interactions with other organisms- novel species
- Changes to persistence or invasiveness
- Any selective advantage to the GMO
- Any selective advantage to sexually compatible species
- Plan for containment and eradication in the event of escape

What does it take to bring a GM crop to market?

- Money
- Patience
- Product

But…is it worth the cost, time and effort?

Documented benefits of biotech crops

- Farmers
  - ✓ Increased yields
  - ✓ Decreased chemical input costs
  - ✓ Cleaner fields, less dockage
  - ✓ Less fuel used
  - ✓ Less tillage

Documented benefits of biotech crops

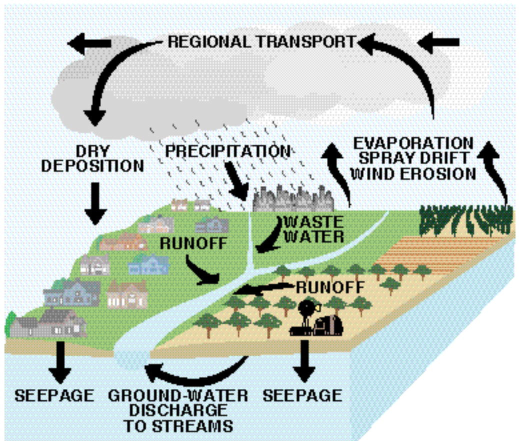
- Consumers
  - ✓ Safer food (less mycotoxin in maize)
  - ✓ Safer food (greater regulatory scrutiny)
  - ✓ Less pesticide
  - ✓ Environmental benefits

Documented benefits of biotech crops

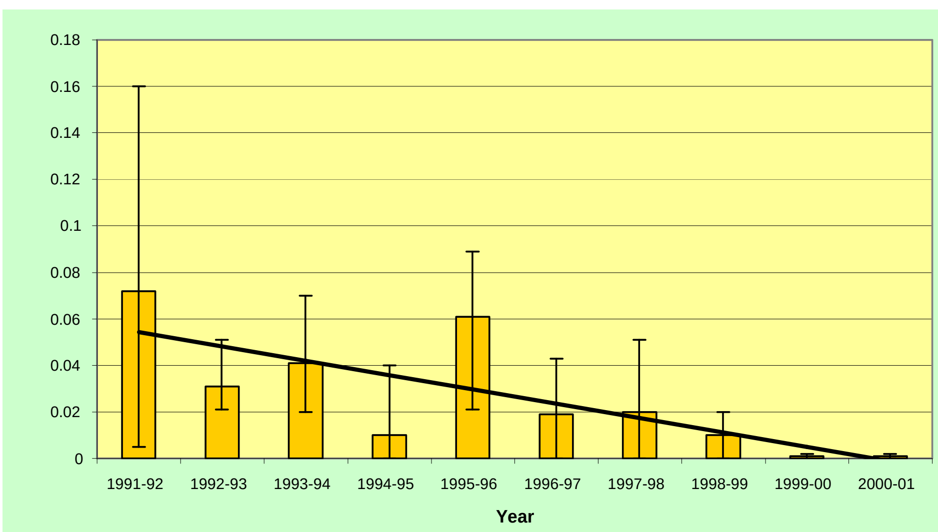
- Environment
  - ✓ Less pesticide burden
  - ✓ Safer pesticides
  - ✓ Improved soil from less tillage
  - ✓ Less fuel usage
  - ✓ Increased biodiversity

– *Sources:* NCFAP, Plant Biotechnology, June 2002;
– Canola Council of Canada, An agronomic and economic assessment of transgenic canola, 2001
– Munkvold, G.P., Hellmich, R.L., and Rice, L.G. 1999. Comparison of fumonisin concentrations in kernels of transgenic Bt maize hybrids and non-transgenic hybrids. Plant Dis. 83:130-138.

Fate of pesticides in environment



CONSEQUENCE:
Endosulfan levels in the Namoi River



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- crystal protein
- roundworm
- nematodes
- Neglected tropical diseases
- parasite
- organic farming
- insecticide
- intestinal parasite

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- Add to Connotea
- Add to Digg
- Add to Facebook
- Add to Newsvine
- Add to Del.icio.us
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Published online 2 March 2010 | Nature | doi:10.1038/news.2010.101

News

Soil bacteria could yield drug to treat roundworm

The natural insecticide Bt treats infections in mice.

Janet Fang

A bacterial protein used in a common pesticide kills intestinal parasitic roundworms in mice and may become a treatment option for humans, researchers say.

Intestinal roundworms, including hookworms and whipworms, infect well over one billion people, lowering immune systems for HIV, malaria and tuberculosis and debilitating both physically and cognitively.

Bt toxin, produced by bacteria, could help battle roundworm infections.
L. V. Bergman/CORBIS

The new approach, published today in *PLoS Neglected Tropical Diseases*[1], uses crystal proteins from the soil bacterium *Bacillus thuringiensis* (Bt). Organic farmers have used Bt to kill insects for decades, and plants have been genetically modified with Bt genes since 1996 so crops such as corn and potato can produce the crystal proteins, protecting themselves from insects without any pesticides.

