Engineering Crops for the Developing World

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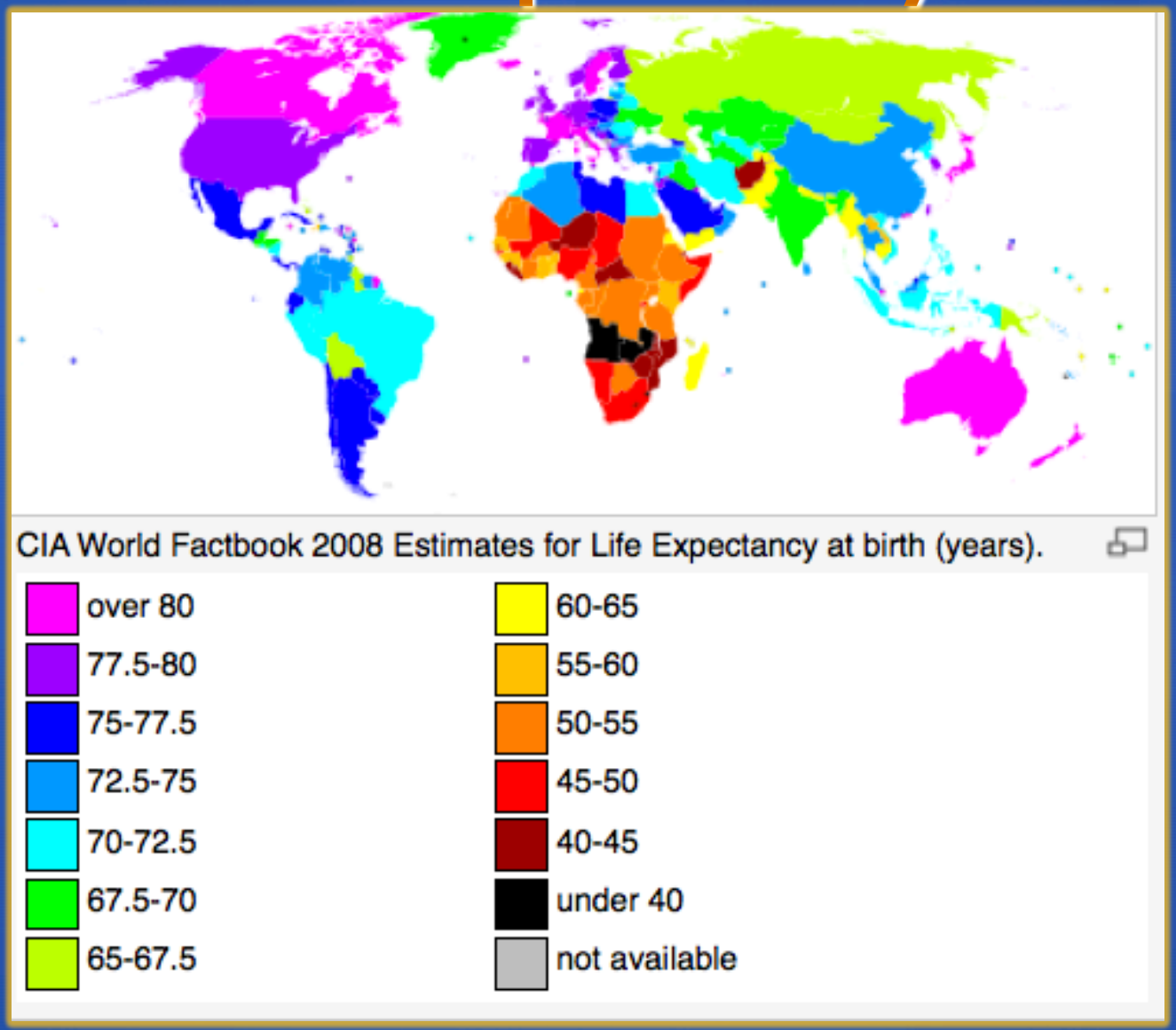
Life Expectancy



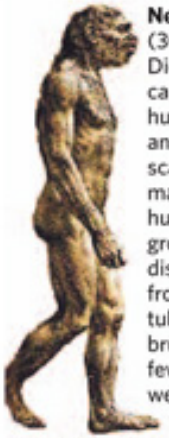
Source: Wikipedia

LIFE EXPECTANCY THROUGH THE AGES

Early humans did not generally live long enough to develop heart disease, cancer or loss of mental function. A snapshot of how life expectancy has changed, and the big killers of each era:

AVERAGE LIFE EXPECTANCY

30 years



Neanderthals (30,000 years ago): Died of injuries caused by rock falls, hunting accidents and conflicts. Food scarcity led to malnutrition. These hunter-gatherer groups contracted diseases that spread from animals. Rabies, tuberculosis, brucellosis, yellow fever and encephalitis were widespread.

38

Neolithic (8500 BC to 3500 BC): Agriculture, irrigation and urbanization brought problems associated with settled populations, such as fecal contamination of water and diseases such as cholera, smallpox, typhoid, polio and influenza. Malaria and other diseases carried by mosquitoes and insects, which fed on domesticated animals, appeared.

35

Classical Greece and Rome (500 BC to 500 AD): Tuberculosis, typhoid fever, smallpox and scarlet fever spread among the denser urban populations. Malnutrition, gastroenteritis and violence were also big killers.

48 EARLY MEDIEVAL **38** LATE MEDIEVAL

Medieval period (500 AD to 1500 AD): Life expectancy grew with urbanization, but famine caused by crop failures and bubonic plague were the big killers. The Black Death (1347-1351) wiped out 25 million people in Europe and 60 million in Asia, returning several times, culminating in the Great Plague of London (1664-1666). By 1500, life expectancy had dropped back to 38.

40

Victorian (1850s to 1900): Typhus, typhoid fever, rickets, diphtheria, tuberculosis, scarlet fever and cholera raged in crowded cities.

MEN **70** WOMEN **75**

1900s: Better health care, sanitation and living conditions boosted life expectancy to 70 for men and 75 for women by 1950.

CANADA: MEN **82** WOMEN **85**

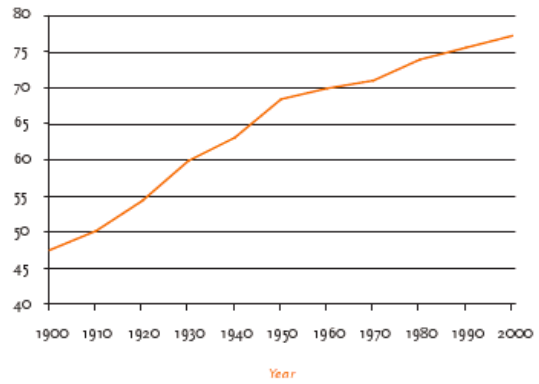
Today: Cancer, heart disease and stroke are the biggest killers in the developed world. Our longer lifespan also comes with unprecedented loss of mental function and mobility problems.

RESEARCH BY RICK SZNAJDER/TORONTO STAR LIBRARY

SOURCES: JOURNAL OF POPULATION RESEARCH, PRINCETON UNIVERSITY, STANFORD UNIVERSITY, WORLD HEALTH ORGANIZATION

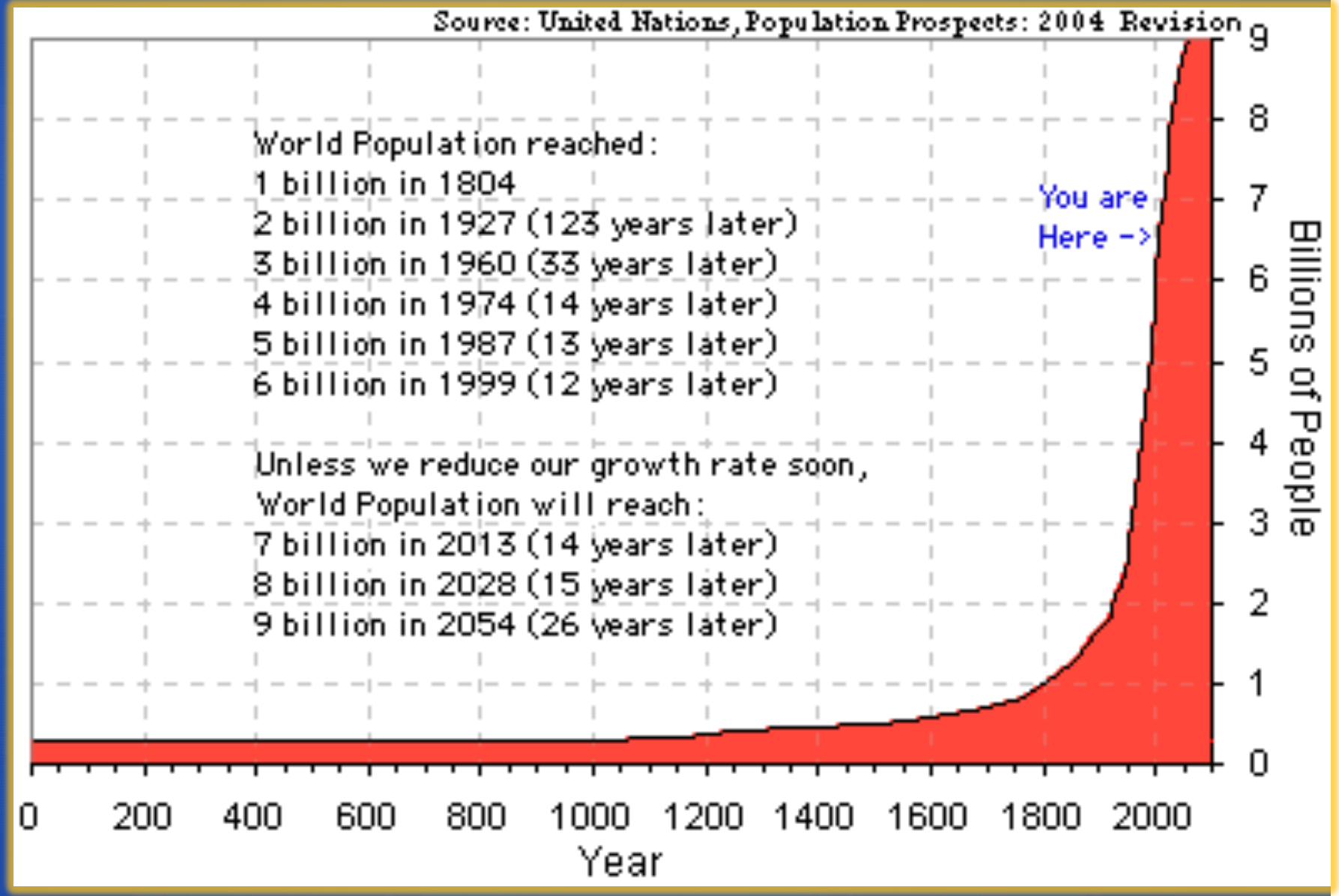
Figure 1

Life Expectancy at Birth in the United States, 1900–2000



SOURCE: E. Arias, "United States Life Tables, 2001," *National Vital Statistic Reports* 52, no. 14 (2004): table 11.

