Part I

INTRODUCTION TO PLANT BIOTECHNOLOGY

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Plant Biotechnology
Vietnam OpenCourseWare
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The word "biotechnology" was first used in 1917 to describe processes using living organisms to make a product or run a process, such as industrial fermentations. In fact, biotechnology began when humans started to plant their own crops, domesticate animals, ferment juice into wine, make cheese, and leaven bread.

Present definition of biotechnology

"Any technological application that uses biological systems, living organisms, or derivatives theory, to make or modify products or processes for specific use''

(According to the Convention on Biological Diversity)

Plant biotechnology

"Plant biotechnology describes a precise process in which scientific techniques are used to develop useful and beneficial plants''

(According to the Council for Biotechnology Information).

1.1. History of Plant biotechnology

Early Plant breeding

- Humans domesticate crops.
- Breed plants to further improve desirable characteristics

Plant breeding 12,000 years ago …

8,000-4,000 B.C

Bread-making wheat grown in Egypt, rice cultivated in China

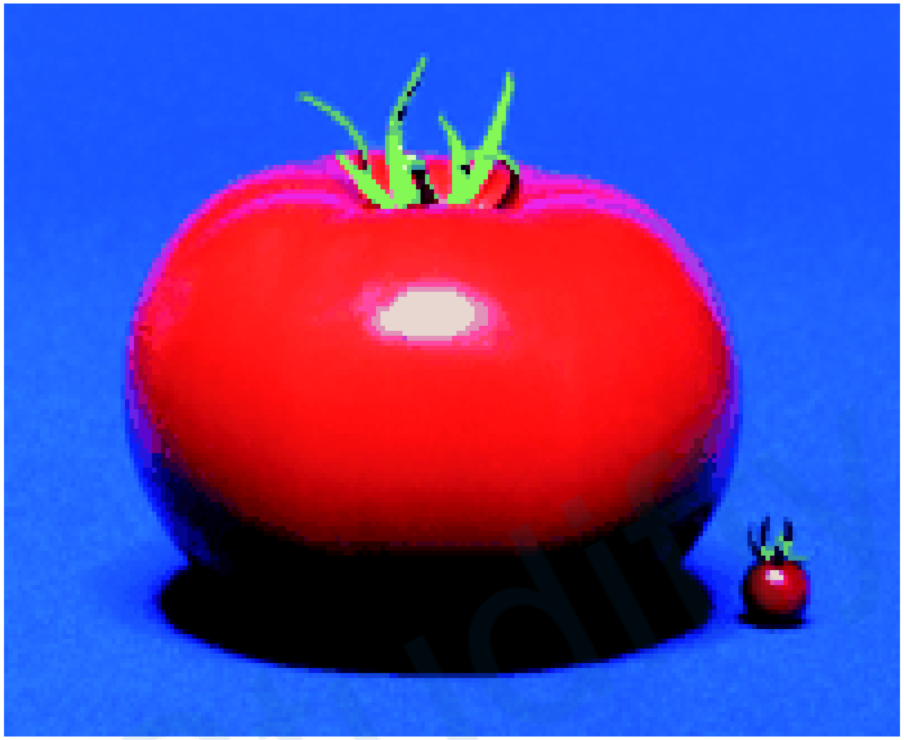
4,000-1,000 B.C

All major food crops being cultivated in Eurasia and in Americas. i.e. Potato, Wheat, Pea, Sunflower, Millet …

1,000 – 0 B.C

Babylonians use selective breeding techniques with date palm (870 BC)

- *Traditional plant breeding selects mutants for best yield and quality (e.g., tomatoes).*
- *Ultimate improved crop is maize: domesticated from teosinte*



Wild tomato (left)
(*Lycopersicon pimpinellifolium*)
D= 1 cm

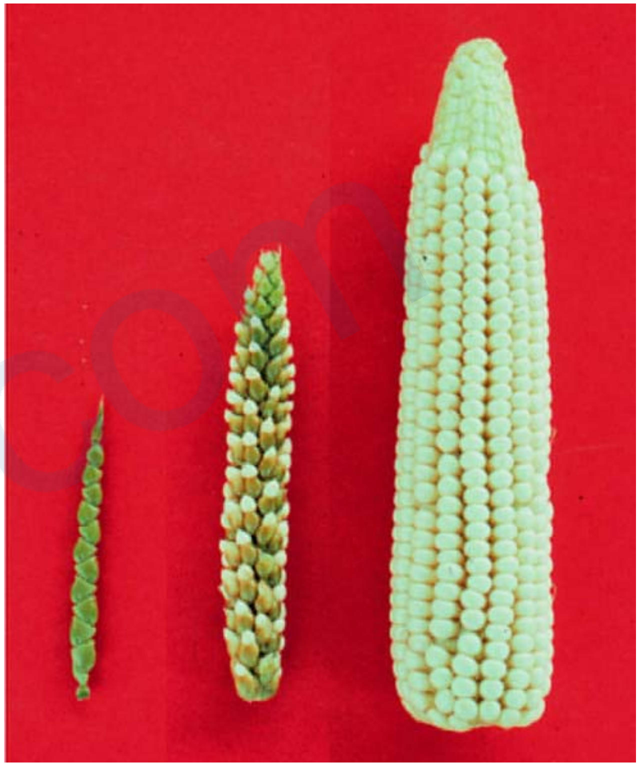
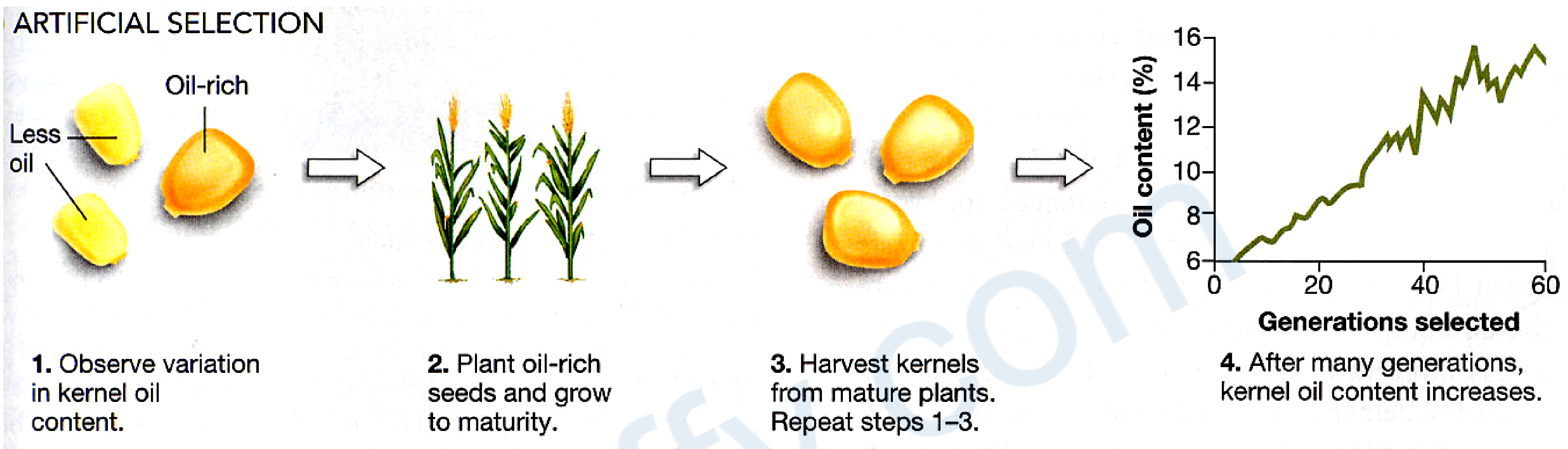


Photo source: Nicholas H. Barton. **Evolution**. *Cold Spring Harbor Laboratory Press* (2007).