"This bacterium is a natural soil predator of nematodes," says author Raffi Aroian from the University of California, San Diego. "The bacterium can kill the worm," he adds, "and it has a great track record for safety around vertebrates."

Hookworms and some other parasitic nematodes have shown signs of resistance to albendazole, the current treatment approved by the World Health Organization. "Compared to the best drugs people have developed to treat human parasitic worms, this natural protein is at least three times better," Aroian says.

Of mice and men

The parasitic worm *Heligmosomoides bakeri* naturally infects mice and is a common laboratory model organism for studying human diseases caused by roundworms, such as river blindness and elephantiasis. The researchers orally infected mice and waited for the parasites to mature and become reproductively active adults before treating the mice with the crystal protein. A few days after treatment, the mice had 98% fewer parasite eggs in their faecal samples and 70% fewer adult parasites in their intestines compared to untreated mice.

Aroian's previous study[2] using a type of human intestinal roundworm parasite to infect hamsters showed a 90% reduction in three doses of Bt. "Taken together, the two *in vivo* studies have shown significant therapeutic activity of a crystal protein against two species of nematode," says Andrew Kotze from the livestock industries division of Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) in St Lucia, Queensland.

Aroian hopes that these mouse and hamster studies will pave the way to human trials within two to four years. Nearly all of the current drugs to treat nematode diseases were invented for veterinary purposes, he says, and then were approved for use in humans. "Do you ever say to your doctor, give me the best vet drug you have for treating my condition?" he says. "This is the only disease I can think of when that's what we do."

According to Aroian, this treatment can be grown cheaply in large quantities. Bt is grown in fermenters that hold thousands of litres for use as an agricultural spray and to control mosquitoes and blackflies.

The cost to treat one child with Bt would be 28 cents, Aroian estimates. It could be driven down more with optimizations in production, such as making sure more of the protein reaches the intestine without being dissolved in the stomach first. "The issue of protecting the toxin as it passes through the stomach to be released in the intestine will have to be addressed but does not seem to be insurmountable," says Ray Akhurst from the entomology division of CSIRO in Canberra.

Aroian adds, "Even at a quarter a pop, it's a cheap way to treat all those children." ■

References

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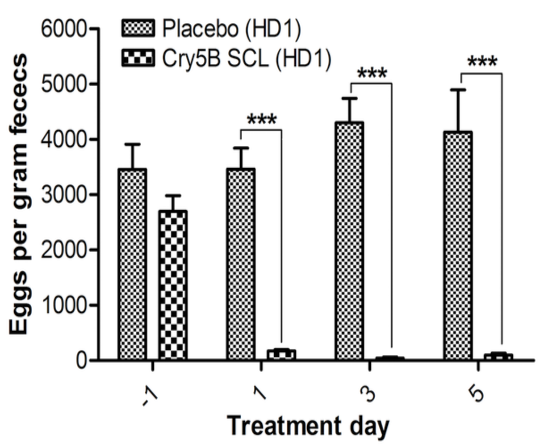

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Plant Biotechnology Product Path

Transgenic Crops Have Many Hurdles

Discovery → Line Generation → Product Advancement

Gene Discovery → Gene Transfer → GH & Field Evaluation → Line Selection → Variety Development → Field Trials → Field Production → Seed Sales → Post Market

DBT Biosafety Audit

Discovery Program

Gene Discovery → Gene Transfer → GH & Field Evaluation

Regulatory Dossier

RDAC IBSC RCGM
GEAC MEC
D&SBC

3 Phases of Safety Assessment

Discovery → Line Selection → Product Advancement

Product Concept → Gene Discovery → Transfor-mation → GH & Field Evaluation → Line Selection → Variety Development → Field Production → Market → Post Market

Phase I

Safety of gene, protein, crop

- Choice of genes / proteins
  - mechanism of action
- Source of genes
  - history of safe use
  - ethics
- Environmental / ecological considerations

Phase II

Biological / agronomic equivalence

- Stringent agronomic performance and efficacy criteria
- Greater than 99% of all events are eliminated
- Key step in product evaluation for conventional varieties

Phase III

Detailed product safety

- Food
- Feed
- Environmental

GM crops

- Rate of Technology uptake is the fastest in history (followed by mobile phones and computers)
- 3% of arable land under GM crops in 1999
  - 72% of this in the USA
  - 16% Argentina
  - 10% Canada
- biggest area = round-up ready soy
  - 22% reduction in total herbicide usage (actual increase in glyphosate)
  - 90% reduction in topsoil runoff (No Till system)
- Bt corn
  - 72% reduction in insecticide use (but not much used anyway)
  - 10% yield increase
  - net benefit $44 per hectare
  - reduction in mycotoxins on grain (aflotoxin, fuminosin)
  - New release MaxGard for corn root worm - 5 Mt insecticide per year in USA alone
- Bt cotton
  - 5.3 million fewer insecticide applications in 1998
- round-up ready canola (not all from GM !)
  - little discussion - But already weed problems reported in Canada