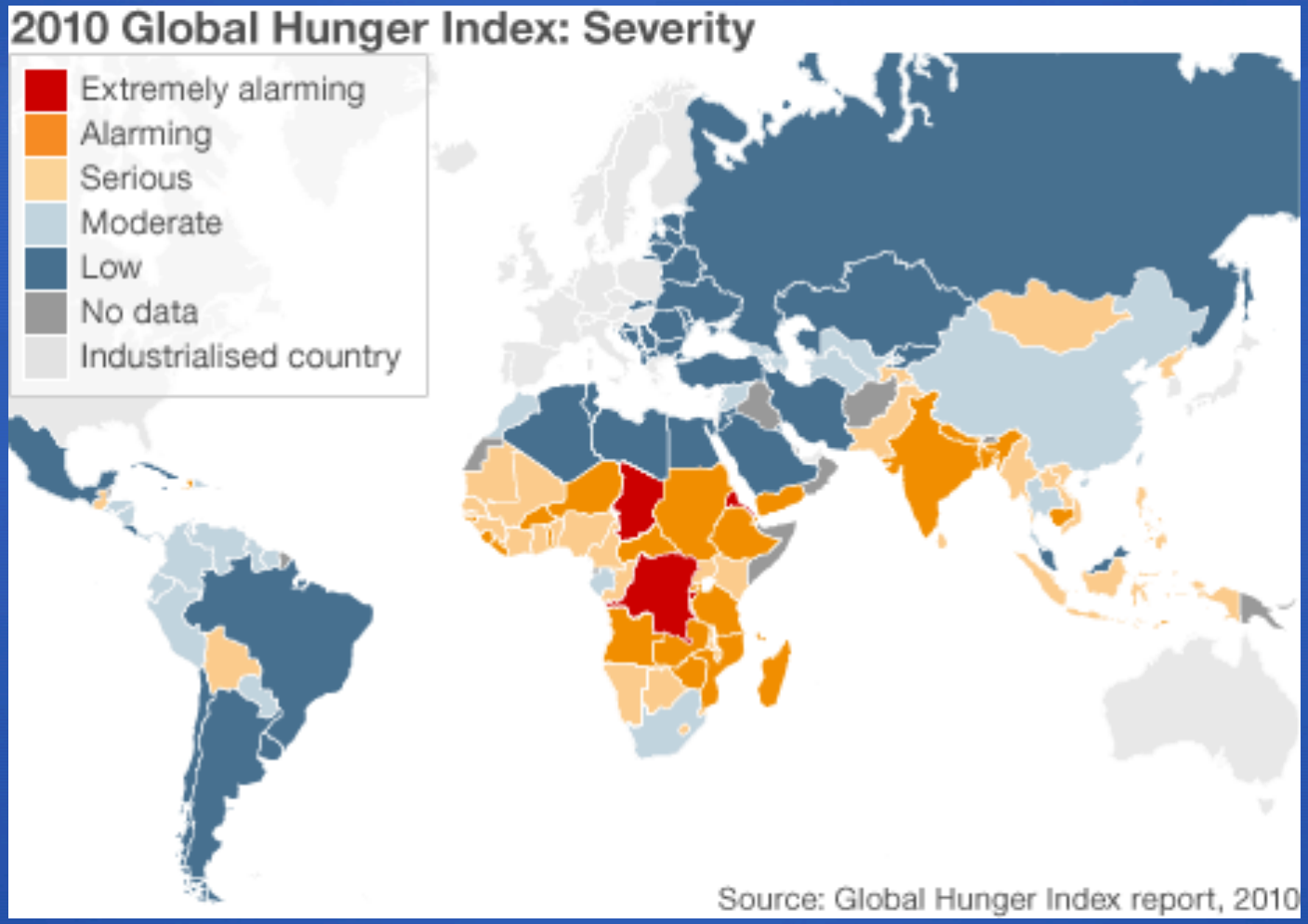
World Population Growth



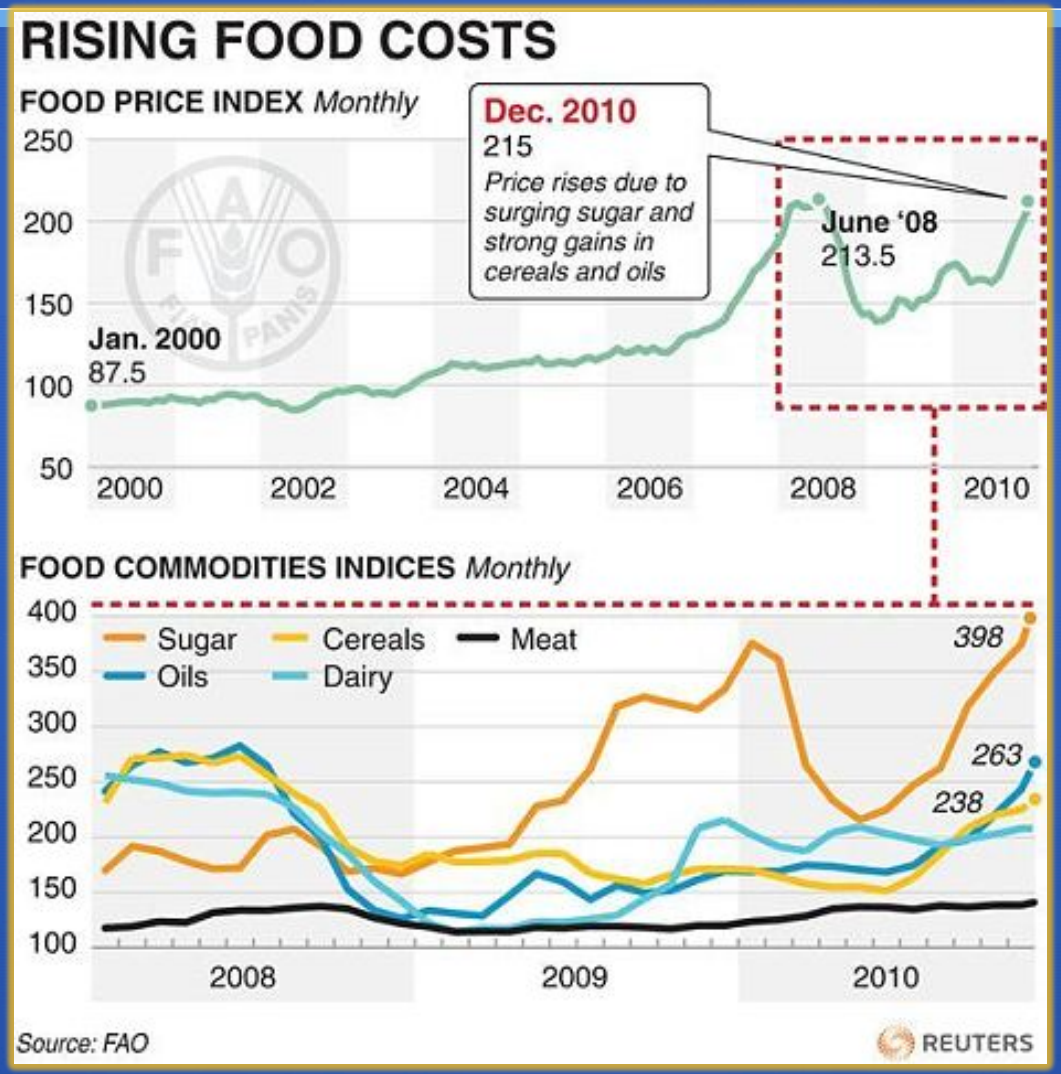
Clicker Question

- The current global population is close to
- a. 2 billion
- b. 7 billion
- c. 10 billion

Global Hunger Map



Cost of Food is Going Up



Stark Realities…..

- **Nearly a billion people go to bed hungry every day**
- **About 30,000 people, half of them children, die *every day* due to hunger and malnutrition**
- **Nearly 1.2 billion people live on less than a dollar a day**
- **650 Million of the Poorest Live in Rural Areas**

"In the next 50 years, mankind will consume as much food as we have consumed since the beginning of agriculture 10,000 years ago - Dr. Norman Borlaug"

Clicker Question

- How many people die every day due to malnutrition and hunger around the globe?
- a. 300
- b. 300,000,000
- c. 30,000

Hunger - why?

- Poverty
- Poor governance
- Low agricultural productivity
- Poor infrastructure (roads, market access..)
- Little science R &D
- Conflicts
- Infectious Diseases (Malaria, HIV)
- International markets

Low Productivity of Agriculture in the Developing World

- Poor soils
- Unfavorable environment
- Little or no chemical input
- Small Holdings
- Drought
- Market Access
- Disease, Pests, Weeds
- Storage and Transportation

Food and Agriculture Organization (FAO)

To feed a world of 9 billion people in 2050, without allowing for additional imports of food:

Africa has to increase its food production by 300 percent

Latin America by 80 percent; and Asia by 70 percent. Even North America must increase food production by 30 percent

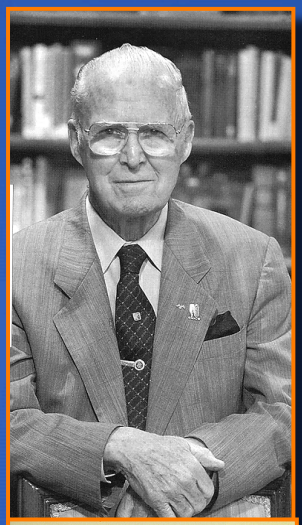
•Without an Increase in Farm Productivity, Additional 1.6 Billion Hectares of Arable Land will be Needed by 2050!

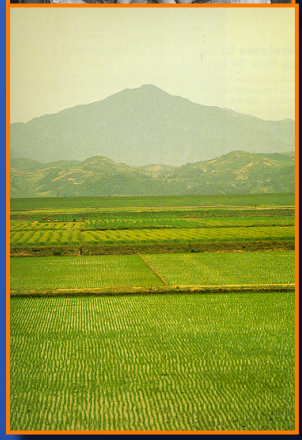
Challenges Ahead….

- **Food Imports Traditionally Do Not Help the Poor**
- **Domestic Food Production Provides for 97% of Consumption in the Low Income Group**
  - ***How to Produce More Food with Less Land, Less Water, Less Chemicals…?***

Innovation in Agriculture

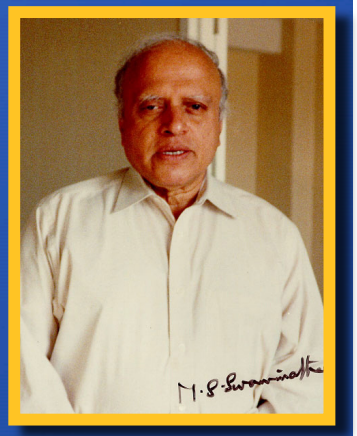
- U.S. Food Production : 252 million tons/year in 1960 to current 700 m. tons/year with 25 million fewer acres
- North American Corn Yields up from 26 bushels/acre (1928) to 180 today
- One North American farmer in 1940 fed 22 people, feeds 150 today.
- 1% of North Americans are Farmers.
- Average 11% of Income on Food

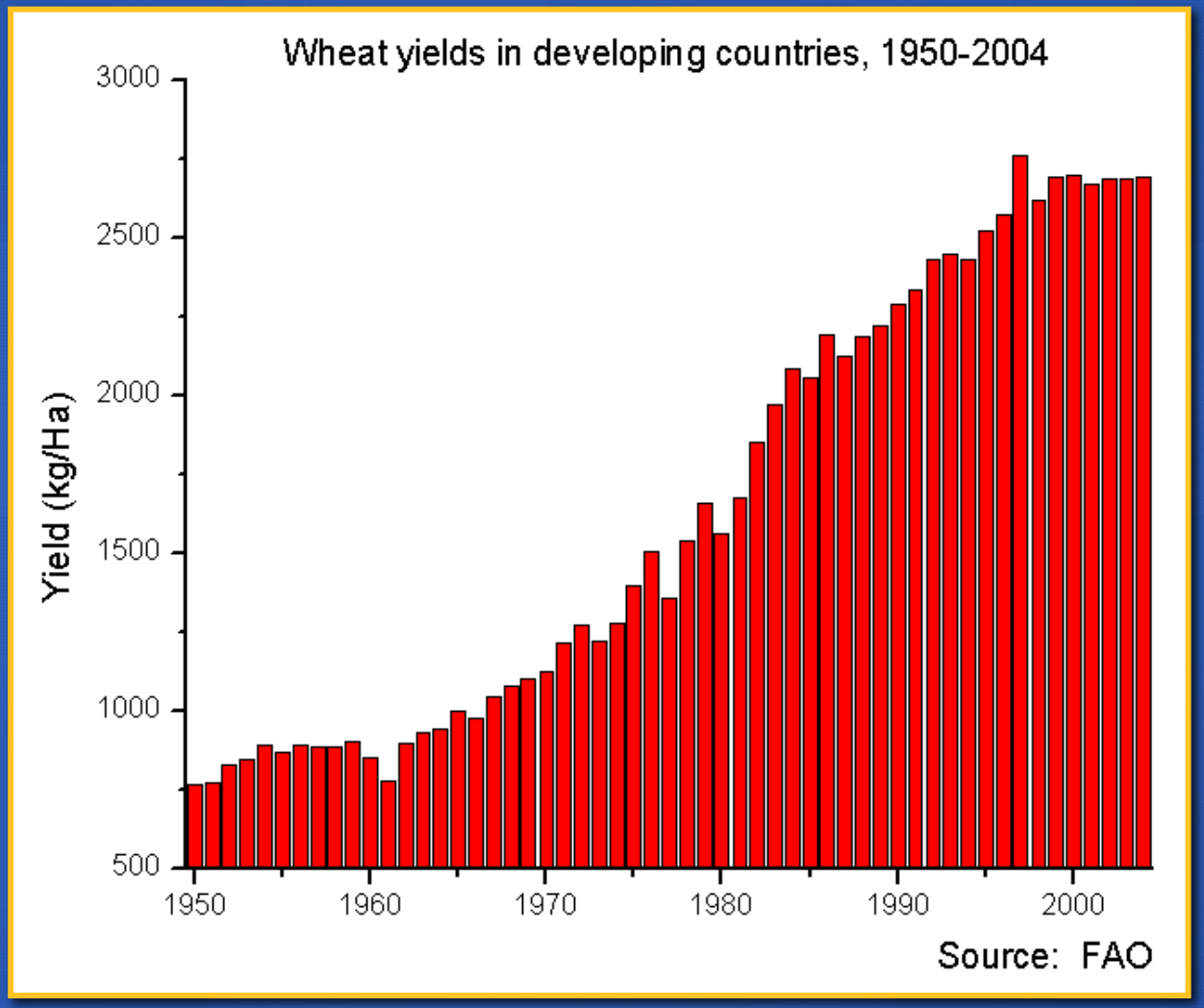




Green Revolution…

- Lifted Billion Plus Out of Poverty
- Undernourished > from 38% to 19% in past 20 years
- Food Consumption per capita has increased everywhere except in Africa - 18% Globally and 28% in LDCs
- India: Food production from 50 to 225 mil tons in the past 5 decades. Wheat : from 6 to 85 million tons per year!
- Less Starvation and Famine
- Increased Food Self Sufficiency



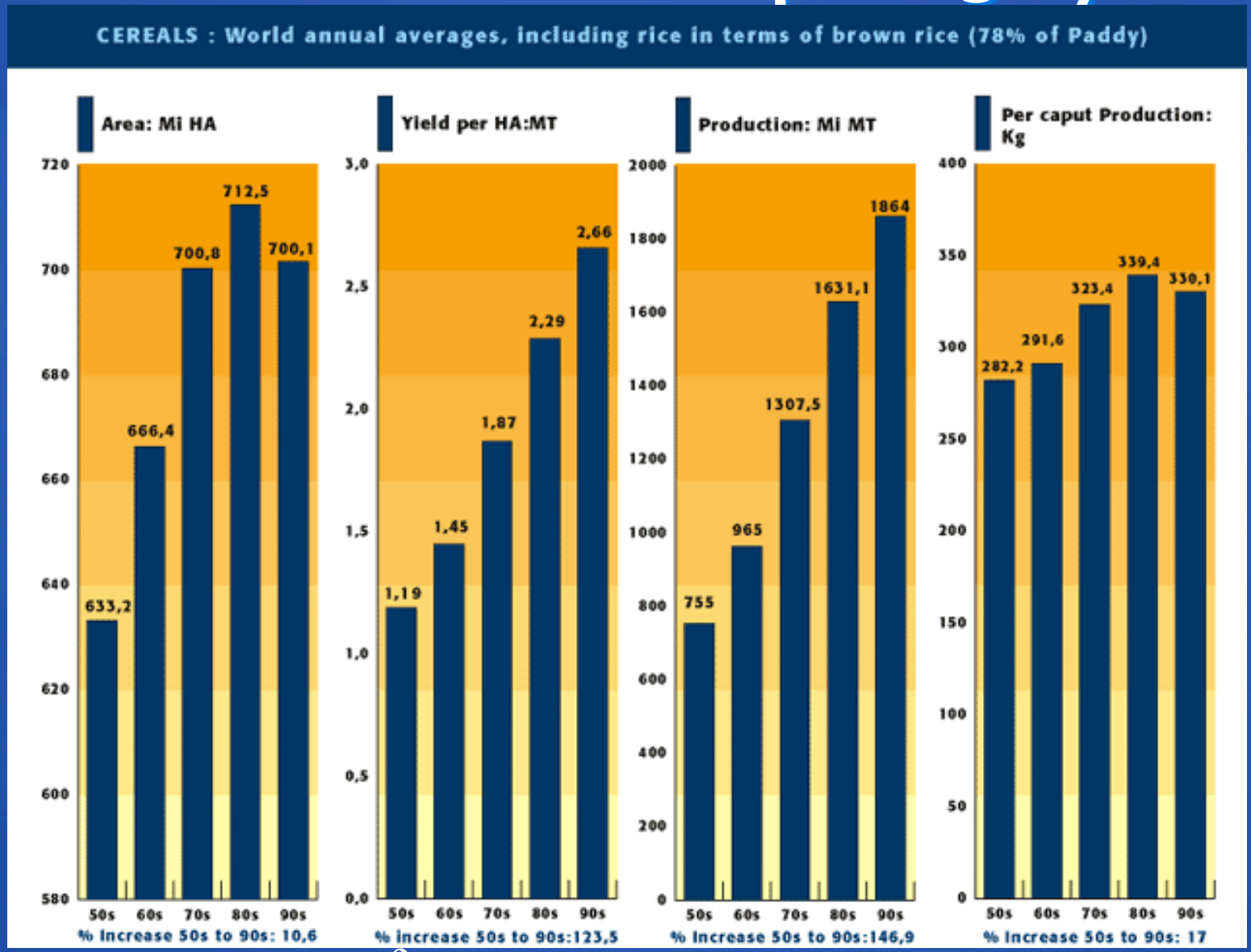

Wheat yields in developing countries, 1950-2004
Yield (kg/Ha)
3000
2500
2000
1500
1000
500
1950
1960
1970
1980
1990
2000
Source: FAO