e.g. *Artificial selection of kernel oil content*

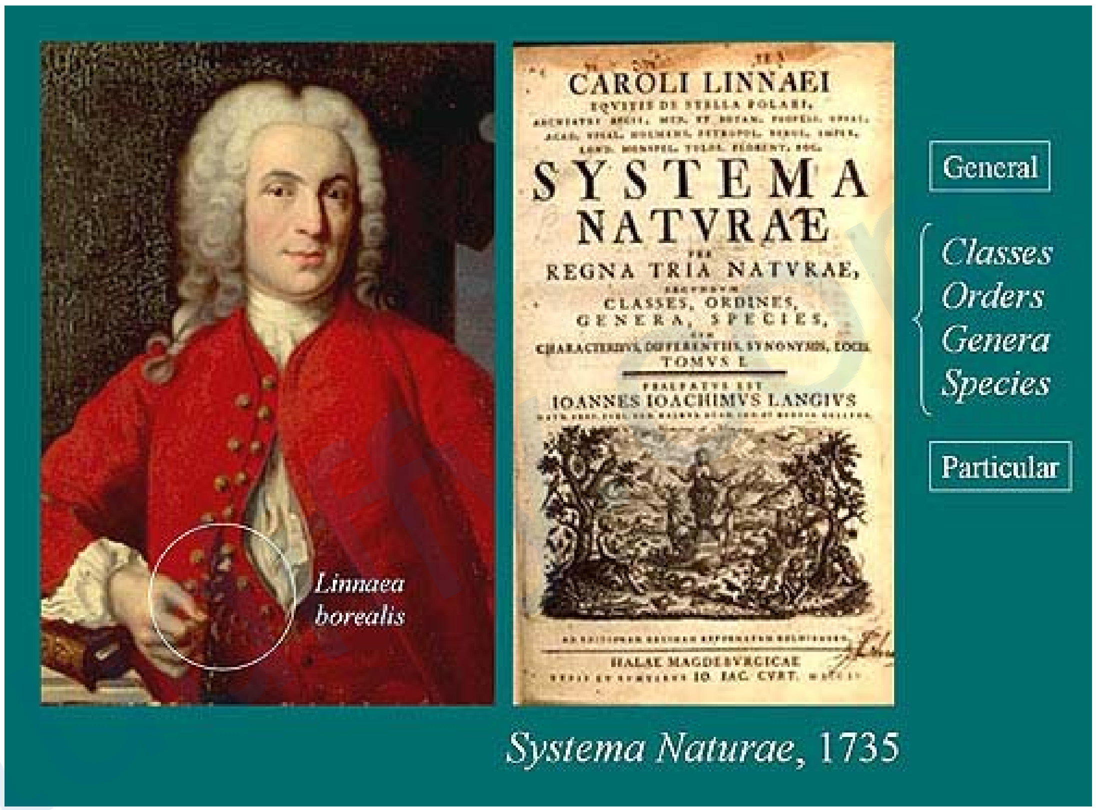


Classical Plant breeding

- *The founding of the science of genetics.*
- *Cross-breeding to strengthen traits*

1735

Linnaeus publishes ‘Species Plantarum’, effectively beginning the science of plant taxonomy

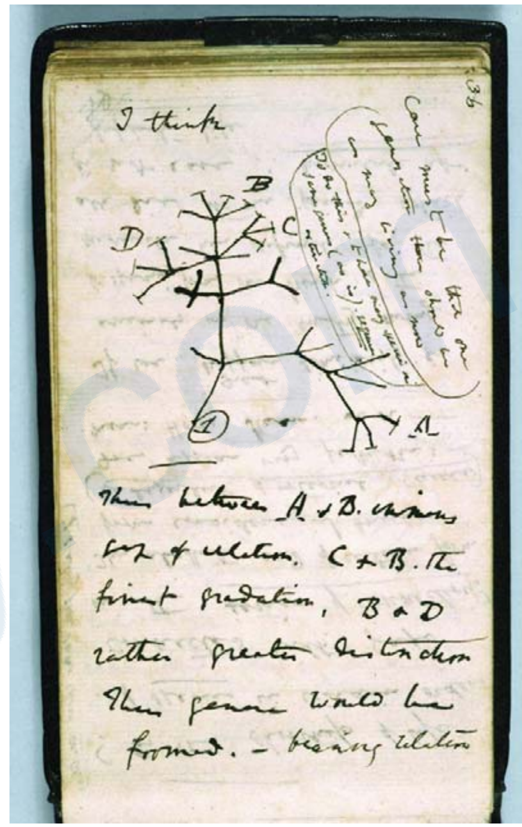


Systema Naturae, 1735

Photo source: *www.library.otago.ac.nz*

1859

Charles Darwin publishes the theory of evolution by natural selection



Photos source: *www.calacademy.org*

1865

Gregor Mendel discovers the laws of inheritance by studying flowers in his garden. The science of genetic begins.

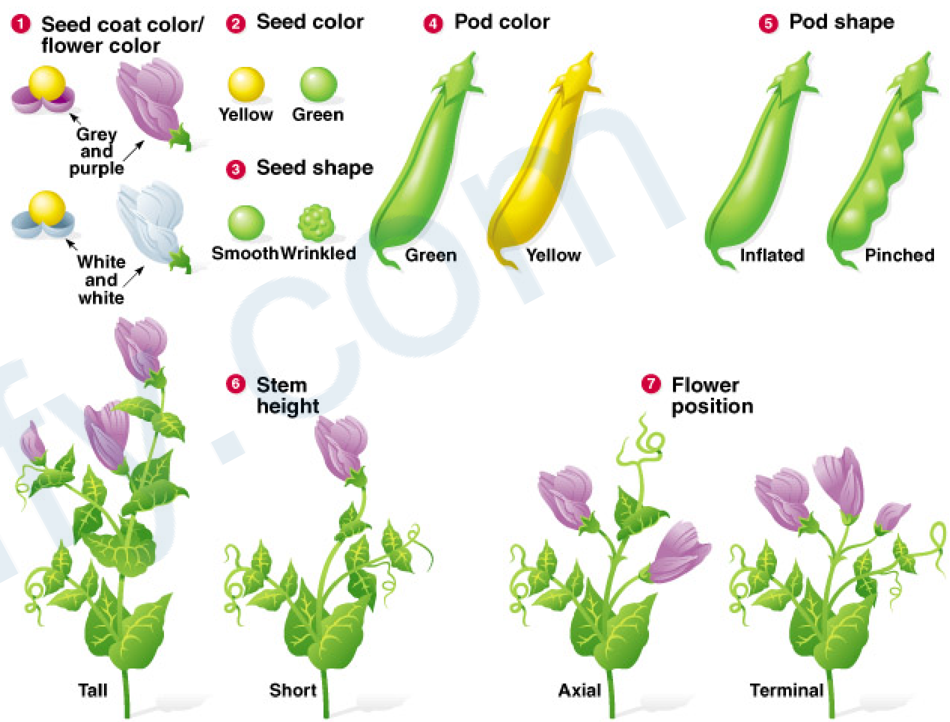
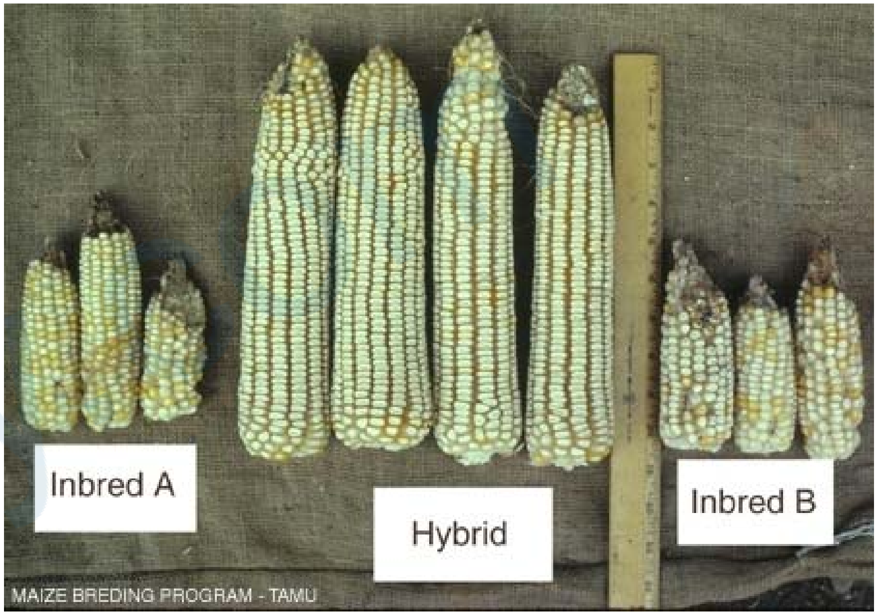


Image source: *www.jic.ac.uk*

Hybrid breeding

- *Two parental lines of normally outbreeding species are inbred through several self-pollinations.*
- *When crossing such lines the first generation has hybrid vigour.*
- *The vigour gradually disappears over the next generations so new sowing seeds have to be purchased every year .*
- *Selection operates on desirable traits, not on survival in the wild.*

A basic type of classical plant breeding: *- Hybrid breeding to strengthen traits. - Variety in genetic structure enhances viability against disease, pests, climate variability.- Selection is the process that plants with desirable characteristics are chosen from a population and then reproduced.*



