"Biotechnology part of a sustainable solution for future agriculture"

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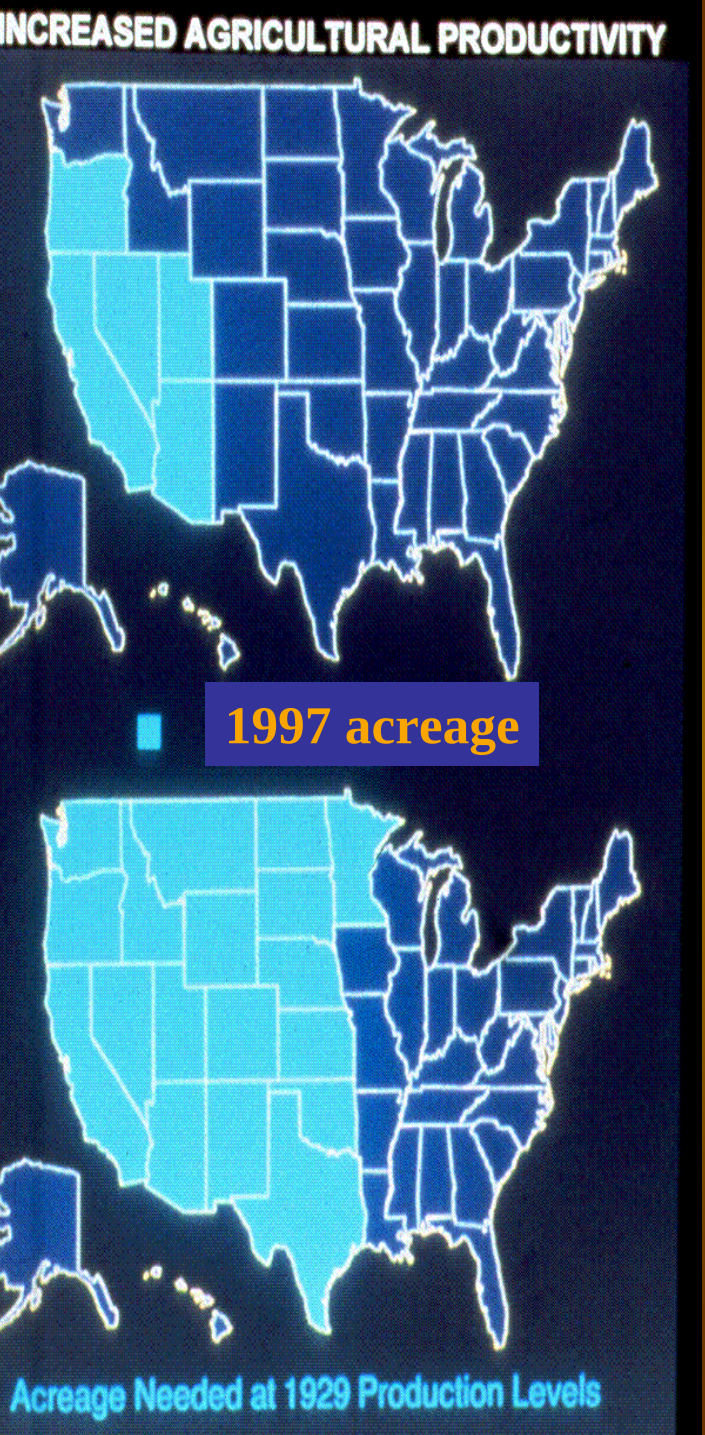
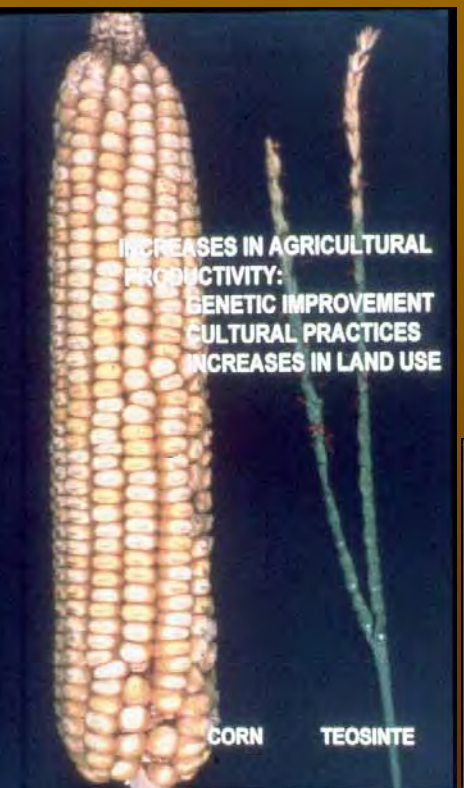