Clicker Question

- Wheat yields in developing countries have increased by how much in the past fifty years?

a. Two-Fold
b. Four-Fold
c. Ten-Fold

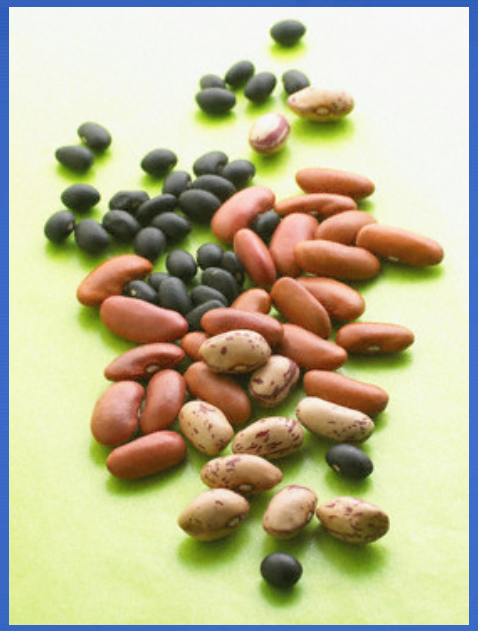
Cereal trends in the past 50 years…

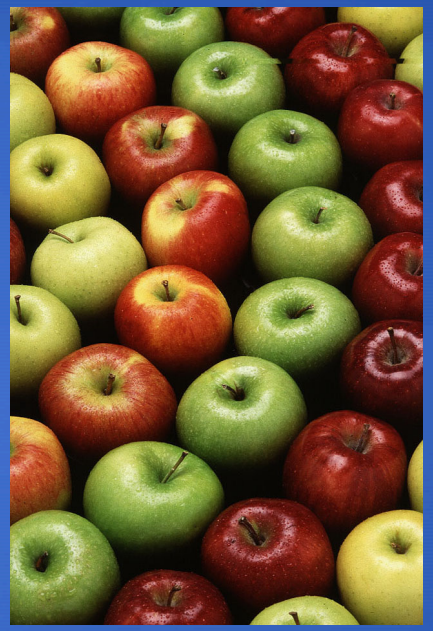


Source: www.fao.org

Plant Breeding - Genetic Modification by Farmers and Conventional Breeding

(photos: Dr. Wayne Parrott, Univ of Georgia)

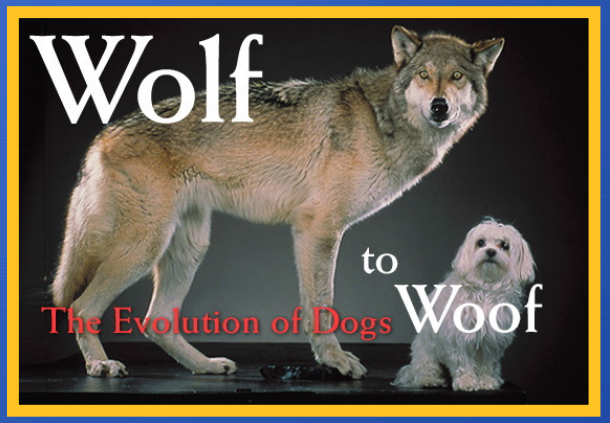




Crop Evolution and Human Civilization

- **Humans have always guided the evolution of crops**
- **A small sample of wild plants were chosen and domesticated**
- **10,000 years of *Selection*.**

- **All crops we grow today were once wild plants. But no crop would survive in the wild any more.**
- **Crops, strains and genes have moved around the globe.**




PARTY

Many crops never existed in nature

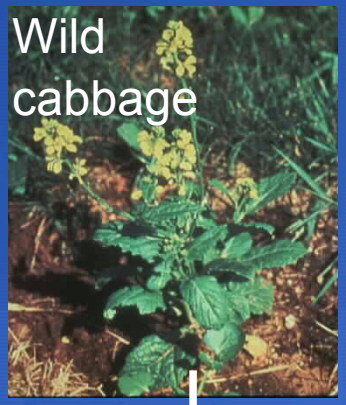
Einkorn x wild wheat

Emmer x goat grass

Bread wheat

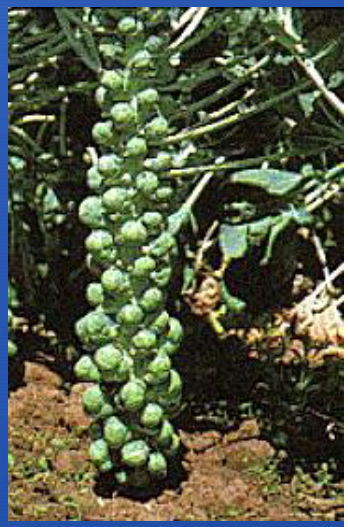
www.mpiz-koeln.mpg.de/pr/garten/schau/Triticumaestivum/wheat.html

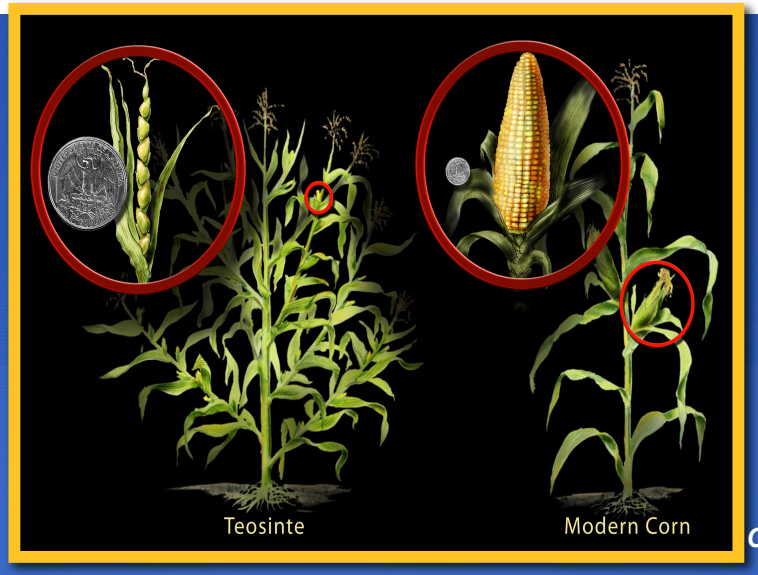
Slide courtesy *Wayne Parrott*, University of Georgia,



Kohlrabi
Germany, 100 AD

Brussel sprouts
Belgium, 1700's





Courtesy: John Dobley, U Wisc.

Teosinte

Maize

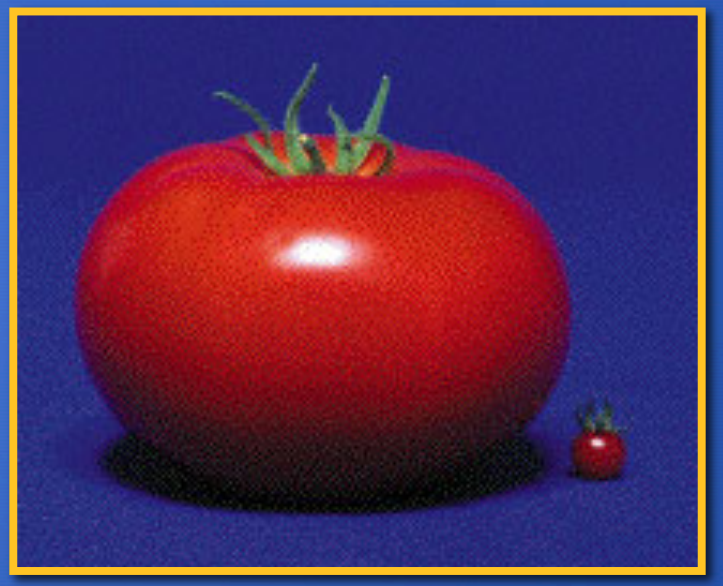
Slide courtesy *Wayne Parrott*, University of Georgia,

Slide courtesy *Wayne Parrott*, University of Georgia,

Carrot

Improving Our Crop Plants

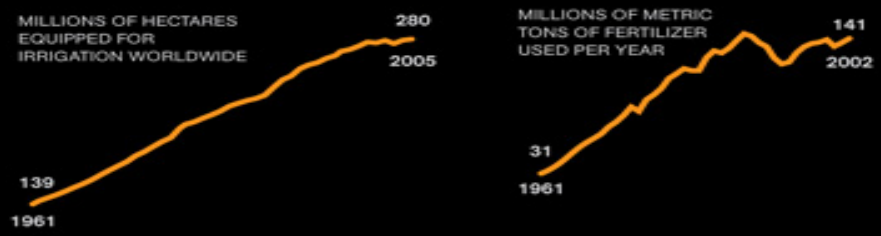
- **Developing Modern Varieties of Crops**
  - **Hybridization**
    - **Crosses with Wild Relatives**
    - **Hybrids**
  - **Mutation**
    - **Irradiation**
    - **Chemicals**
  - **Cell Culture**
    - **Embryo Rescue**
    - **Somaclonal variation**



TO MEET RISING FOOD DEMAND, WE NEED ANOTHER GREEN REVOLUTION, AND WE NEED IT IN HALF THE TIME.

HOW WE DID IT BEFORE

Few agricultural achievements have been as profound as the green revolution, the farming system of irrigation, high-yield varieties, pesticides, and fertilizers that more than doubled yields in Asia during the 1960s and '70s, lowering prices of the staple crops that feed most of the world today. But these breakthroughs have come with ecological costs.



IRRIGATION can double yields compared with those in rain-fed fields. India subsidized more than a million tube wells, resulting in higher production but also aquifer depletion and salinized soils.

DWARF VARIETIES of wheat and rice allowed farmers to use large amounts of fertilizer and water to produce more grain without the plants getting top-heavy and falling over.

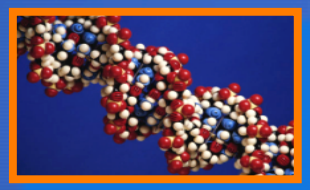
CHEMICAL PESTICIDES were needed because densely planted fields were more susceptible to insects and diseases. Overuse may result in 39 million poisonings a year.

SYNTHETIC FERTILIZERS helped the new varieties hit record yields. But they require huge amounts of fossil fuels to produce and apply, so their cost skyrockets with the price of oil. Nitrogen fertilizers also pollute aquifers and streams.

(Source: National Geographic)

Modern Genetic Modification

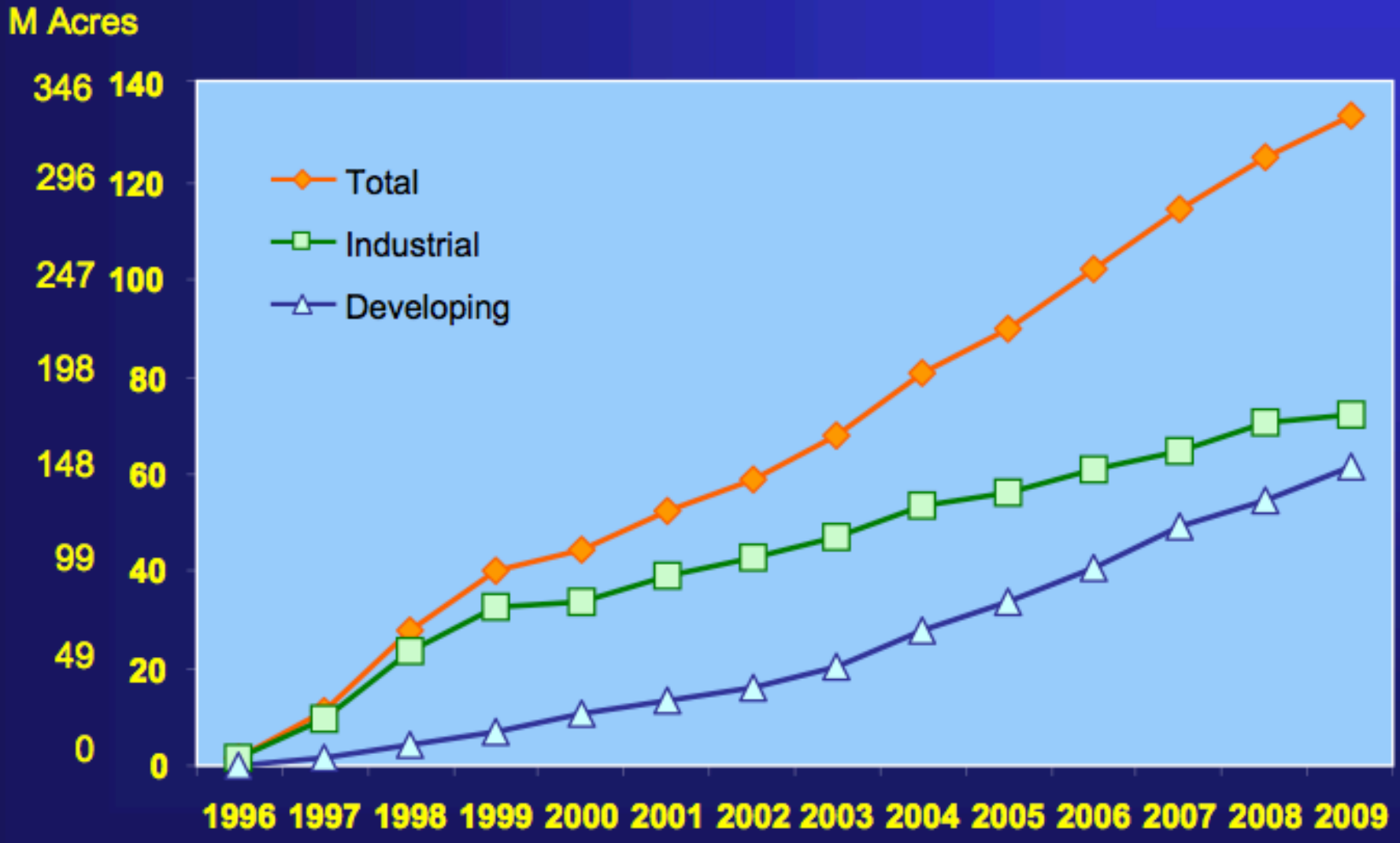
Inserting one or few genes to achieve desired traits.