1923

Russet Burbank hybrid potato launched

1933

First hybrid maize variety launched in USA

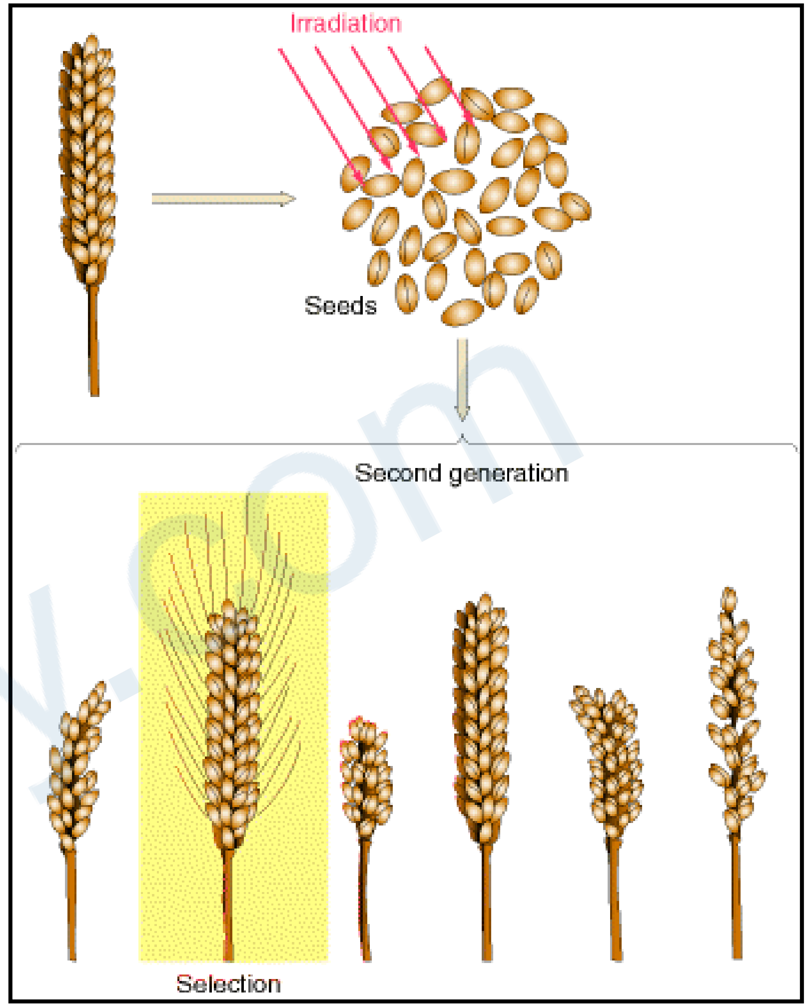
Modern Plant breeding

A basic type of modern plant breeding:

- *Mutation breeding*
- *Green revolution*
- *Plant tissue culture breeding*

Mutation breeding

- Seeds are treated with either radiation or mutagenic chemicals to induce larger or smaller lesions in the genes.
- The mutations are at random over the genome.
- Usually mutation results in a loss of function of genes



1928

Stadler produced mutations in barley

Mutation breeding became a bandwagon for about 10 years

Green revolution (1960-1970)

Green revolution' leads to greatly increased crop yields based on the incorporation of dwarfing genes discovered by Norman Borlaug and the widespread use of agrochemicals

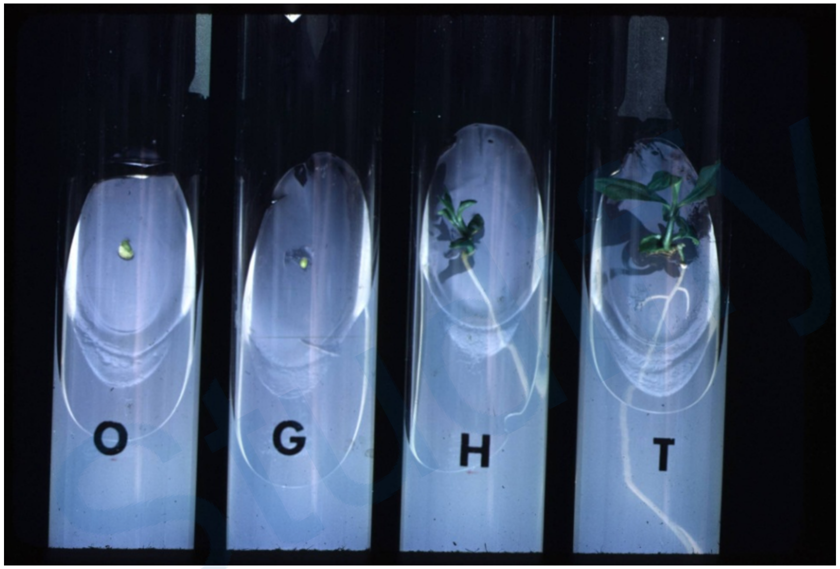
Food for thought. Breeders saw big yield jumps from traditional *(left)* to modern rice plants *(center)*, but newer advances *(right)*, are less dramatic.

Dr. Norman Borlaug Nobel peace prize 1970
Father of Green Revolution

Plant tissue culture breeding

The process of selectively mating plants in aseptic culture.

- *Embryo rescue*
- *Somaclonal variation selection*
- *Somatic hybrid (i.e. fusion protoplast).*
- *Generation of haploid (i.e. anther/microspore culture)*



Highlights of Plant tissue culture

1902

Gottlieb Haberlandt proposed that all cells are totipotent.

Photo source: *www.uni.graz.at*

1904

Hanning isolated nearly mature zygotic embryos from seeds of Crucifers and successfully grew them to maturity in a defined medium.

1925

Laibach isolated and grew embryos of interspecific cross *Linum perenne* and *L. austriacum* that aborted *in vivo*

1948

Folke Skoog discovered that kinetin could induce organogenesis in callus culture of tobacco

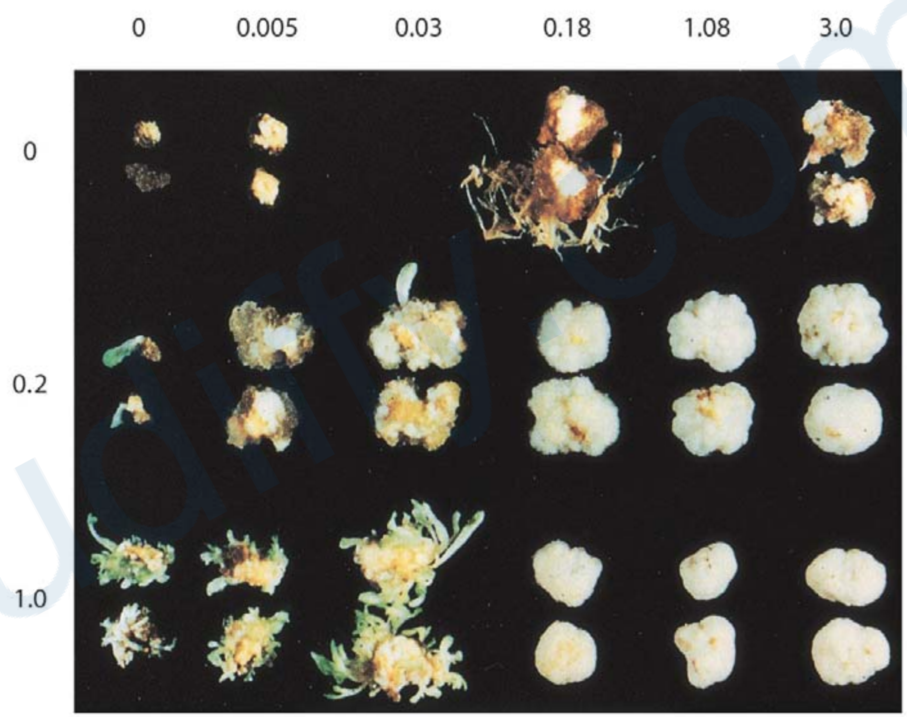
1957

Skoog and Miller demonstrated the effects and interaction of phytohormones

Auxin : cytokin > 1 → root formation

Auxin : cytokin <1 → shoot formation

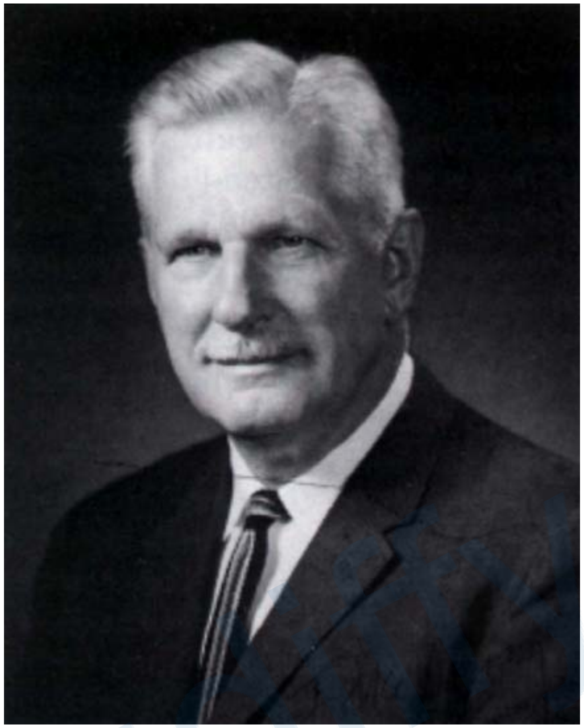
Auxin : cytokin = 1 → callus formation



1962

Development of MS medium.

Murashige T. and Skoog F., Physiol.Plant., 15: 473-497



Folke Skoog

Toshio Murashige

Photos source: *www.botany.org*

1964

Haploid plants derived from cultured Datura anthers

1972

First interspecific hybridization of *Nicotiana* sp. by fusing protoplast

1974

Haploid plants derived from cultured tobacco microspores

1977

Successful integration of T-DNA in plants.