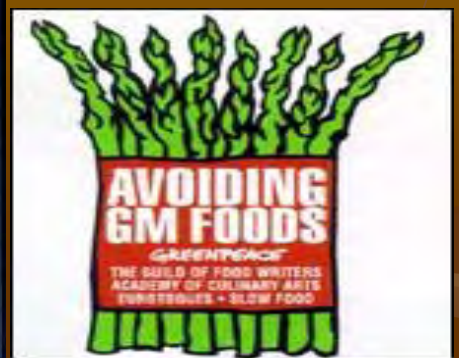
Reality check

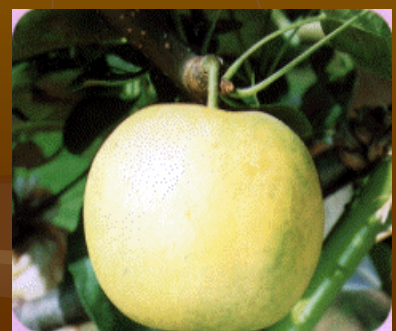
- High yielding affordable high quality food feed and fuel with minimum inputs
- 17% of land under cultivation degraded by human activity 1945 to 1990. Ag land shrinks by 20,000 ha yearly. (World Bank)
- Without yield increase land use will 2X by 2050.
- Latin America: greatest yield increase had lower land use (less deforestation)
- High yield “land sparing” better than “wildlife”-friendly inefficient land use farming (Green, Royal Soc. Bird Protection 2005)
- EU pursuing 19th C technology, young scientists will flee. If the EU engages rational harmonized regulatory framework it will encourage a more rapid international diffusion of the technology.
- EU Commission "need to take urgent action to avoid negative implications for EU livestock production and agriculture overall".

Agriculture: A history of Technology



8,000 BC	Cultivation
19thC	Selective Cross breeding
Ea 20th C	Cell culture
Md 20th C	Somaclonal variation
1930s	Embryo rescue
1940s	Mutagenesis and selection
1950s	Anther culture
1970s	Recombinant DNA
1980	Marker assisted selection
1990s	---omics - Bioinformatics
2000s	Systems Biology
21st C	Epigenetics/RNAi/Paramutation
	Adaptive technology/transgenomics

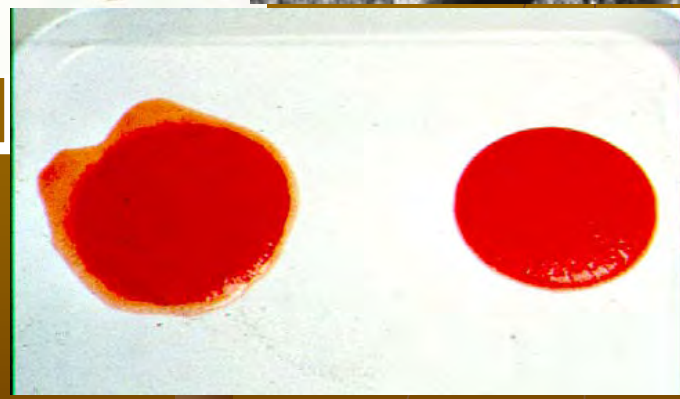




Wide Crosses

Tomatoes are members of the Deadly nightshade family

- **High solids = More sauce: Two approaches one end: "Natural" cross with high solanine "toxic" wild tomato**
- **Using antisense, switch off existing gene – no introgression of genes from the toxic plant**



Biotech Crops –"process" regulation

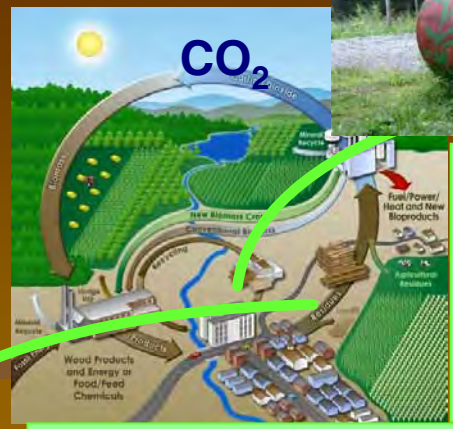
- Commercialization: 7 to 10 years -at least 9 review stages
- Biotech crops and foods more thoroughly tested than conventional varieties ("assumed" to be safe)- One biotech soybean subjected to 1,800 separate analyses
- 23 feeding studies - dairy, beef, poultry, soy/corn equivalent in composition, digestibility and feeding value to non-GM. Clarke et al 2000
- Product description (7 items) - Substantial equivalence with parent variety - Molecular characterization (17)
- Toxicity studies (as necessary) (5) - Antibiotic resistance marker genes (4) - Nutritional content (7+)- Allergenicity potential - Anti-nutritional effects - Protein digestibility
- Environmental aspects (5 items)- Ecological impact (5 items)

Recent studies

Wheat (Baker 2006), Potato (Catchpole 2005)