Transfer of Genes into Crop Plants

- **Relatively Precise and Predictable**
- **Changes are Subtle**
- **Allows Flexibility**
- **Expeditious**

Global Area of Biotech Crops, 1996 to 2009: Industrial and Developing Countries (M Has, M Acres)

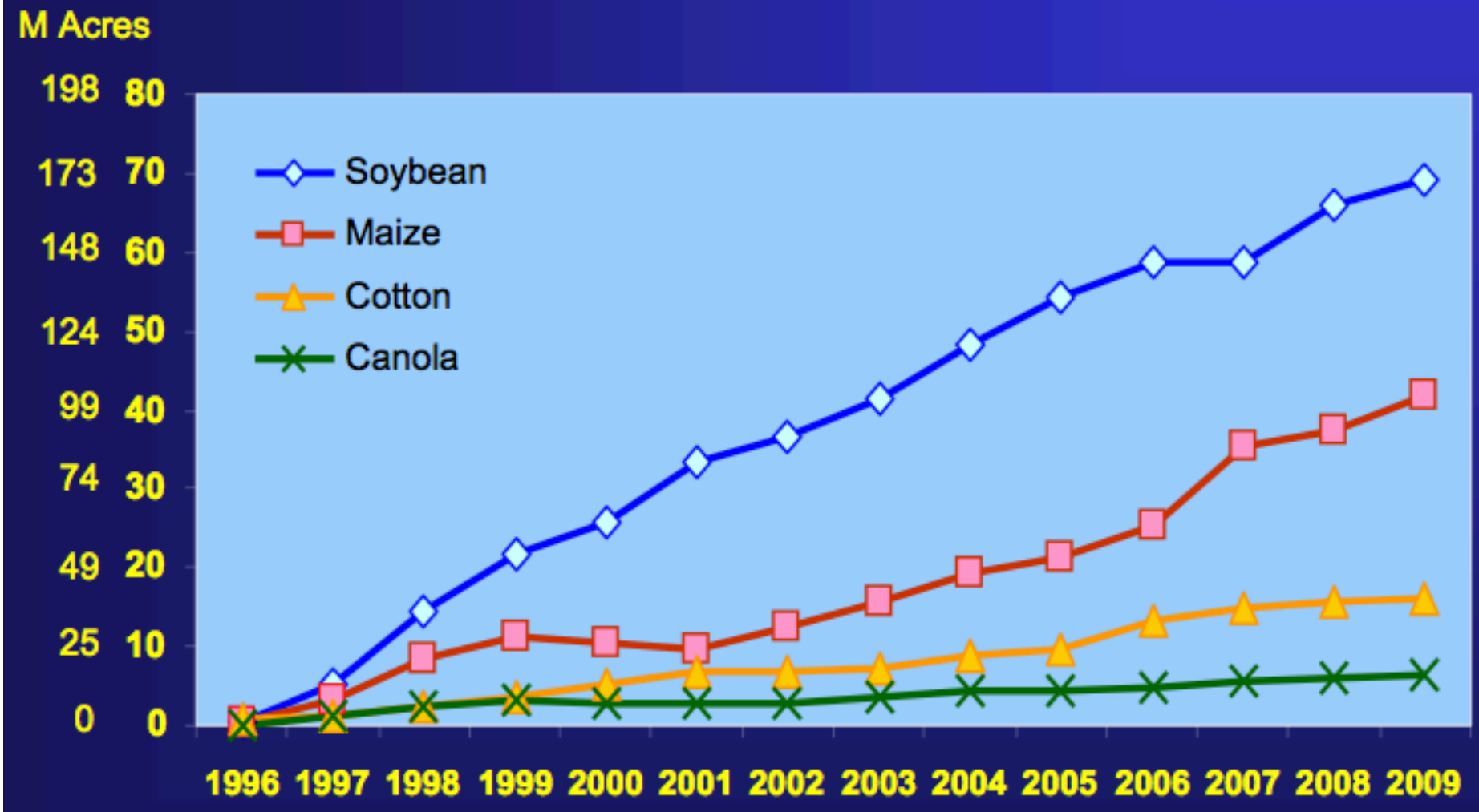


Source: Clive James, 2010

Clicker Question

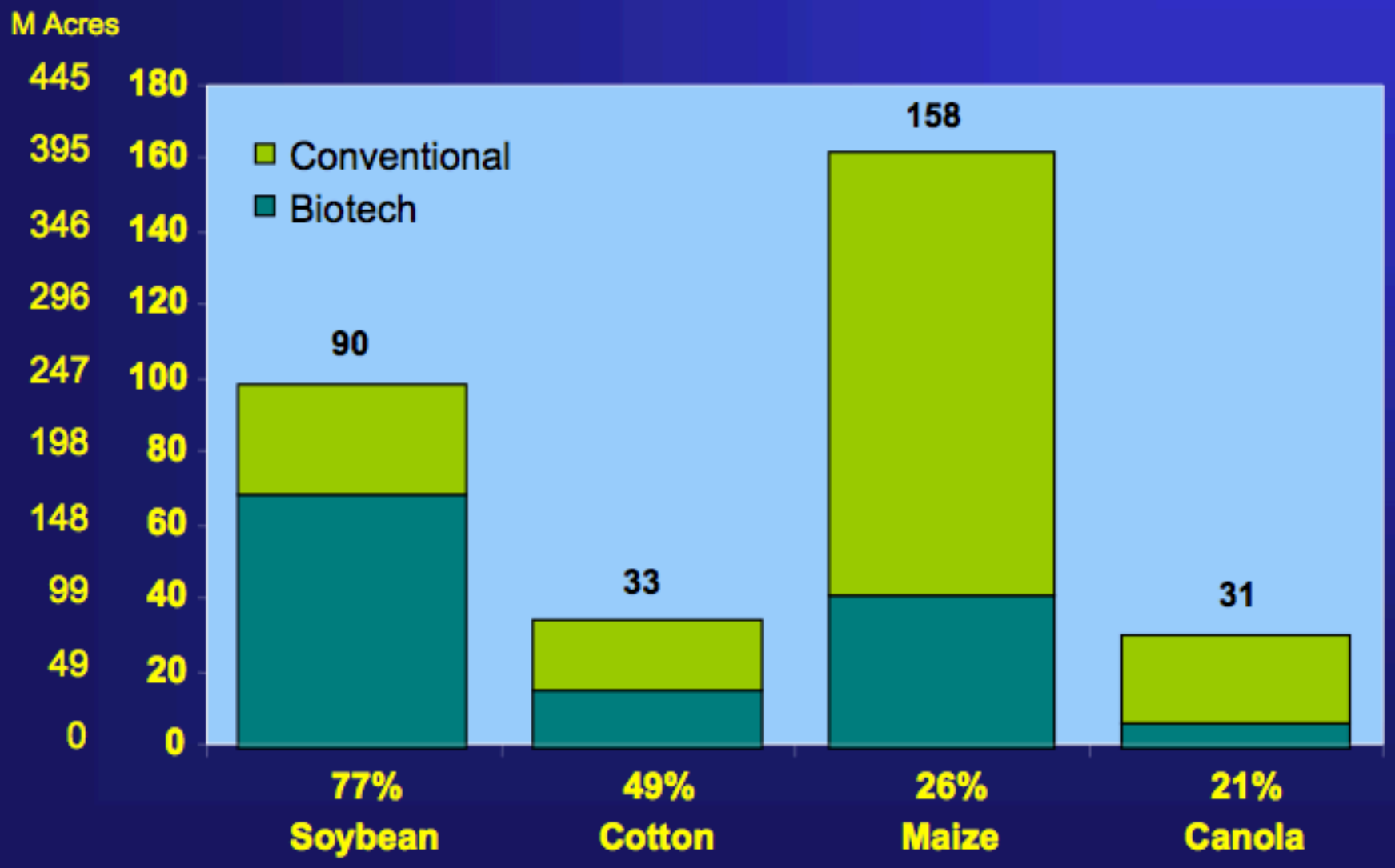
- Globally, Biotech crops were planted on how many acres in 2009?
- a. 340 M acres
- b. 340,000 M acres
- c. 30 M acres

Global Area of Biotech Crops, 1996 to 2009: By Crop (Million Hectares, Million Acres)



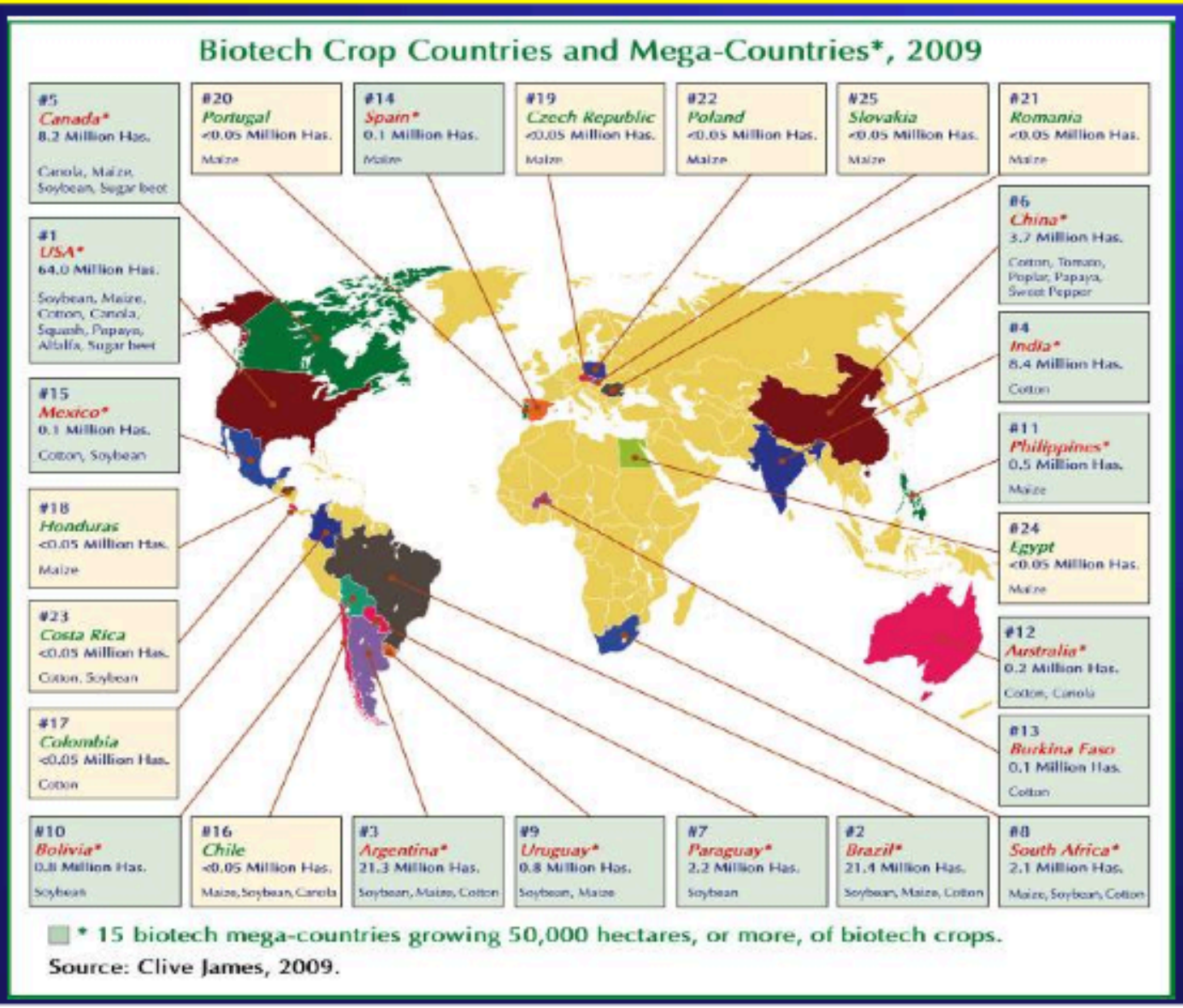
Source: Clive James, 2010

Global Adoption Rates (%) for Principal Biotech Crops (Million Hectares, Million Acres), 2009



Source: Clive James, 2010

Biotech Crop Countries and Mega-Countries, 2009



The benefits so far…

- $44 billion addition income
- Reduced pesticide spraying by 359 million kg
- Environmental Footprint of pesticide down 17%
- Reduced greenhouse gas - removing 6 million cars from the roads
- Produced 150 million tons more food

Source: *Graham Brookes and Peter Barfoot* (PG Economics Ltd., UK)

How Can Biotechnology Add Value to Global Agriculture?