1.2. Plant biotechnology

Two major areas of plant biotechnology:

- Plant Tissue Culture (plants cloning)

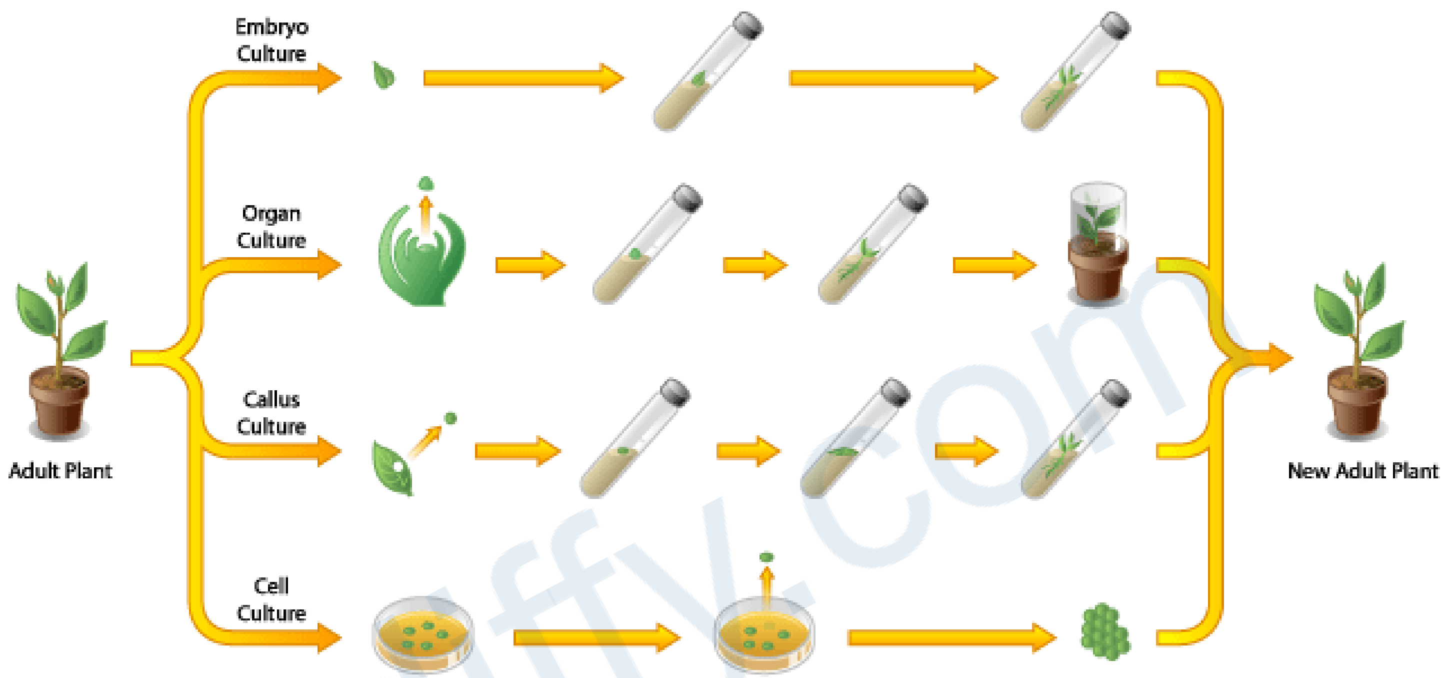


Image source: *www.scq.ubc.ca*

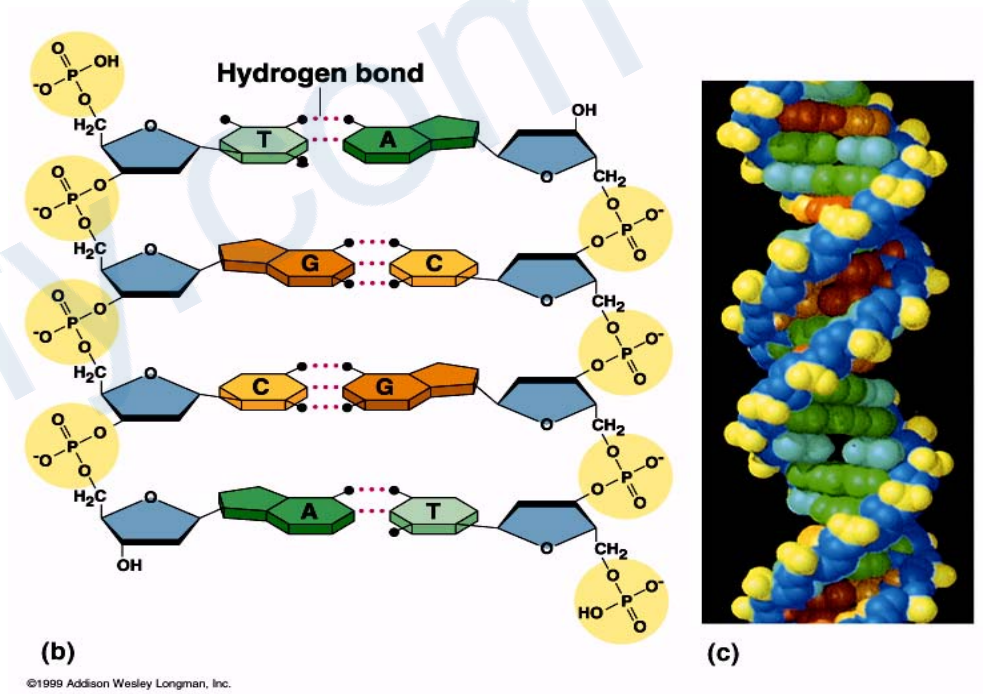
- Recombinant DNA technology (gene cloning)

Highlights of Plant Biotechnology

1953

James Watson and Francis Crick describe the double helical structure of DNA. They shared the 1962 Nobel Prize in Medicine or Physiology with Maurice Wilkins.

Photo source: *www.chem.ucsb.edu*



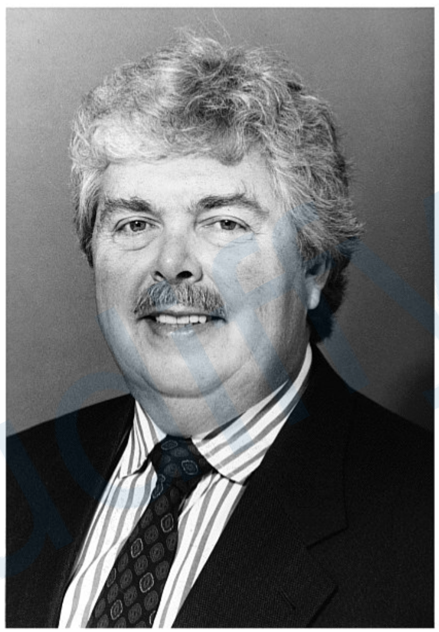
1972

Paul Berg discovery *restriction enzymes* cut and splice genetic material in a very specifically way. This opens the way for gene cloning.

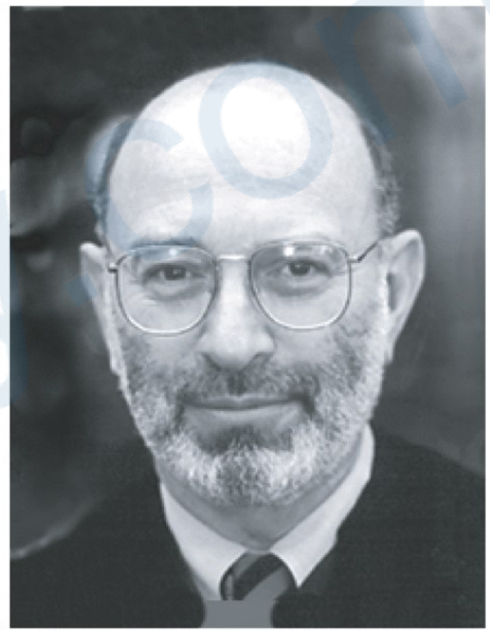
1973

Cohen and Boyer created the first recombinant DNA using bacterial genes. The era of recombinant DNA technology begins.

Paul Berg



Herbert Boyer



Stanley N. Cohen

Photos source:
www.shawprize.org
www.salsa.net

What is the difference between a traditional breed and GMO? Attitude

- **Agriculture is inherently about genetically modifying crops.** While we know that there has been various forms of agriculture for more than 10,000 years or so as evidenced by seed production. Hand pollinating, cross-breeding and controlling “weeds” are all part of this long history of selecting for specific genetic structures of desirable crop traits.
- Genetically modified crops, or transgenic crops, are different in that we are taking genes that would otherwise never be able to get into a given genetic structure to alter crop traits. DNA transfer could be from another crop species or even from bacteria or virus…

1983

First GM plants:

- Tobacco: *resistant to kanamycin and to methotrexate*
- Petunia: *resistant to kanamycin*
- Sunflower: *containing a gene from French bean*

Source: *www.grad.uga.edu, www.en.wiki.com*

1985

First GM plants in field in the UK.