Transcriptomic and Metabolomic studies show greater variation between conventional bred cultivars and even growth locations than between GM and parental variety (except of course for the intended modification!) - differences between sites were generally greater than differences between lines

Economic wealth could be created by GMOs



Renewable Resources

$5 B to farmer profits by 2025

Value

Plants as Factories

Pharmaceuticals/ Industrial products (Ventria – Rice Lactoferin Lysozyme Peru 30% Less Diarrhea, Quicker recovery 3/6 days, 1/3 less recurrence

Quality Traits - ($210B by 2010)

Shelf life –

Improved Nutrition –Improved Functionality

Macro: protein, oils, carbs, fibre

Micro: Vitamins, minerals, Phytochemicals – Antioxidants

Remove Antinutrients/allergens/ Toxins

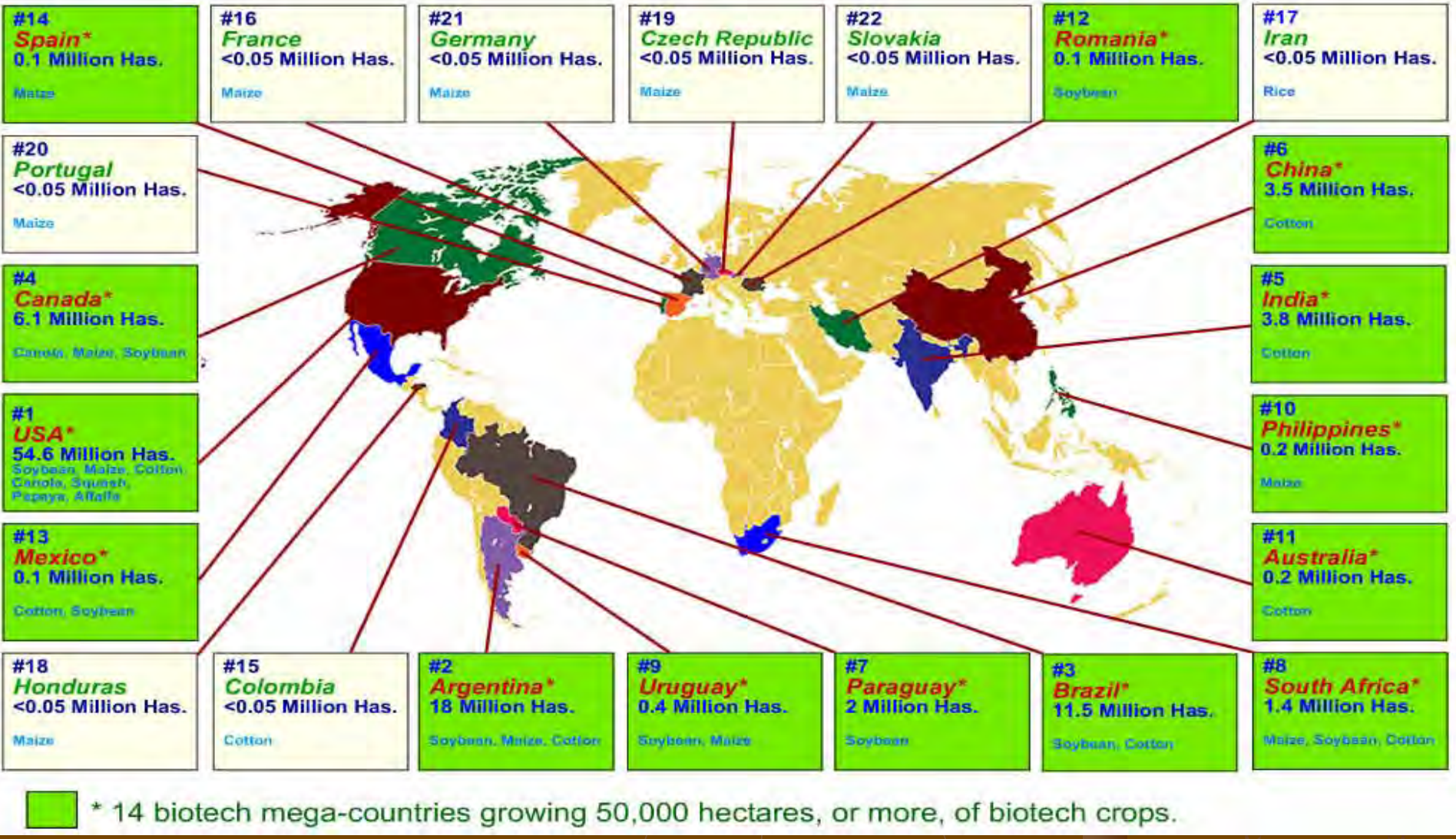
Agronomic Traits – $30B

Biotic/ Abiotic Stress /Yield

1st Wave **2nd Wave** **3rd Wave** **4th Wave**

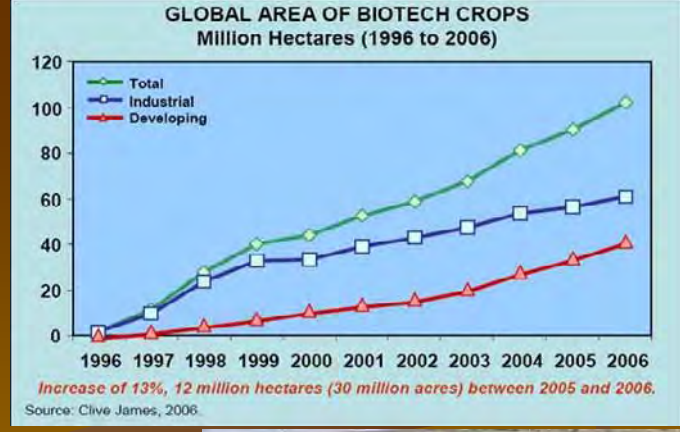
Biotech Crop Countries and Mega-Countries (2006)

Source: ISAAA



- Biotech Crops 2006: 252 M acres (102 M hts) 22 (11 LDC) 13% over 2005
- Spain lead country in Europe planting 60,000. Collective Bt maize hectarage in the 5 (France, Czech Republic, Portugal, Germany, and Slovakia) up 5X
- 2007: French over 21,000 HA with GMO maize four times the area sown in 2006.

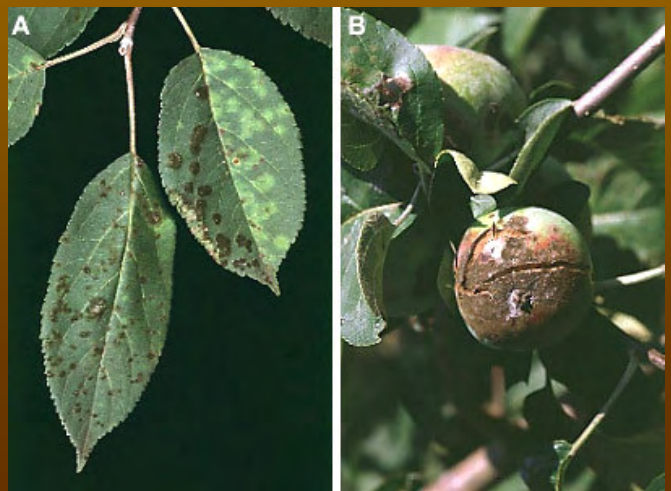
Benefits 1996- 2006



- **Biotech Crops 2006: 252 M acres (102 M hts) 22 countries up 13% - 1996 to 2006 60X increase, highest adoption rate of any crop technology** (James, 2007)