- Environmental Impact - Decreased use of pesticides
- Reduce losses from pests and diseases
- Improve nutrient efficiency
- Improve productivity

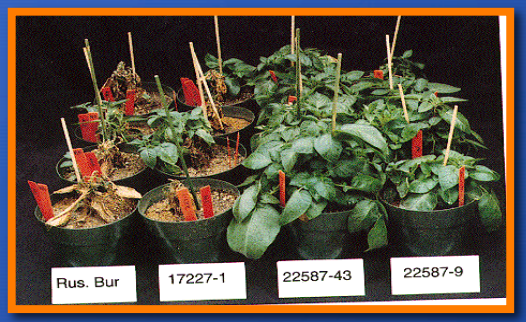
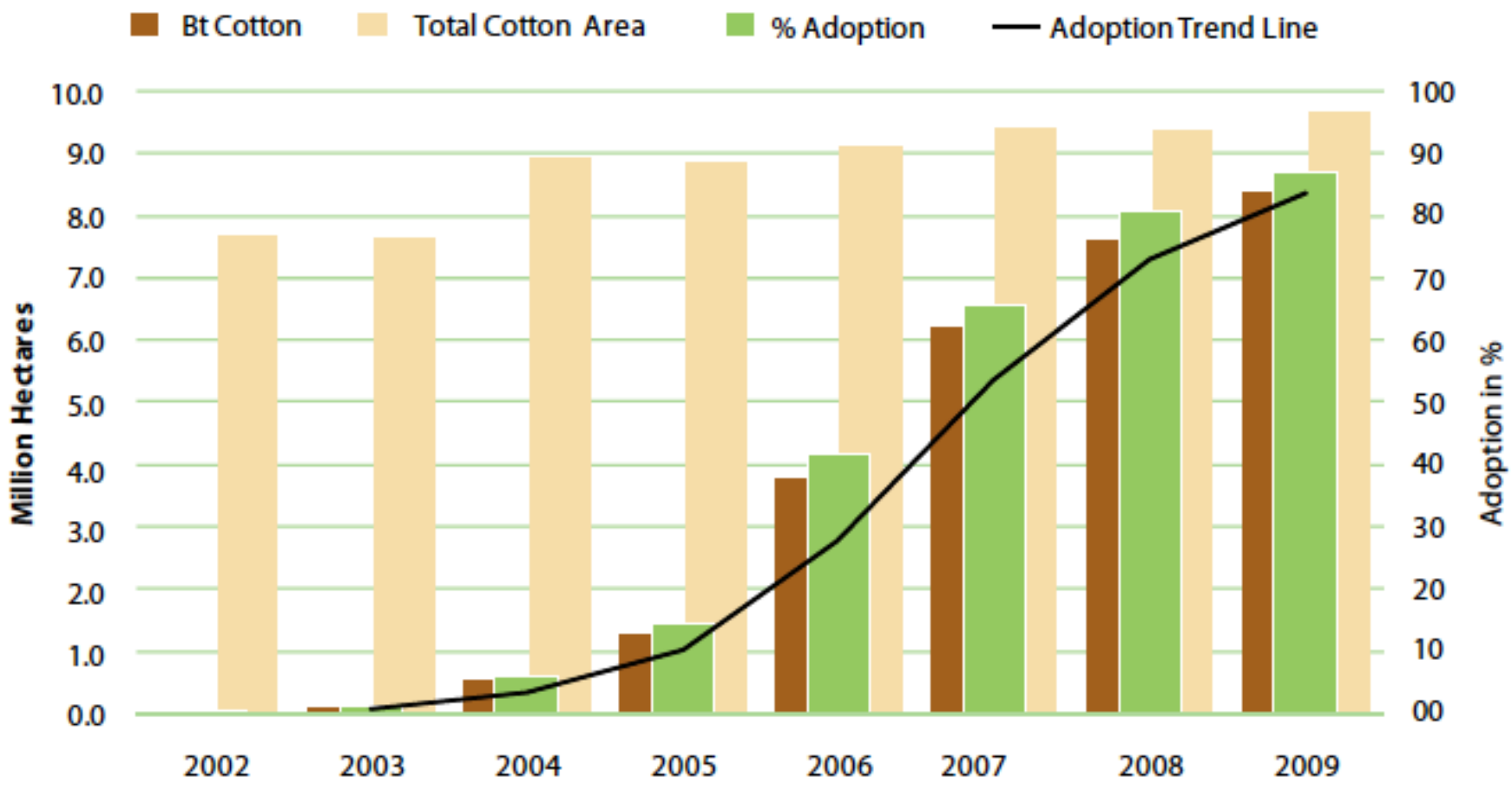


Figure 1. Adoption of Bt cotton in India for the eight year period, 2002 to 2009



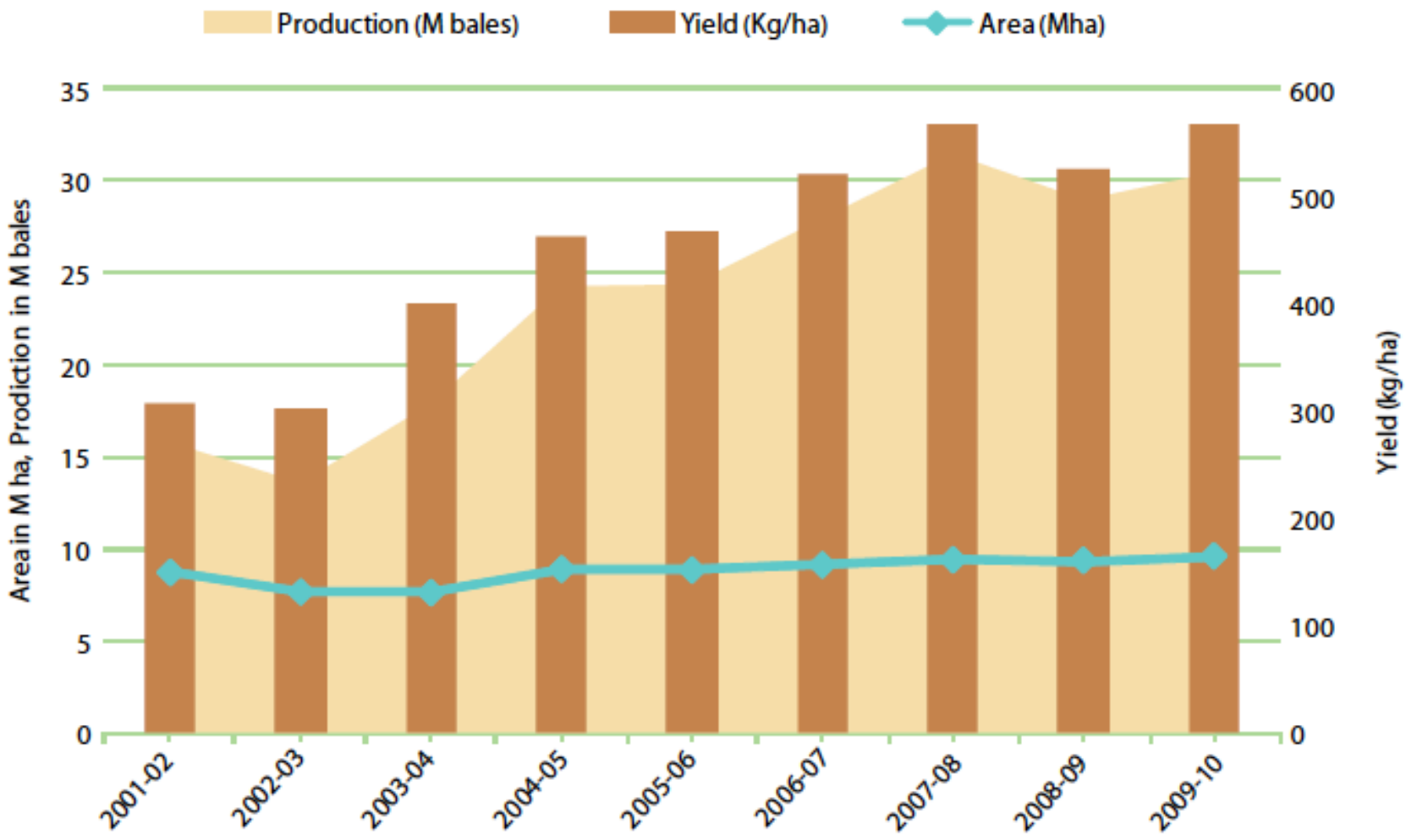
Source: Compiled by ISAAA, 2009.

Clicker Question

The percentage of Indian cotton farmers growing Biotech Bt Cotton now is

a. 20
b. 50
c. 90

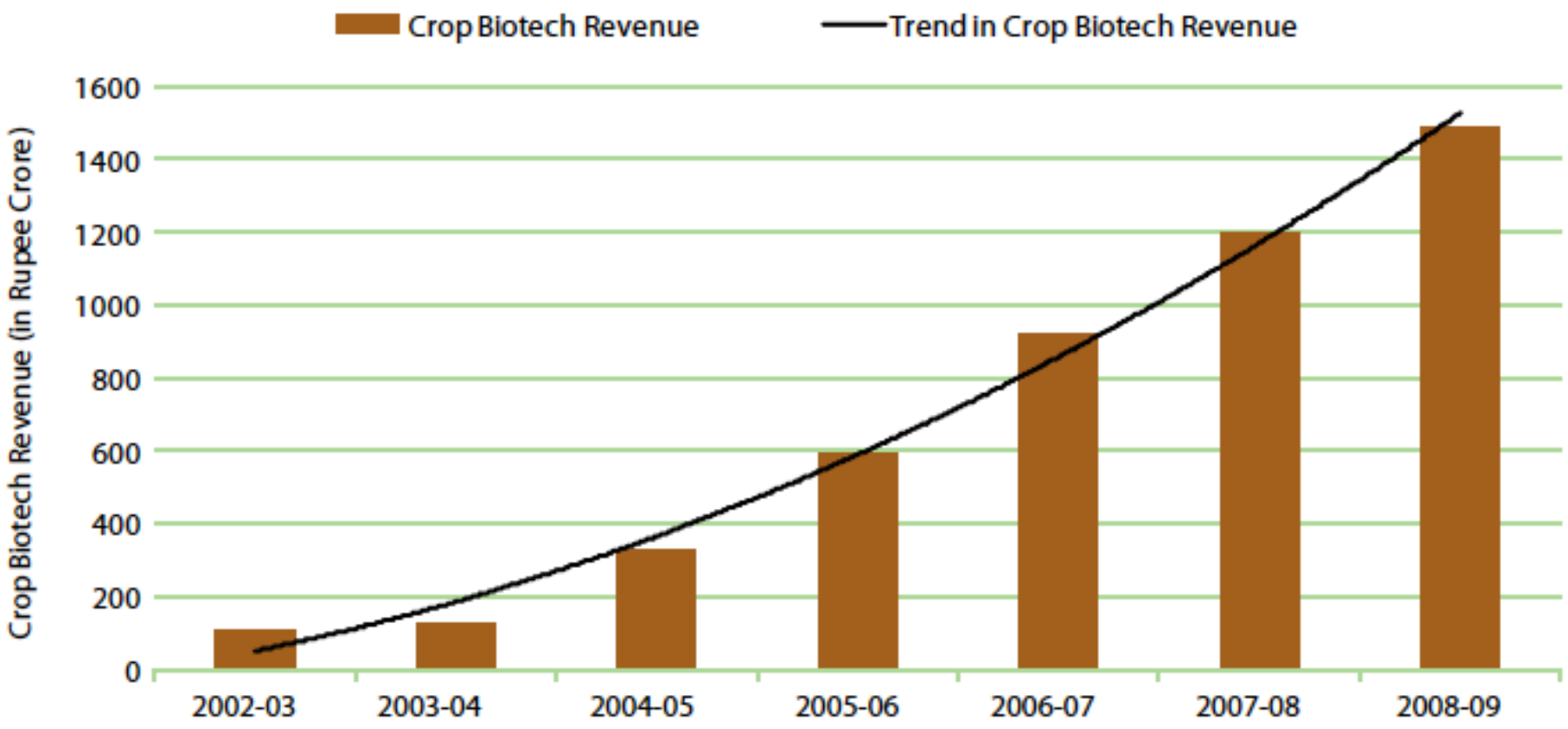
Figure 5. Cotton hectarage, production and yield in India, 2001 to 2009



1 bale = 170 kg

Source: Cotton Advisory Board, 2009.

Figure 7. Bt cotton hybrids market in India (in rupee crore), 2002 to 2008

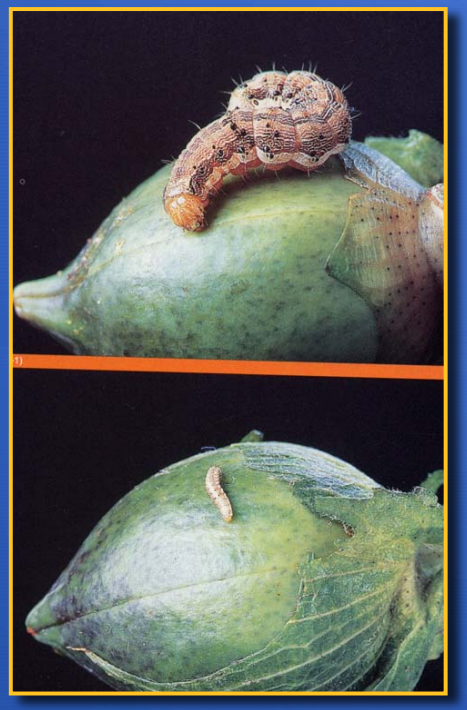


(1 Crore = 10 Million Rupees)

Source: BioSpectrum India, 2009.