1990

The first field trial of GM cotton

Source: *www.biovisioneastafrica.com*

1992

FDA (Food and Drug Administration) decided GM foods would be regulated as conventional foods.

1994

FlavrSarv Tomato - the first GM food to be approved for sale in the U.S. It promised a longer shelf life and “that homegrown flavor”, even in winter.

Because of the widespread concern about genetic modification, the process was restricted by 1997.

Photos source: *www.deliver2u-com.my*

1996

First large-scale cultivation of GM soybean and maize

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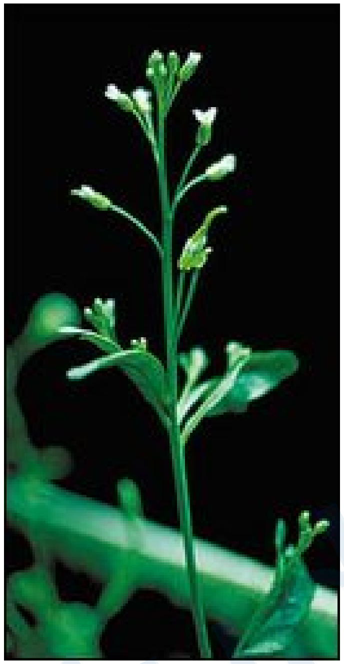
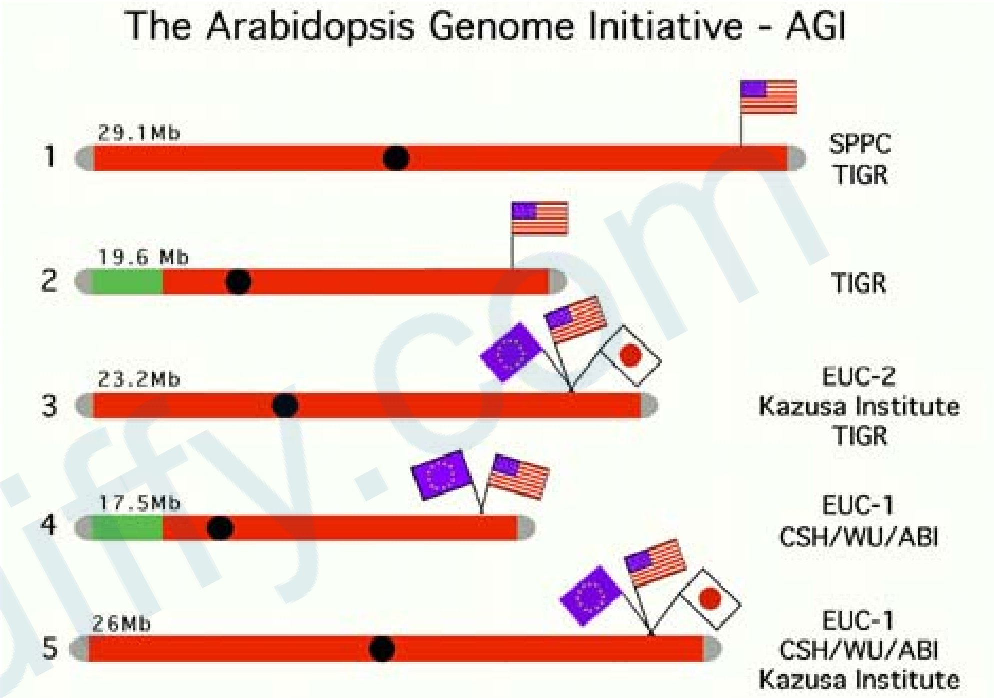
2000

Arabidopsis genome sequence completed. The genome contains 25,498 genes encoding proteins from 11,000 families





The participating groups of AGI

2003

The International Rice Genome Sequencing Project, a 10-nation publicly funded effort, had unveiled the most complete draft yet - and it's available to all.

2004

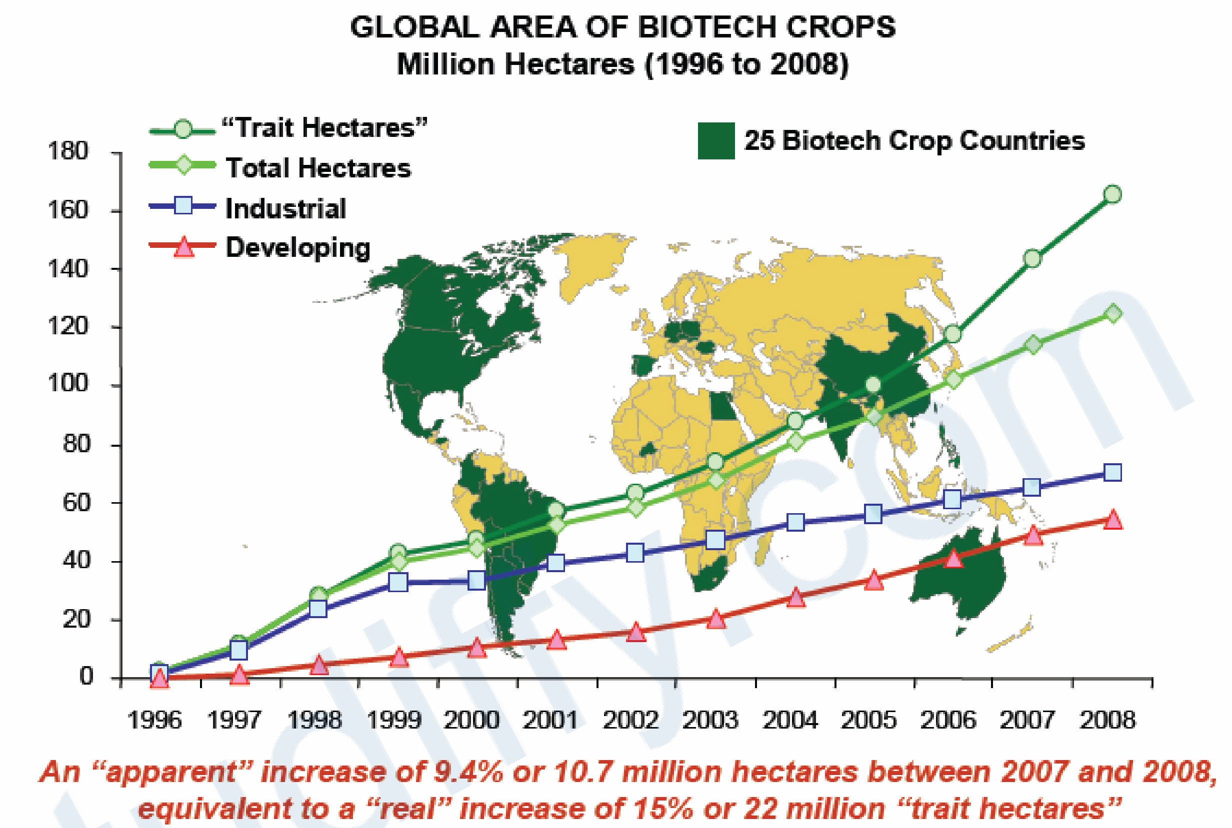
First generation Golden rice field trial. Golden rice was developed as a fortified food to be used in areas where there is a shortage of dietary vitamin A

Ingo Potrykus and Peter Beyer and the first Golden Rice field trial worldwide in September 2004.