- **10.3 M farmers up 8.5 M 90% resource-poor LDC**
- **Net economic benefits cumulative $27 billion.**
- **Pesticide spraying down by 380 M lbs (172 M Kg.) Environmental footprint of pesticide use by 14%.**
- **GM reduction in 9.4 billion kg of CO_2 emissions in 2004 equivalent removing 5 M cars from the roads.** (Brookes 2005)
- **Herbicide-Tolerance - increase in no- till: reduction in erosion, soils much healthier, organic matter, less soil compaction, fuel use down by 20 gals/acre**
- **CP papaya saved Hawaii papaya industry (and helped organic farmers!)**
- **China BT rice pesticide use down 80% lives saved**
- **Organisms "Bt crops" fared better in field trials than those with insecticides (Marvier et al 2007)**

Fire blight -bacterial disease of apple E. amylovora hard to control limited effectiveness of antibiotic sprays Transgenic apple expressing the cecropin lytic peptide analog showed increased resistance to E. amylovora in field tests. Norelli, 1998. Acta Horticulturae 489:273-278.

Plum pox virus (PPV) is contagious pathogen - devastating consequence for prunus fruit. Transgenic clone CP C5 highly resistant to PPV - post-transcriptional gene silencing (PTGS) This system is totally resistant so that the virus is not harbored unknowingly - Tolerant trees can harbor virus



***Venturia inaequalis*, apple scab fungus, fruit productivity, marketability, and shelf life. Multiple applications of fungicides needed during the growing season. Transgenic 'McIntosh' apple trees expressing the endo/exochitinase gene or both genes have increased resistance to apple scab**