Cotton - China, South Africa, India, Mexico, Burkina Faso

- Losses due to Bollworm $1.5 billion in India and China
- Cotton - 50% of the total pesticides



India

- Bt Cotton - yield increases up to 40%.
- ~90% of Indian cotton farmers grow Bt
- Savings up to $182 per hectare
- More than 600 varieties
- Spraying reduced from 12 to 1
- Both private and public sector

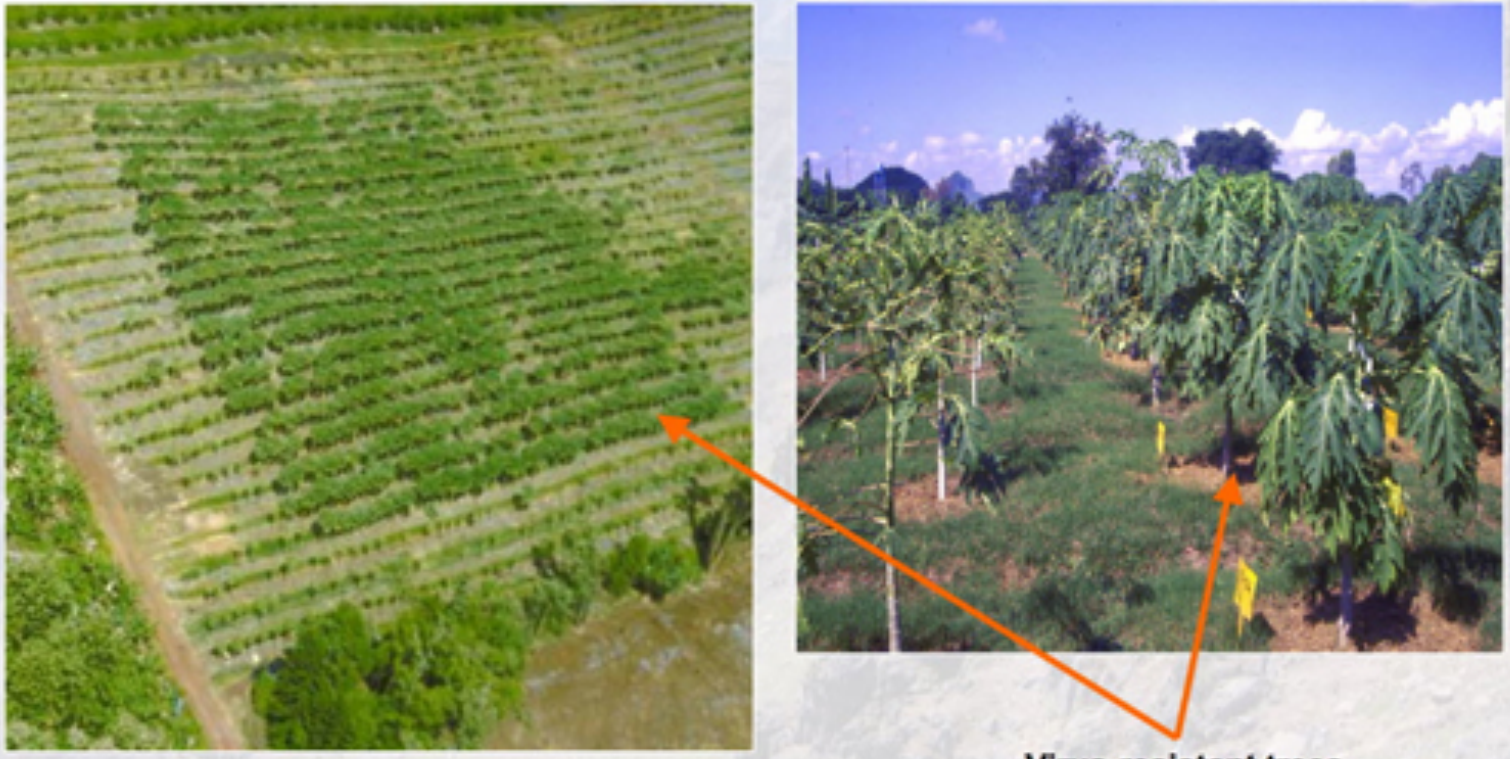
'GM' Eggplant in India – Not Approved!

Bt Corn

(Low Mycotoxin)

Virus-resistant papaya

Saved the Hawaiian industry in the mid-1990s
90% of crop today

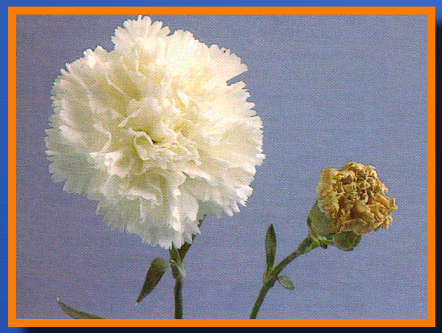


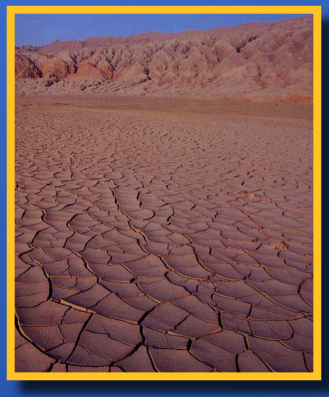
Provided by Denis Gonsalves, formerly of Cornell University

Virus resistant papaya in Hawaii

Benefits of Biotechnolog

- Post Harvest Quality - prolong shelf life of fruits, vegetables and flowers
- Extend crop area and season
- Stress tolerance - drought, acidity, salinity, heat, flooding





Freeze Tolerant Biotech *Eucalyptus*

Results from first winter in South Carolina

Control

Lead Line

Results from second winter in Alabama

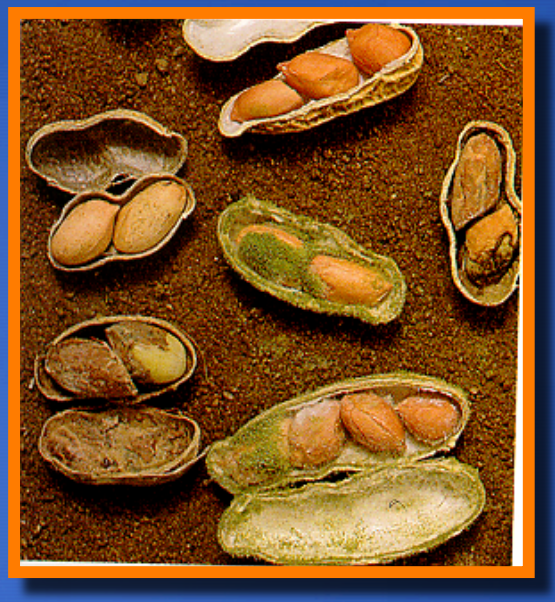
Lead Lines + Control

Field results indicate freezing tolerance to ~16°F (- 8° to - 9°C)

Source: www.arborgen.us

Enhancing Food and Agriculture

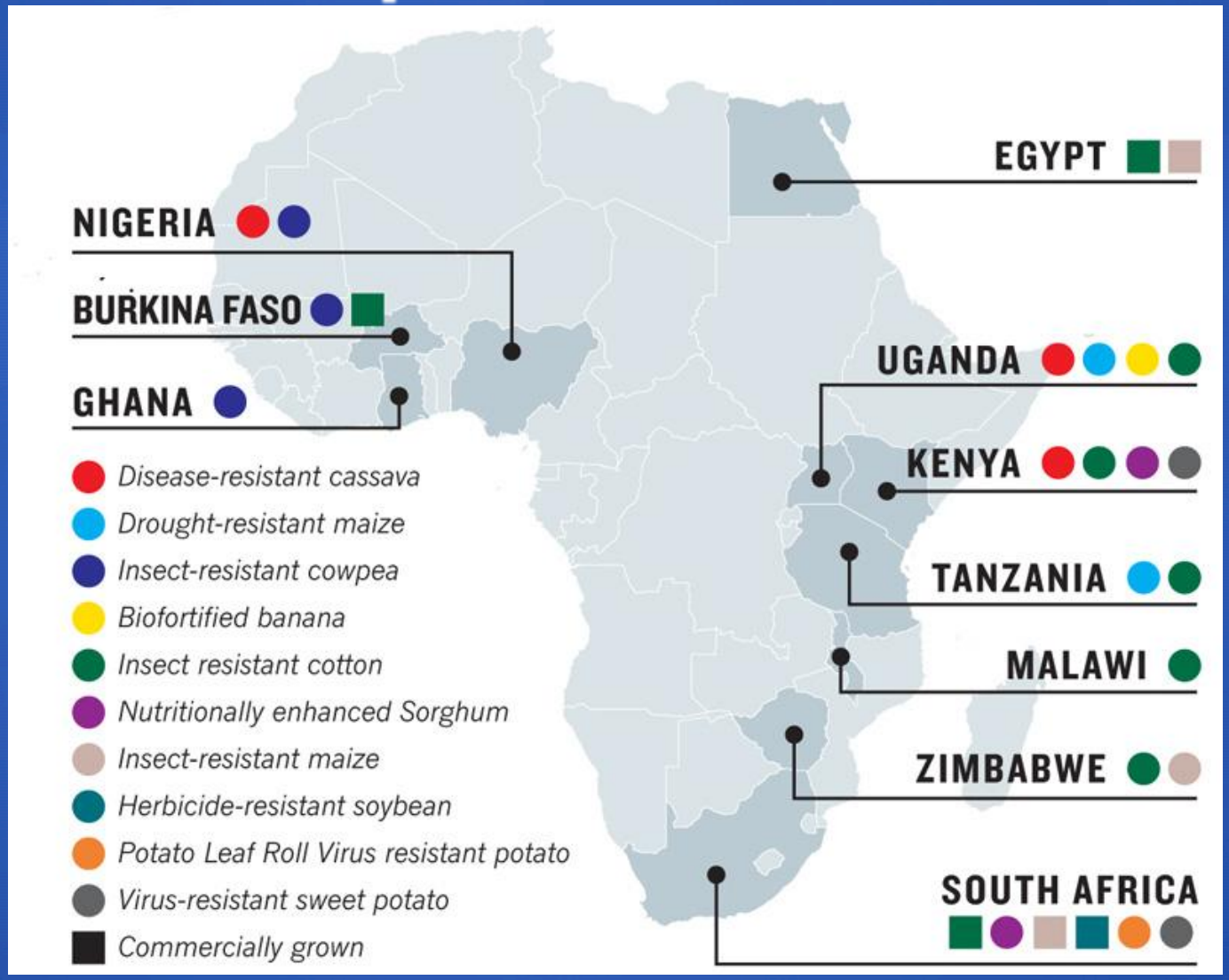
- More Nutritious Food
- Healthy Produce. Low Toxins
- Pharmaceutical Proteins
- Clean Up Environment
- Biofuel - Ethanol, biodiesel
- Industrial Products
- Value-Added Products



Golden Rice

- Milled rice has no beta-carotene
- Vitamin A deficiency - 200 million children and woman
- About 500,000 children go blind (60 every hour!)
- 2 million children die each year
- Golden Rice may provide one of the many solutions

GM Crops in Africa



(From Nature, Oct. 1 2010

Sweetpotato

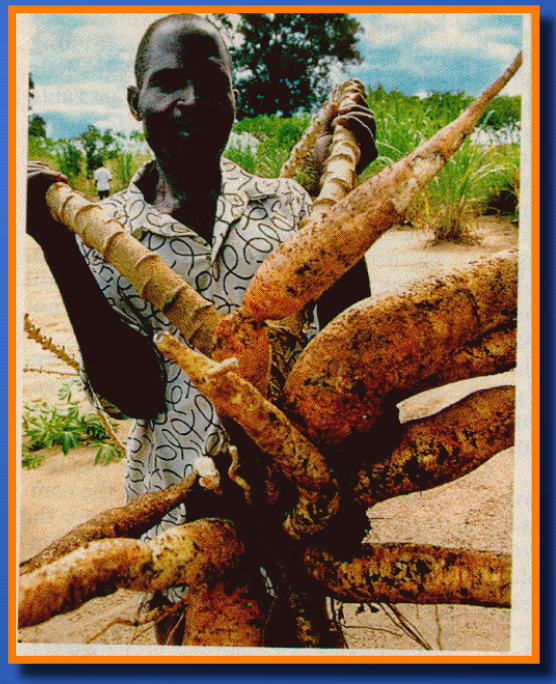
- Fourth largest crop in the developing world
- Excellent source of calories, vitamins and minerals
- Grown by resource-poor farmers
- Very hardy

Resistance to Virus and Weevil
Enhancement of Nutritional Protein

Cowpea

Cassava

- Eaten by 500 million Africans
- Very productive, drought-tolerant
- Rich in Calories. Cyanogenic glucosides.
- African Cassava Mosaic Virus devastating the crop
- ILTAB - Danforth Ctr (Beachy, Fauquet)