Photos source: *www.goldenrice.org*

2008

GM crops grown on 120 million hectares in 25 countries

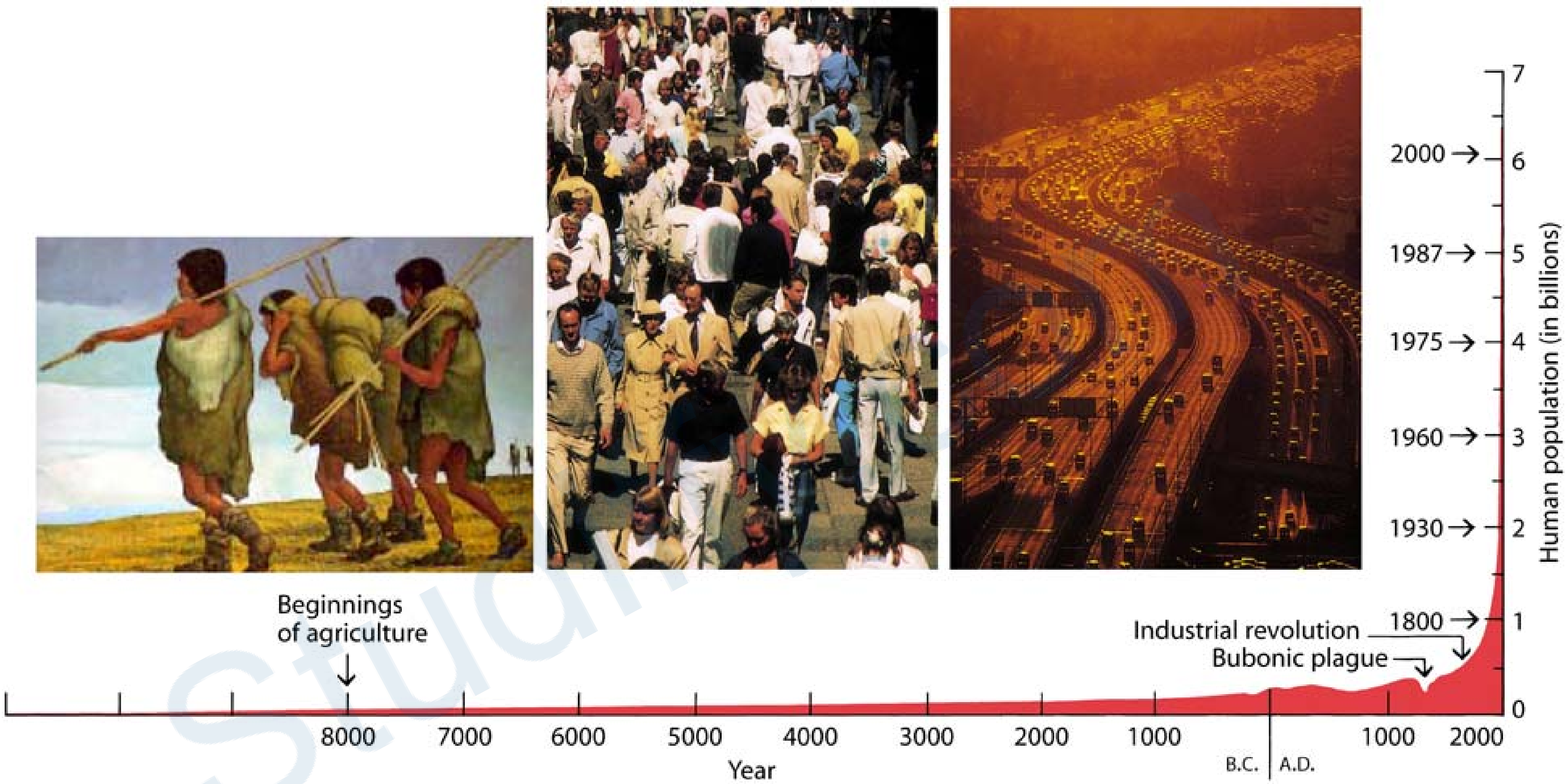


Source: Clive James, 2009.

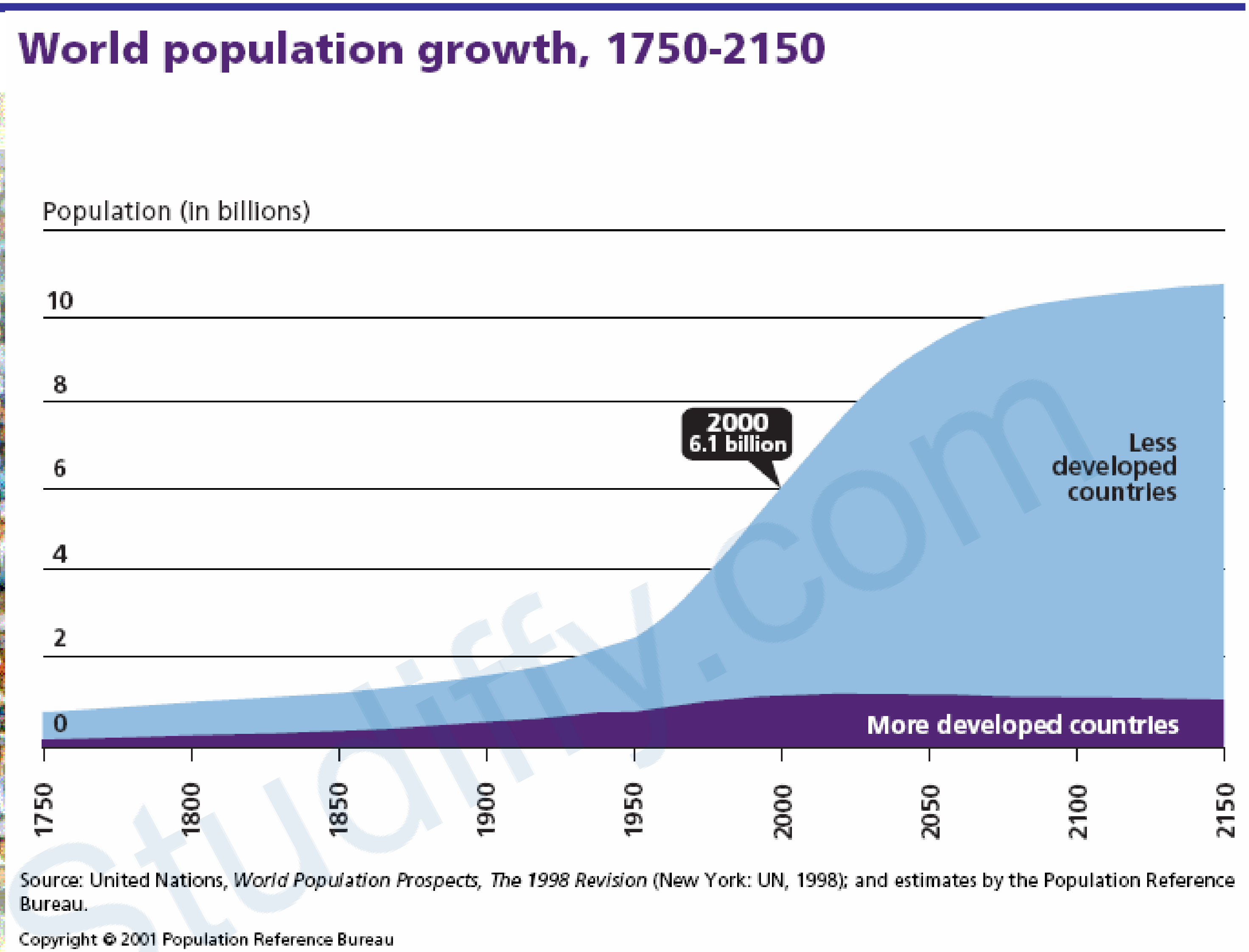
future …

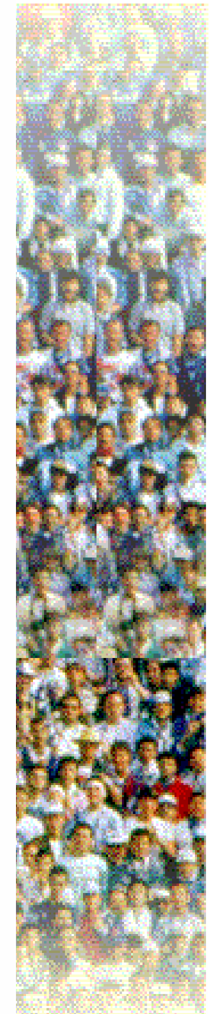
1.3. Why plant biotechnology?