From Genomics to Improved Crops

The 2 Phases of Biology

Genotype ⇄ Phenotype

Reverse Genetics →

← *Forward Genetics*

Gene ↳ RNA ↳ Proteins ↳ Metabolites ↳ Organism

Bioinformatics

Sequence Map

Transcriptome

Proteome

Metabolome

Profiling

Genomics Platform

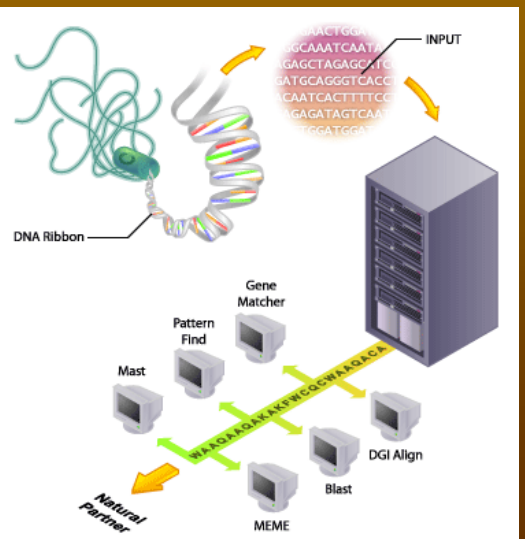
Phase 2

Molecular Breeding

New Plant Traits

Transgenics

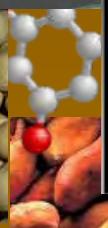
Improved Crops

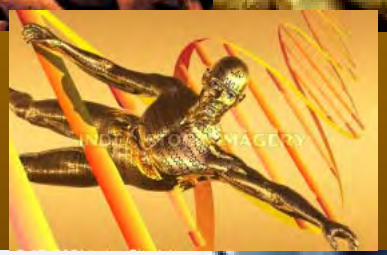


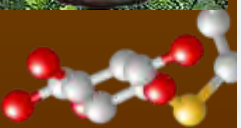
Phase 1

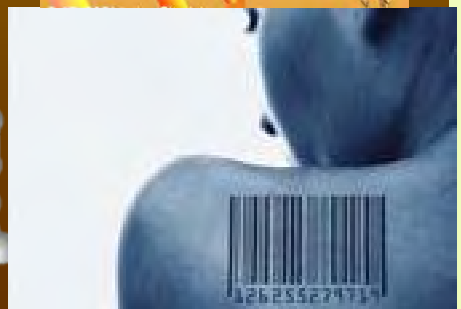
---omics – Metabolic Pathways - Systems Biology –Epigenetics –RNAi- Paramutation - - Adaptive technology - transgenomics

Improved Nutritional Content









- Many common food crops not perfect for nutritional requirements of humans or animals.

Functional Foods: offering potential health benefits that go beyond satisfying basic nutritional needs.

- Functional components associated with least four of leading causes of death: cancer, diabetes, cardiovascular disease, and hypertension (aging?)

Macro:

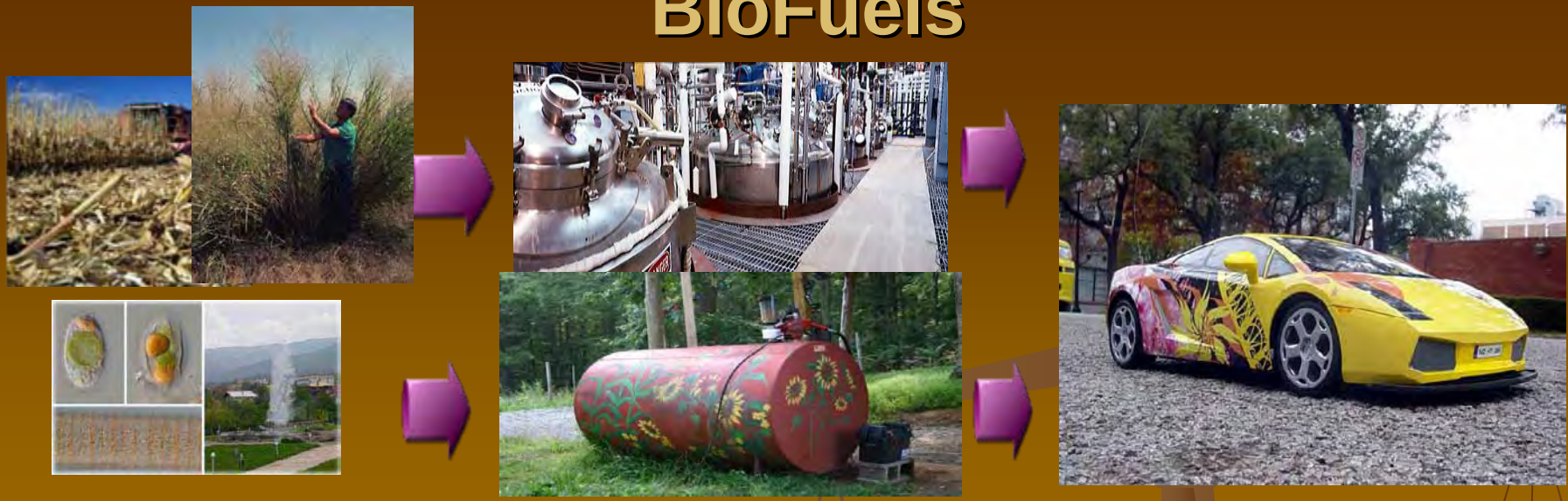
- Protein (Better ratio, High lys/ meth, artificial)
- Carbohydrates (>complex – resistant starch)
- Fats (Higher Oleic (MUFA), Ω-3, Ω- 6 GLA, CLA, MCFA, lower SFA, PUFA)
- Fibre (low for animals, high for humans (prebiotics, FOS, inulins, lignans)