Healthy Cassava

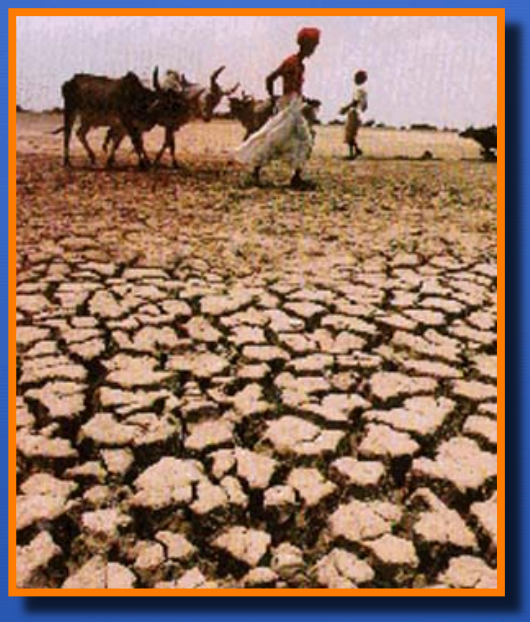
Virus-infected Cassava

Black Sigatoka Disease of Banana

Banana

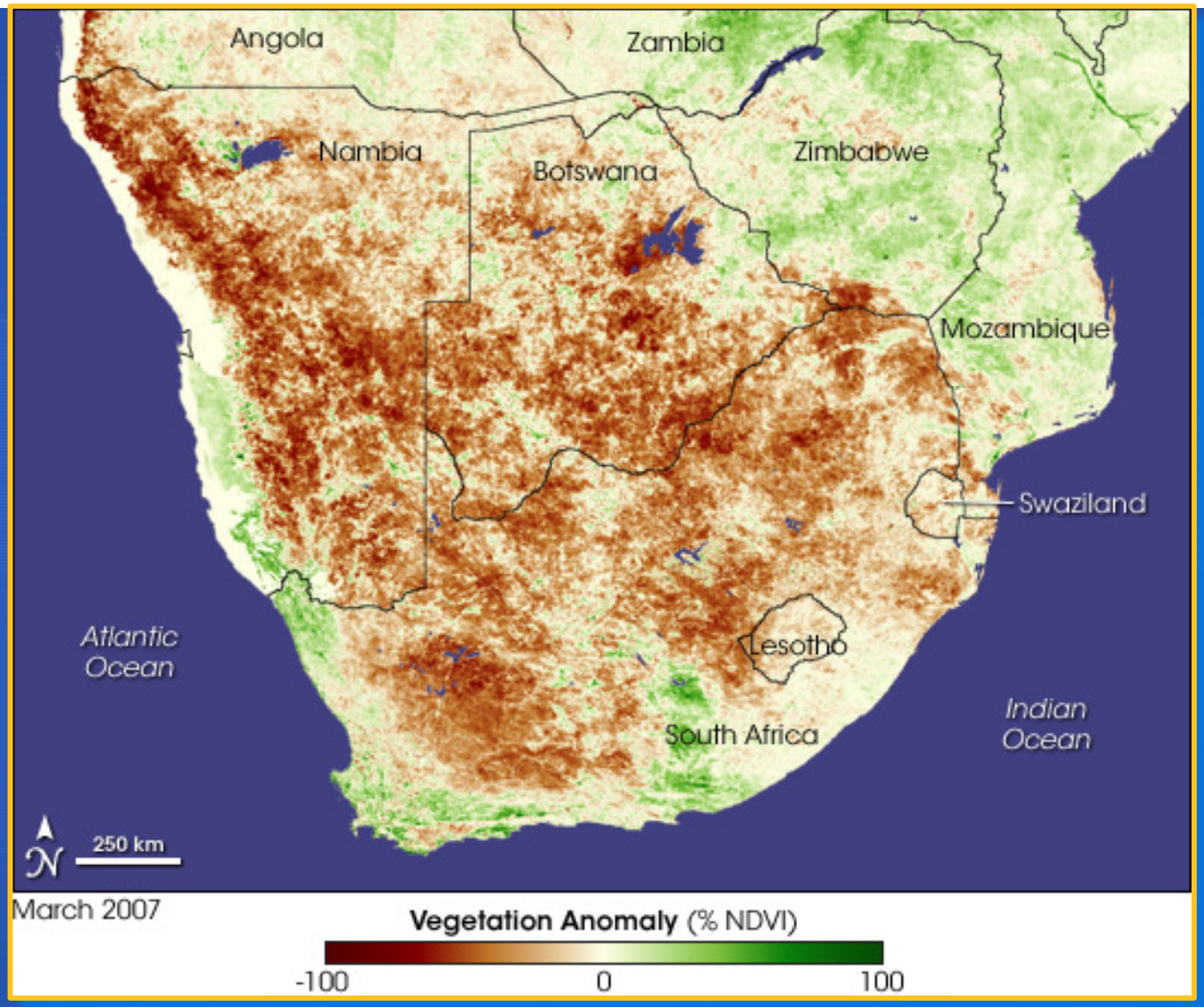
Drought

- Extended period of deficiency in water supply
- Major constraint to farming
- Spurred Green Revolution in India?



Drought and Farming

- *Most important environmental stress on farming*
- *Average 50% crop loss*
- *Agriculture - 85% of freshwater withdrawal*
- *Need more "crop per drop"*



Drought in Southern Africa - Impact on vegetation (Source: NASA)

Drought and African Agriculture

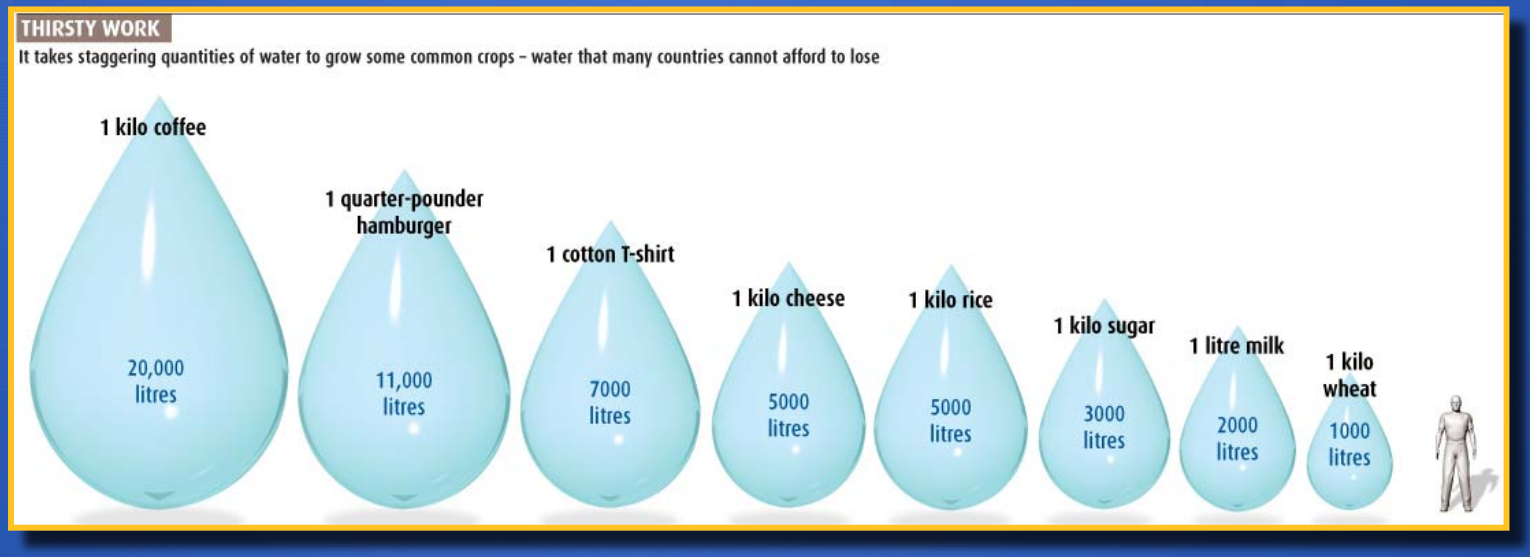
- Over 95% of cropland in SSA is rain-fed and will remain so in the near future
- The risk of drought prevents investment in improved agricultural products
- ***Yield stability is key to unlock the value of basic inputs***

Recorded droughts between 1971 and 2000, and the number of people affected

(Slide source: Dave Songstad, Monsato)

Virtual Water

- Embedded water or hidden water
- Water used in the production of a good or service In the context of trade



Source: *http://technology.newscientist.com/*

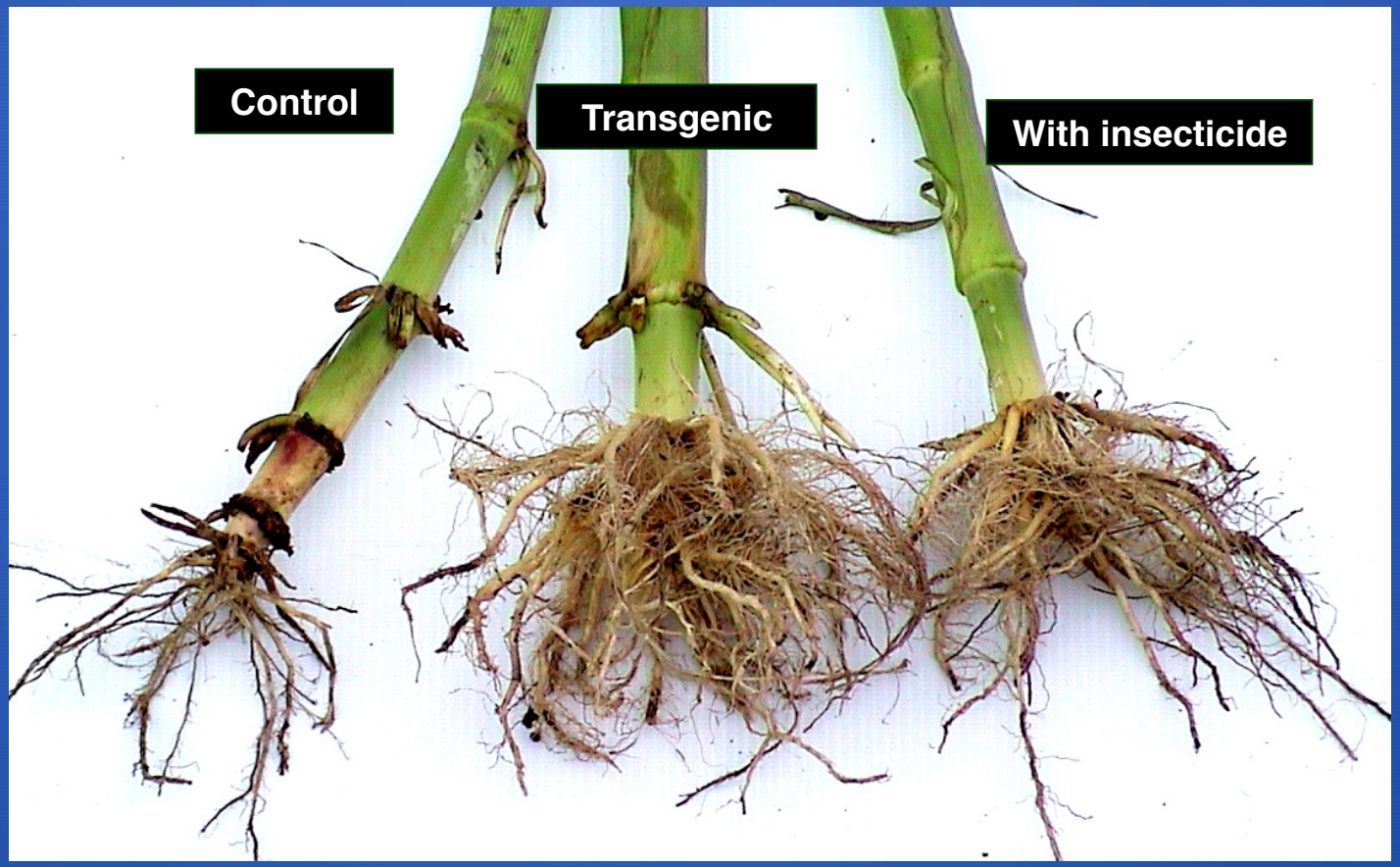
Clicker Question

- To produce which commodity does it takes the least amount of water?
- a. Coffee
- b. cheese
- c. wheat

Drought Tolerant Corn

Photo: Monsanto Co.

Rootworm-resistant corn




Striga = witch weed

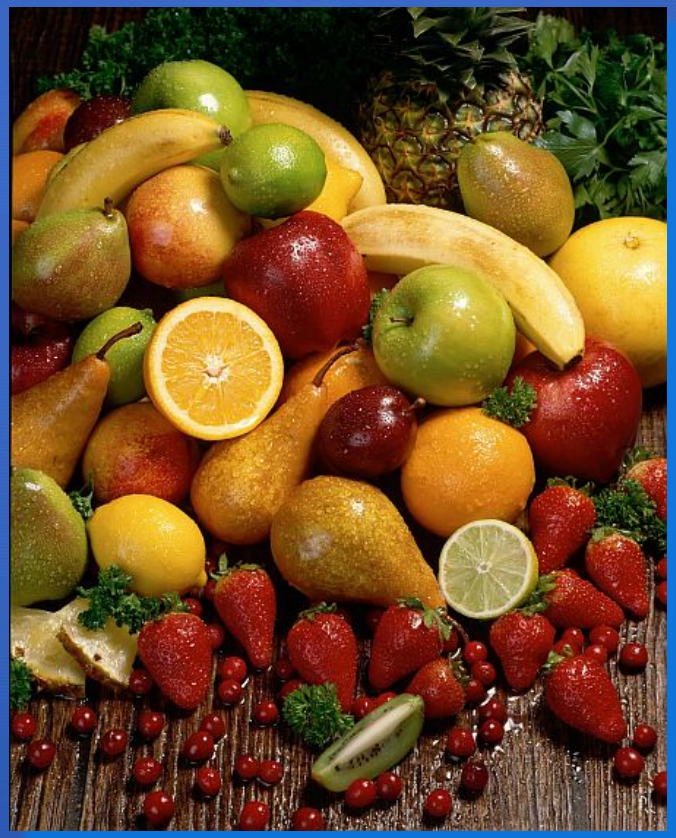

LOCAL CHECK
H513
IR MAIZE
SINGLE CROSS 1

Wheat

Rice

Vegetables

Fruits



Transgenic Carnation

(Photo: Wayne Parrott)

In Colombia


I WON'T EAT ANYTHING THAT'S GENETICALLY MODIFIED...
IT COULD BE UNHEALTHY...
CHIPS
Rex Babin is on vacation
Anderson / Courier Journa

How Safe is GM Food?

- As Safe as Conventional Food
- Subject to High Regulation - FDA, EPA, USDA
- Every Product Tested on Case-by-Case
- Over Billion Acres Grown Since 1996
- More than 10,000 Food Products Contain GM
- Not One Single Instance of Hazard
- Dozens of Scientific Societies Have Endorsed it
- >5,000 Scientists plus 24 Nobel Laureates
- EU Scientific Commission - 'Safer than Conventional Food'

Assessment of Food Safety

- Standard - “Reasonable certainty that no harm will result from intended uses under the anticipated conditions of consumption”
- **Food is not inherently safe**
- Considered to be safe based on experience
- **Not absolute but relative safety**

Regulatory Systems in the U.S.

USDA

Field testing permits notifications

Determination of nonregulated status

FDA*

Food safety

Feed safety

* Voluntary Consultation process for substantially equivalent products.