Human population is rapidly outgrowing



Global Population Growth



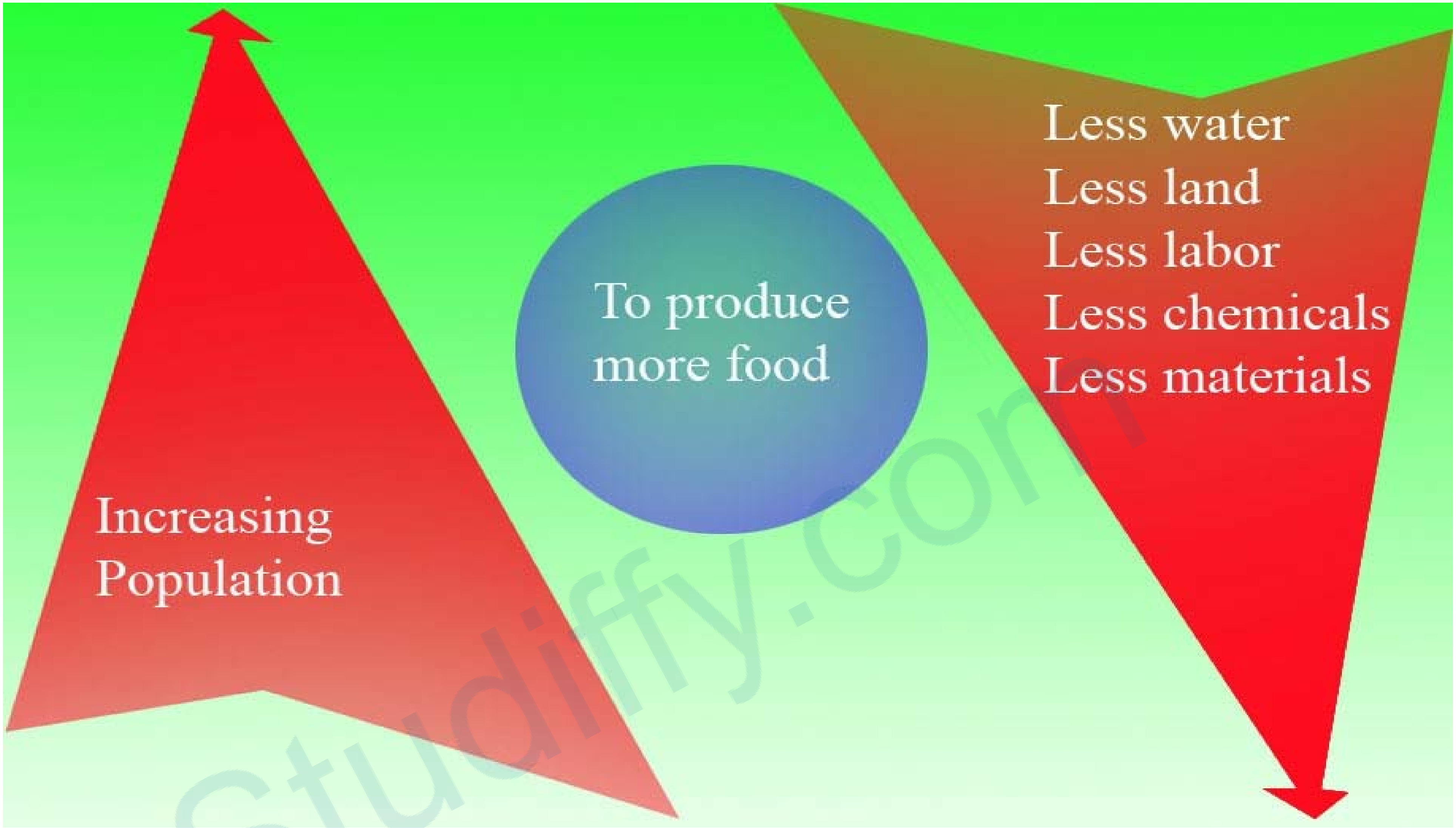


Sources: United Nations Population Division and Population Reference Bureau

Region	Population (billion)		Food grain (million tons)	
	1997	2025	1997	2025
Asia	3.54	4.80	1019	1510
Africa	0.79	1.62	116	416
South America	0.46	0.78	119	231
North America	0.29	0.33	433	450
Europe	0.72	0.74	448	479
Oceania	0.03	0.04	31	26
World	5.83	8.31	2166	3112

Higher yield or Food crisis?

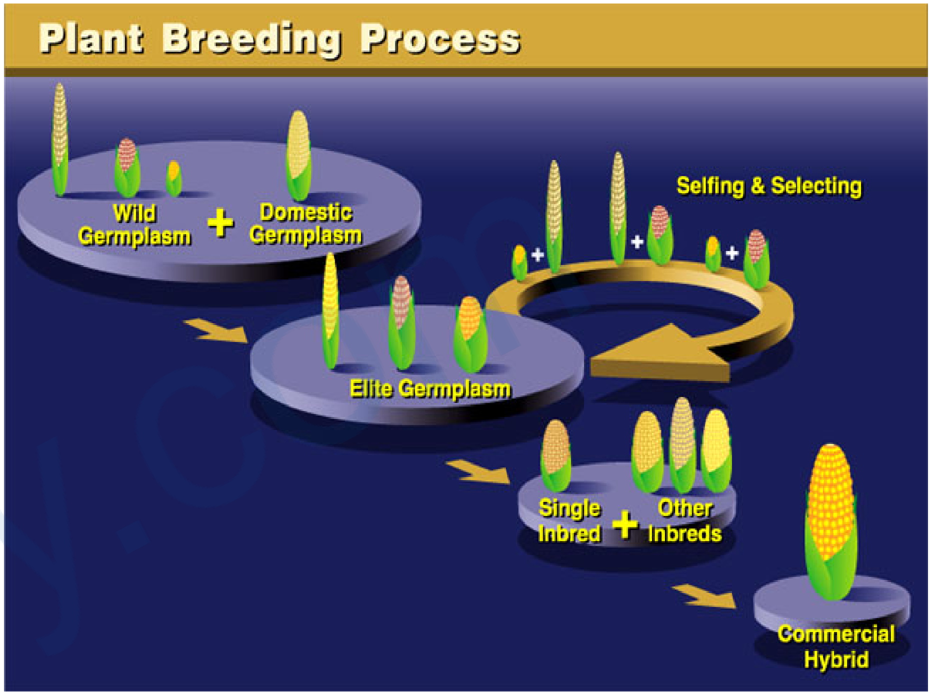
Worlds' current status



The improving process

For higher yield, what did people do in the past?

- ✓Conventional Breeding
- ✓Ideotype Breeding
- ✓Hybrid Breeding
- ✓Wide Hybridization
- ✓Mutation Breeding
- ✓Germplasm Breeding

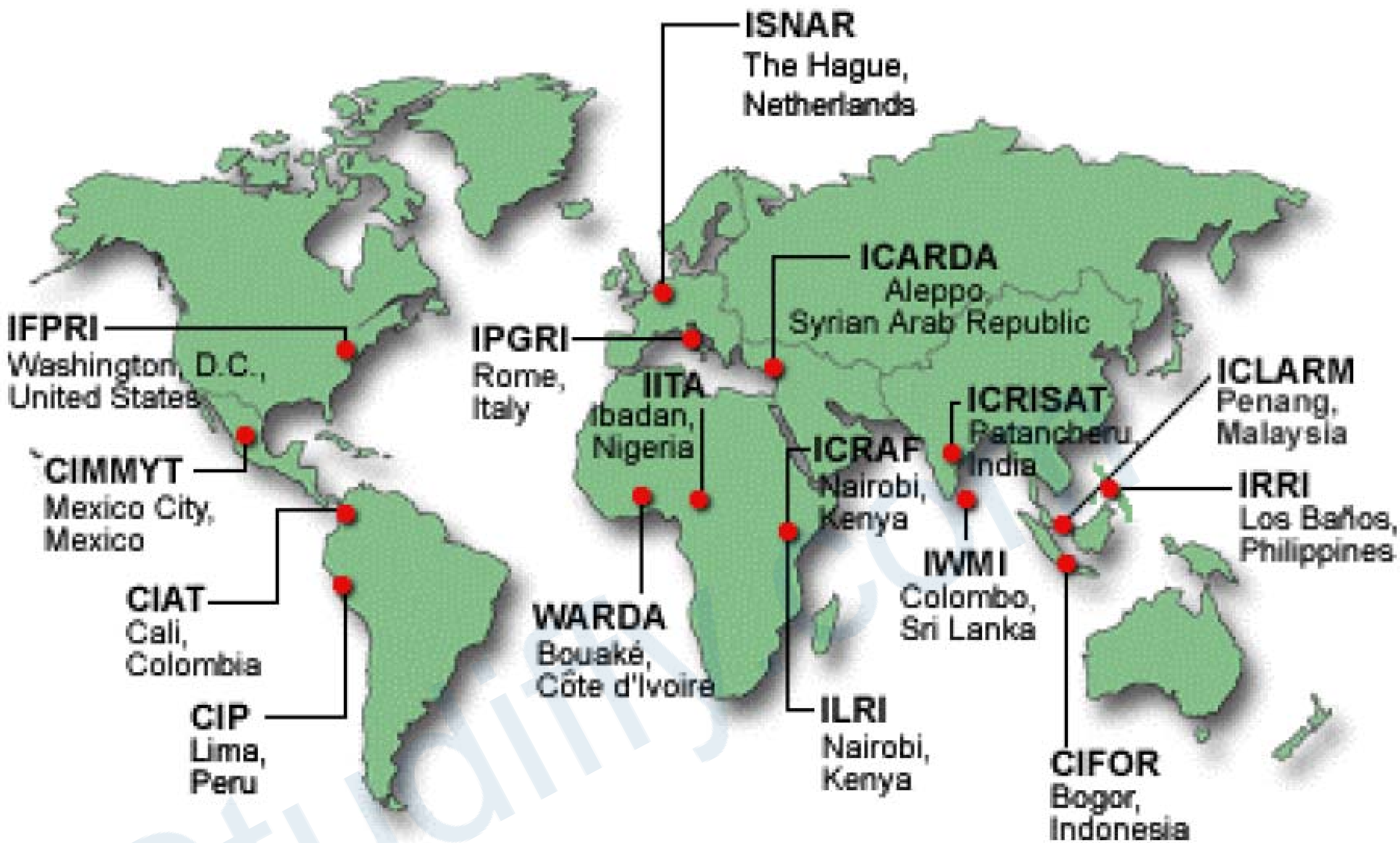


Many centers for plant breeding had established around the world.