Micro: Vitamins (Golden rice II, vit C, vit E), co-factors, minerals (Fe, Ca, Zn)

Phytochemicals: carotenoids, flavonoids, isoflavones, isothiocyanates, phenolics (Sirtuins)

Anti-nutrients: TI, Phytate; Allergens: soy P34, Toxins: glycoalkaloids, cyanogenic glucosides

BioFuels



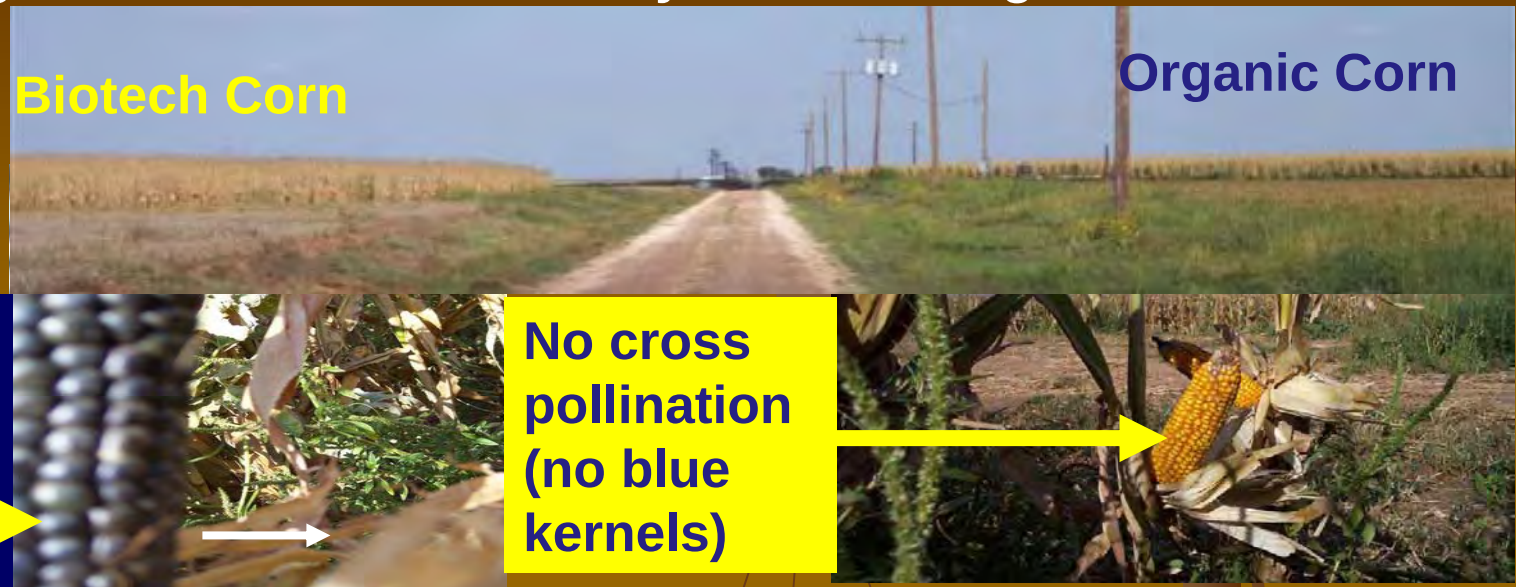
- The challenge: 5-10 times more efficient than today.
- **Biomass Conversion:** Biomass includes organic polymeric material: lignin, starches, celluloses, and oils . Plants and algae billions of tons annually through photosynthesis. Other sources food processing wastes, paper
- Plant biomass include cellulose bioconverted ethanol; hemicellulose hydrolyzed to sugars, xylose and glucose; lignin potential feedstock;
- Maize other cereals, Switch grass, willow, poplars, Elephant grass
- Biodiesel biodegradable alkyl esters transesterification of vegetable oils or animal fats., (60% less CO_2) the hydroxy fatty acids from these oil sources used in lots products, (cosmetics, waxes, nylons, plastics) Rapeseed, Botryococcus braunii (Bb) colloidal microalgae
- Concerns: Food costs trade off – Production Efficiency – ecological impact