EPA

Pesticidal plants tolerance exemption registrations

Herbicide registration

Safety Testing of GM Crops

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

Substantial Equivalence - Evaluation

PHENOTYPE

- Morphology
- Agronomic
  - disease resistance
  - drought resistance
  - yields
- Organoleptic

COMPOSITION

- Macronutrients
- AA composition
- FA composition
- Anti-nutrients
- Toxic substances
- Allergens
- Specific constituents

SAFETY ASSESSMENT

- Toxicity
- Allergenic potential
- Nutritional

FEED EQUIVALENCE

- Performance

Compositional Equivalence

- Evaluate Key
- - Nutrients
- - Vitamins
- - Minerals
- - Anti-nutrients
- - toxicants
- - Allergens
- - Others

List depends on crop

Grain	Forage
- Protein	- Protein
- Fat	- Fat
- Fiber	- Fiber
- Starch	
- Amino acid composition	
- Fatty acid composition	
- Ash	
- Sugars	
- Calcium	
- Phosphorous	

OECD Consensus Documents

Feed Performance

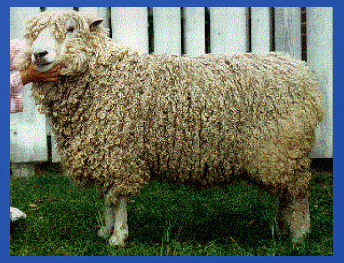
Animals fed biotech corn products perform in a comparable manner to animals fed conventional corn products

No Significant Differences in:

Feed Intake	Feed Conversion	Nutrient Composition
Body Weight	Milk Yield	
Carcass Yield	Milk Composition	
Feed Efficiency	Digestibility	

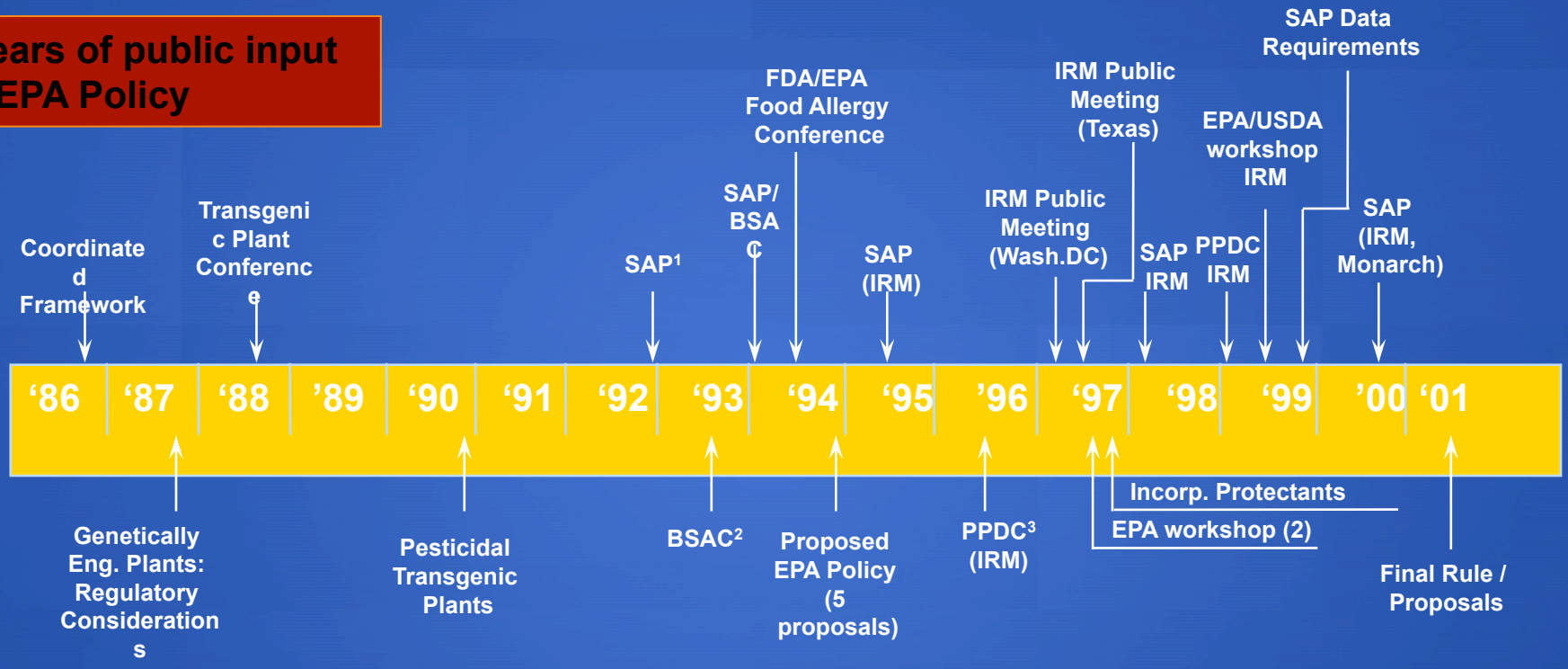






Regulatory Path for Bt Corn

15 years of public input into EPA Policy

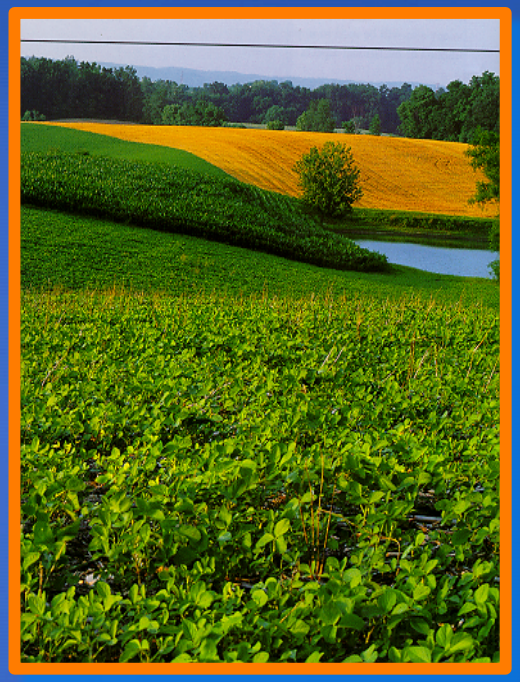


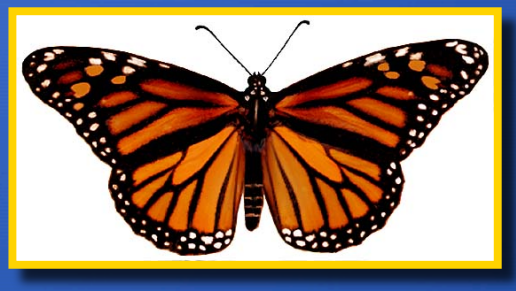
[1] Science Advisory Panel
[2] Biotech Science Advisory Committee
[3] Pesticide Program Dialogue Committee


NO
GREENPEACE
NO GMO
NEWS STAR
EUROPEAN STUDIES SAY GMOS SAFE!
THAT'S OKAY, THIS CAMPAIGN WAS NEVER BASED ON SCIENCE, ANYWAY.

Environmental Issues

- What are the Ecological Effects of New Crops?
- Would Superweeds Emerge?
- Does Biotech Affect the Biodiversity?
- Genetic Pollution?
- Horizontal Transfer…..Will Bacteria or I get those genes?
- ….What about Monarch Butterflies?





Addressing Environmental Concerns

- Extensive Risk Assessment for the Past 15 years with 5,000 Field Studies; Careful Monitoring
- Evaluate Risk on a Case-by-Case Basis.
- Most Introduced Traits Not Unique to Biotechnology;
- Plant Breeding History - Introducing Novel Genes All the Time

Addressing Environmental Concerns

- **Extensive Risk Assessment for the Past 15 years with 5,000 Field Studies; Careful Monitoring**
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Famine in Southern Africa

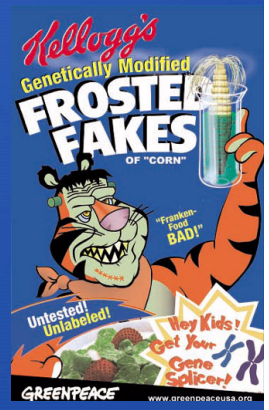
- Nearly 13 Million people in 19 African countries faced severe hunger and starvation during 2003-2004
- About 300,000 faced death
- World Food Program
- US Donated 500,000 tons of corn

Zambian President, Levy Patrick Mwanawasa
"We would rather starve than get something toxic."

African rejection of GM crops

- Only 3 countries (S. Africa, Egypt and Burkina Faso) out of 53 countries growing biotech-enhanced crops
- Lack of government support
- Absence of regulation or law
- NGO Campaign
- UN Convention on Biological Diversity

  - Biosafety Protocol



Downgrading and withdrawing support for Agricultural science in the West

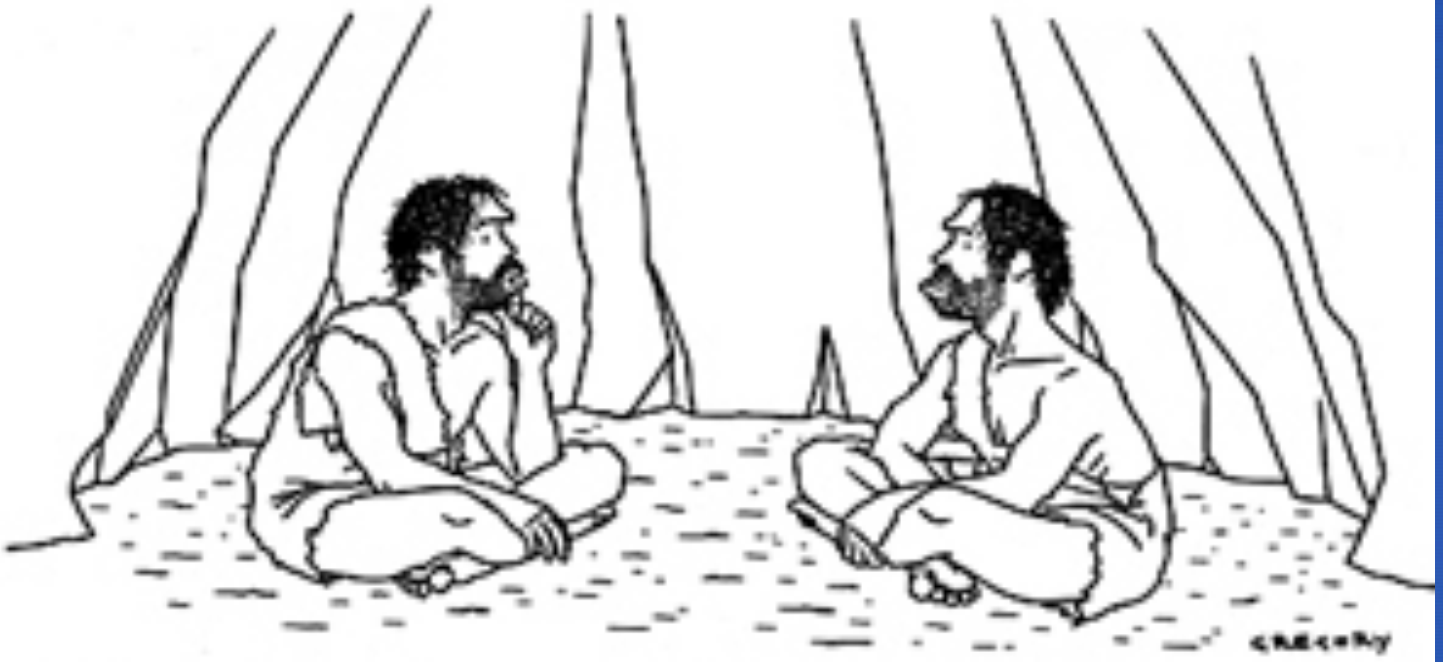
- Very low R&D spending in agriculture
- Not a top priority for politicians
- Poor donor support
- Hostility from NGOs
- Advocates of organic farming in Africa
- Uncertain support from philanthropic foundations
- “Caring about Africa, but not agriculture” (R. Paarlberg, 2008)

Keeping Biotech Crops Out of Poor Countries

- Regulatory environment (Precautionary Principle)
- Trade barriers (European pressure)
- Orchestrated public perception
- Imported environmental activism
- Negative media portrayal
- Food industry and retailers
- Organic food industry

Why Europeans Dislike Biotech Crops?

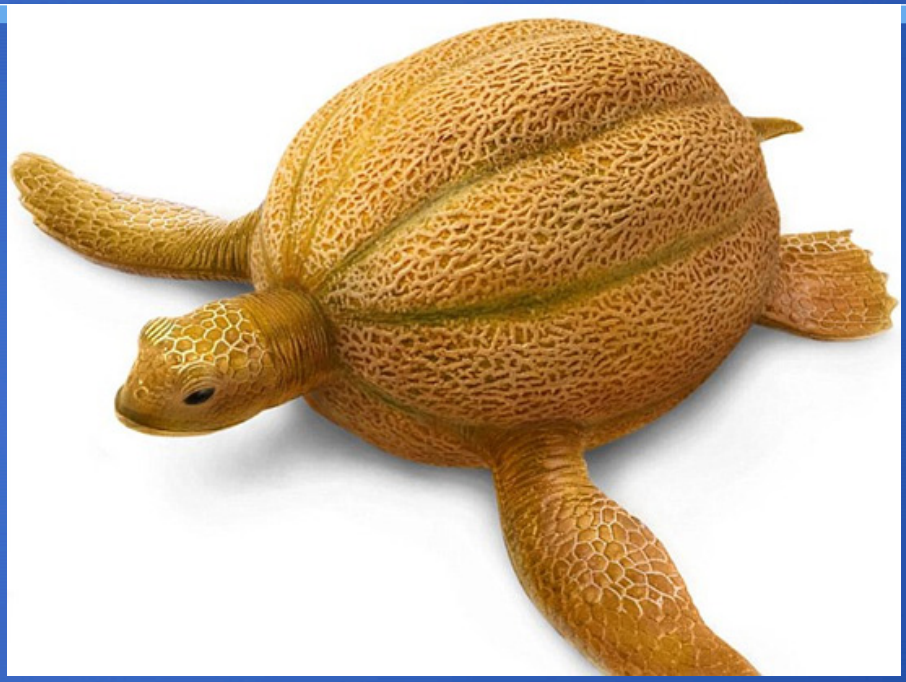
- High subsidy for farmers
- 'We have plenty of food'
- 'This is an American technology'
- Supermarket control of markets
- Negative media opinion
- Opposition by interest groups
- Mistrust of regulators ("mad cow disease")



"Something's just not right—our air is clean, our water is pure, we all get plenty of exercise, everything we eat is organic and free-range, and yet nobody lives past thirty."

How Can Biotech Help Third World Agriculture?

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



So, Are GM Crops the Answer to All Farming Problems?

- No single solution is a panacea or *'cure-all'*
- *But Biotechnology can play a significant role*
- One tool in a toolbox
- World hunger - myriad reasons
- Can only work with other traditional approaches
- We must weigh all options. Choose the most effective solution

History of Technology Adoption

- Resistance to Innovations Related to Food
  - Pasteurization, Canning, Freezing, Microwave
- Certain Innovations Not Readily Accepted
  - Recalcitrance to Adopt (Dvorak v/s QWERTY)
  - Entrenched Economic Interests (Metric in US)
  - Ideology & Politics (Plant Breeding- Soviet Lysenko)
  - Exaggerated Notions of Risk (Food Irradiation)
  - Initial Scare and Misinformation (Saccharine, MSG)
  - Ill Timed Introduction
  - Conflict with Societal Values and Beliefs

Change is Inevitable, Progress is Optional

www.agbioworld.org

Thank you!