Concerns

- Antibiotic Resistance
  - Transposon tagging
  - Positive selection – exclusive energy source
- Gene Flow-
  - Space
  - Male sterility
  - "Terminator" technology
  - Chloroplast transformation
- Effect on non-target species
  - Tissue specific expression
  - Chloroplast transformation
- Loss of effectiveness – resistance management
  - Refugia
  - Gene Pyramiding
  - Gene shuffling
- Reduced diversity
  - More sources of genetic diversity – rescue heritage varieties and landraces
- Co-existence

Cooperation works

Organic Blue Cornfield near yellow non-organic field Fred Yoder Ohio

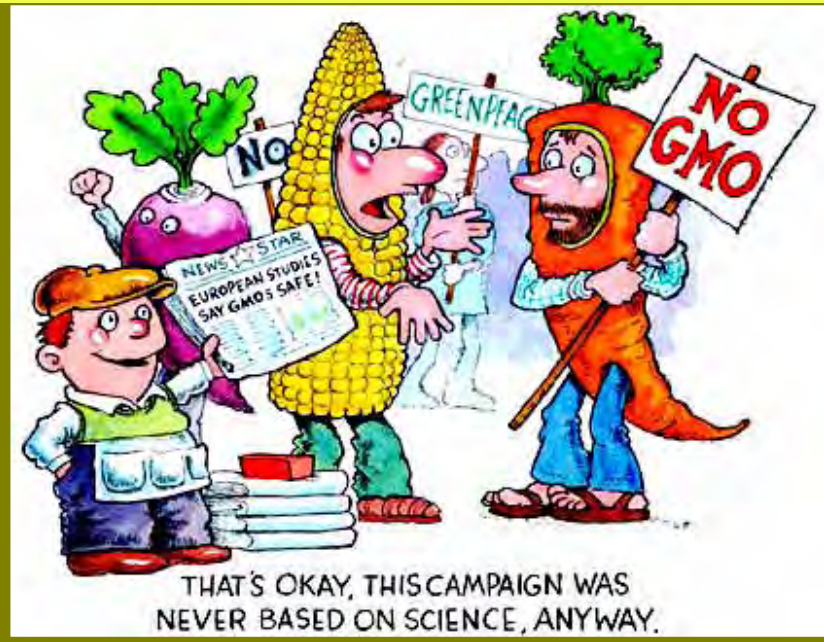


- Historically, worldwide the market adequately addressed economic liability issues relating to trace presence of unwanted material in any agricultural crop.
- Onus is on growers of any specialty crops to take action to protect the purity of their crops since these are self-imposed standards for and by that market.
- US organics cannot be downgraded or growers decertified by unintentional presence when best practices followed: no producer impacted to date
- Every case brought for infringement has involved a claim that the farmer charged with infringement was an intentional infringer (i.e. trace presence was not the issue) To date, each of these cases was upheld by the courts.

Following are from "trusted" Sources? EU? WHO?

- EU Commission Report – Results from 400 teams over 15 years- The use of more precise technology and the greater regulatory scrutiny probably make GMOs even safer than conventional plants, foods.
- WTO: Europe failed to follow its own procedures, resulting in undue delay of decisions (Feb 2006).
- Declaration signed by over 4,000 scientists including 25 Nobel Laureates

http://europa.eu.int/comm/research/fp5/eag-gmo.html



World Health Organization (2005)

- Indirect benefits include reduction in ag chemical usage, enhanced farm income, crop sustainability and food security, particularly in developing countries
- The report concludes, "GMOs offers potential of increased agricultural productivity, improved nutritional values that can contribute directly to enhancing human health and development..
- http://www.who.int/foodsafety/biotech/who_study/en/index.html

Better Quality "Livestock"

EnviroPig
Phytase in saliva

Transgenic Coho Salmon Sockeye GH grows 6X times faster converts feed 20% more effectively reaches maturity ½ time WT

Sweetheart (2006) GTC Biotherapeutics. ATryn, anti-clotting first drug approved by the European Medicines Agency (EMEA). Pharming Group anti-inflammatory drug in Transgenic rabbits.

Vegetarian milk (Improved FA)

Lysozyme Goats (Also Improved FA)

HemaTech "knocked out" the prion gene in 12 cloned calves. No disease when brain tissue from two of the animals exposed to mutant prions

Animal Biotechnology Oversight

- Biomedical: xeno mobilization of new infectious agents

Food/feed: Substantial Equivalence

- New proteins, and food safety concerns posed by biological activity, allergenicity, or toxicity evaluated case-by-case
- Clones: genomic reprogramming - altered expression – epitasis – concern
- No current evidence adult somatic cell clones or their progeny safety concern.

FDA: Dec 2006 Clones good to go but "voluntary" withholding to remain!

- Cloned cattle 6-18 months "virtually indistinguishable" from donors, can give birth to healthy offspring (elite breeders not likely to end up on the plate).
- Live neonatal clones pose an extremely limited risk as unlikely to be food

Environment

- Escape and become established in the natural environment.
- Current reg framework not adequate – esp. arthropods.

Animal Welfare

- Potential to cause pain, physical and physiological distress, problems, also potential to alleviate or reduce those problem

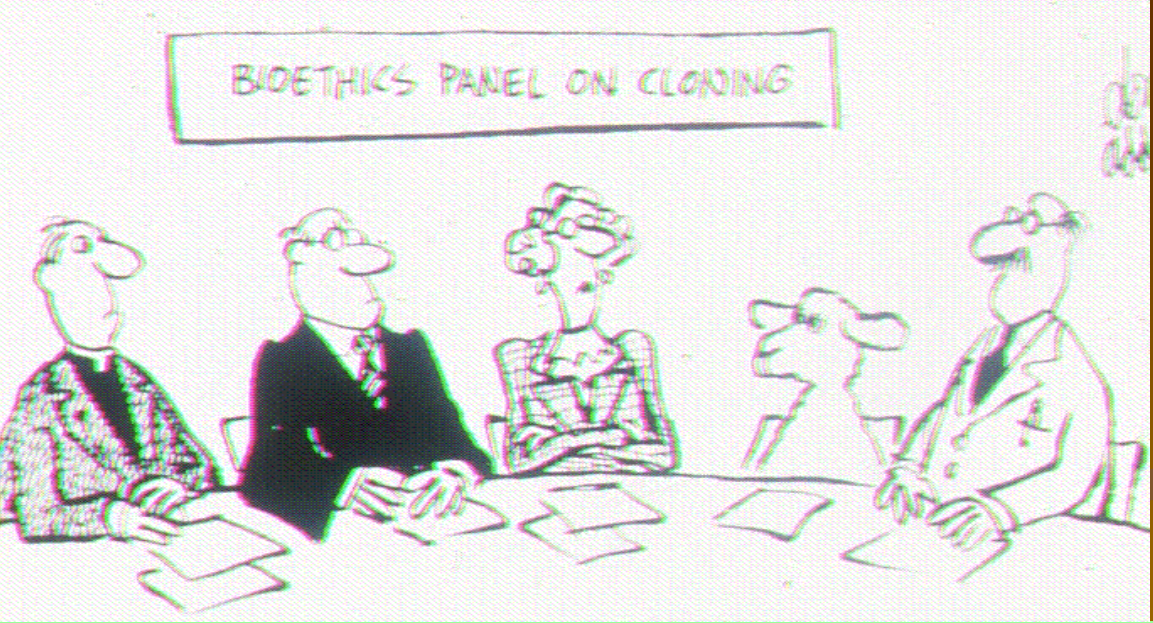
Farming/Pharming

- TG animals for production or therapeutics under CVM as new animal drugs.

IFIC 60% state potential benefit of animal biotechnology improving "the quality and safety of food" would positively impact their impression. Favorability may increase slightly with FDA assurances of safety of food produced using animal biotechnology.

International Food Information Council (IFIC) 2006

- 72% consumers confident in the safety of the food supply.
- Food safety concerns, most mention microbial foodborne illness (36%) or improper handling (35%), 3% cite food biotechnology.
- 59% report avoiding some type of food or ingredient (none mention biotech foods as something they are avoiding.
- Consumers who have an opinion almost twice as likely to have a positive view (32%) than to have a negative view (17%).
- 82% state no information would like to see added to labels.
- Only 1% name biotech as information they would like to see.
- 60% potential benefit of animal biotechnology improving “the quality and safety of food” would positively impact their impression. Favorability may increase slightly with FDA assurances of safety
- Learning biotech benefits significant impact on likelihood to buy
  - 77% likely to buy for increased omega-3 fatty acid content;
  - 75% for reduced saturated fat content
  - 75% insect protection/pesticide reduction
  - 63% improved taste or freshness
- Between 40% to 70% of foreign consumers state their purchasing behaviour would remain unchanged if GMOs used in NZ (CGI Survey)



Greatest Challenges going forward

- Technical
- Intellectual Property: PIPRA - Specialty crops – FTO
- Liability
- Biosafety: so–called – LDCs – Specialty crops
- Acceptance: - countering fear and misinformation - moral imperative real need v. hypothetical risk

Take Home Message

Biotechnology is a useful tool not a panacea

- Improve Food and Nutritional Security
- Enhance Production Efficiency
- Promote Sustainable Agriculture
- Reduce Environmental Impact
- Empower the Rural Sector through Income Generation & Reduce Economic Inequity
- Increase Crop Productivity
- Reduce Crop Damage & Food Loss
- Improve Food Safety
- Enhance Orphan Crops

Trust:

- Openness Competence
- Scientific honesty Admission of problems

Communication:

- Proactive agenda setting
- Providing easily understandable contextual information