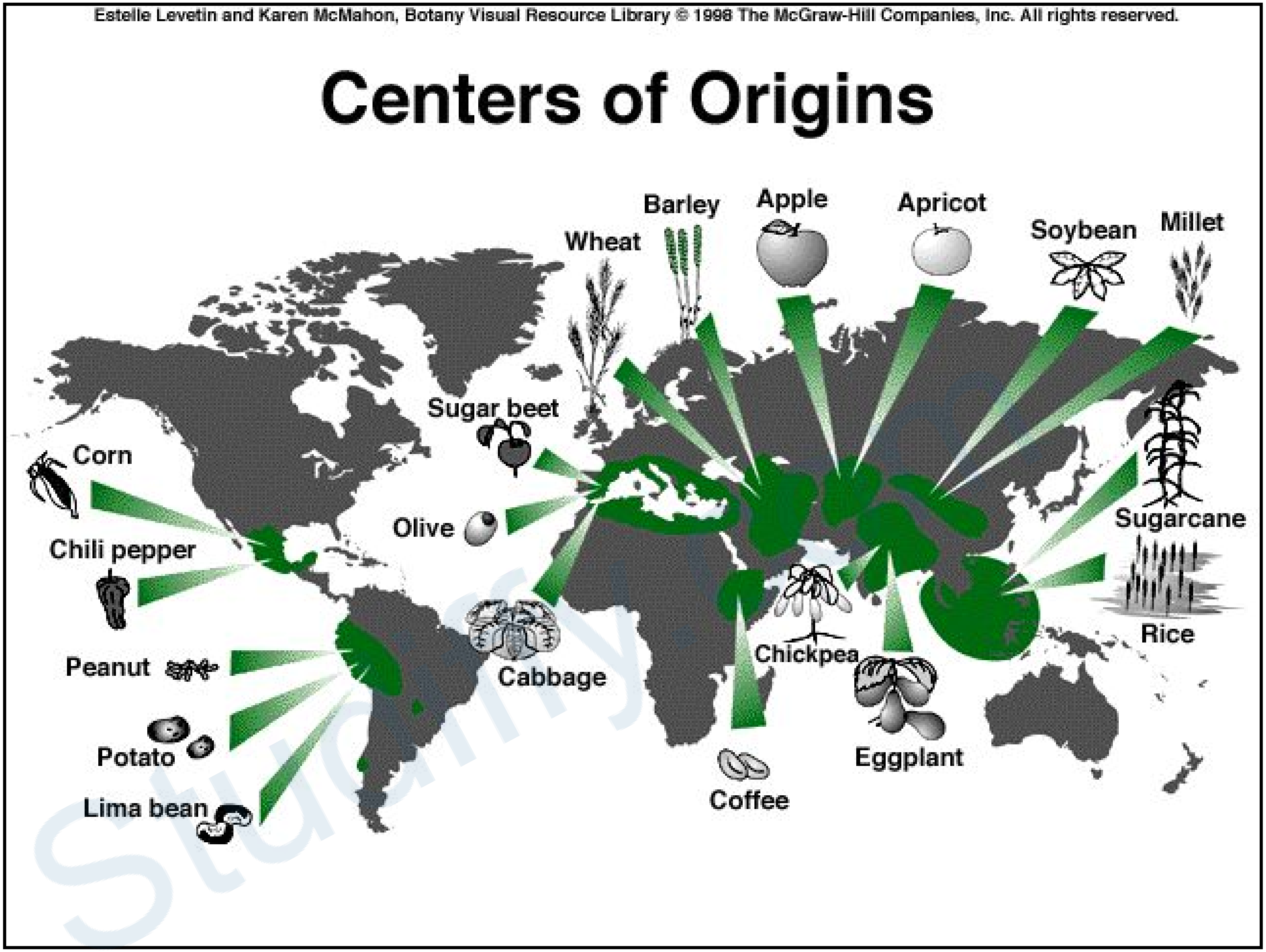
International agricultural research centers within the consultative Group on International Agricultural Research, Listed in order of year established.

Acronym	Center	Year Established	Research Programs
IRRI	International Rice Research Institute	1960	Rice
CIMMYT	International Maize and Wheat Improvement Center	1964	Maize, heat, triticale, barley
HTA	International Institute of Tropical Agriculture	1965	Maize, rice, cowpea, sweet potato, yams, cassava
CIAT	Centro Interncional de Agricultura Tropical	1968	Cassava, beans, rice, pastures
WARDA	West Africa Rice Development Association	1971	Rice
CIP	International Potato Center	1972	Potato
ICRISAT	International Crops Research Institute for the Semi-arid tropics	1972	Chickpea, pigeonpea, pear millet, sorghum groundnut
ILRAD	International Lab. For Research on Animal Diseases	1974	*Trypanosomiasis, theileriosis*
IBPGR	International Board for Plant Genetic Resources	1973	Plant genetic resources
ILCA	International Livestock Center for Africa	1974	Livestock production systems
IFPRI	International food Policy Research Institute	1975	Food policy
ICARDA	International Center for Agricultural Research in the Dry	1976	Wheat, barley, triticale, faba bean, lentil, chickpea, forages
ISNAR	International Service for National Agricultural Research	1980	National agricultural research

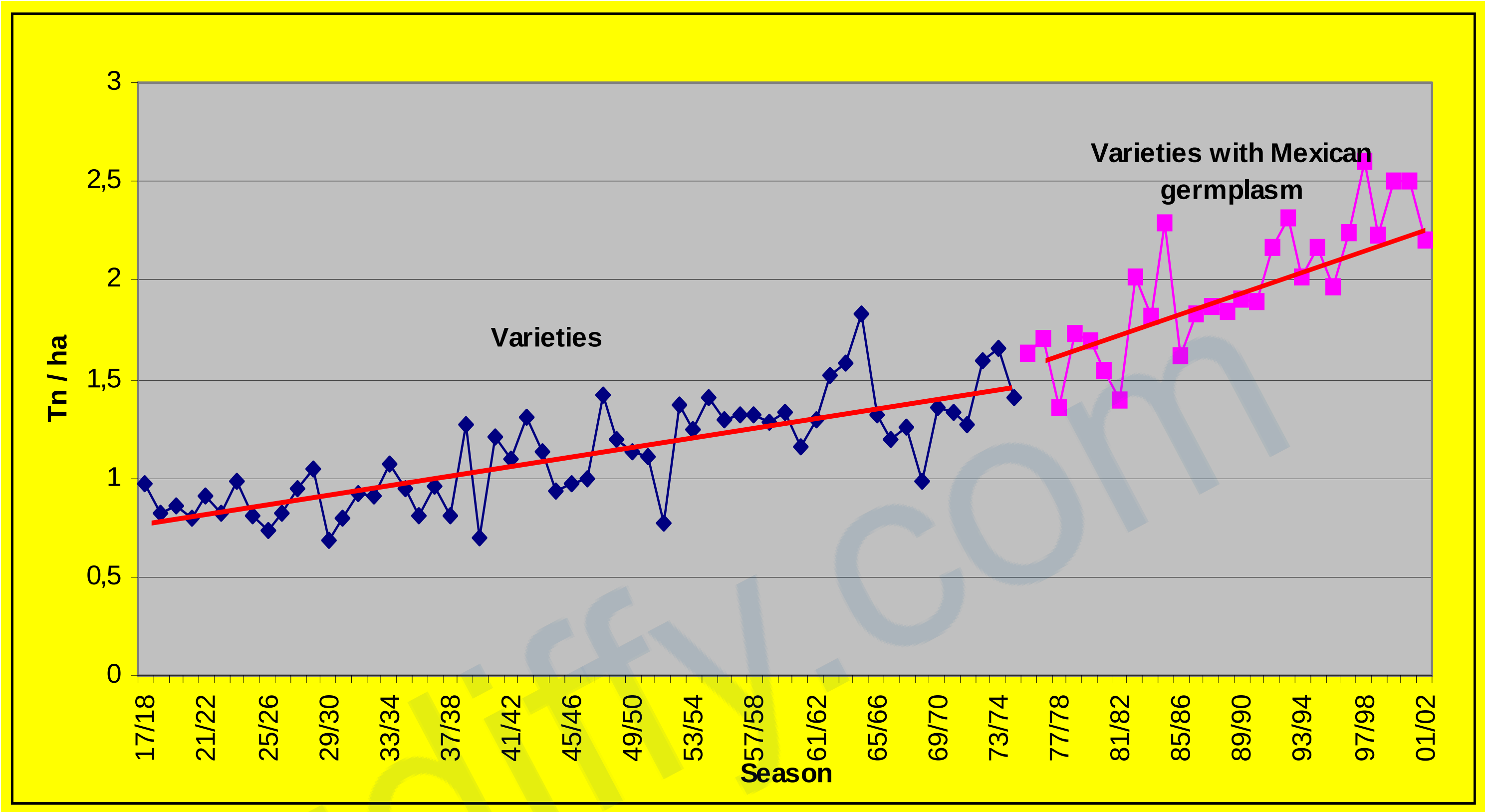
Notes: Many of the centers also have economic or farming systems research programs


ISNAR
The Hague,
Netherlands
ICARDA
Aleppo,
Syrian Arab Republic
IFPRI
Washington, D.C.,
United States
IPGRI
Rome,
Italy
IITA
Ibadan,
Nigeria
ICRISAT
Patancheru,
India
ICLARM
Penang,
Malaysia
CIMMYT
Mexico City,
Mexico
ICRAF
Nairobi,
Kenya
IRRI
Los Baños,
Philippines
IWMI
Colombo,
Sri Lanka
CIAT
Cali,
Colombia
WARDA
Bouaké,
Côte d'Ivoire
CIP
Lima,
Peru
ILRI
Nairobi,
Kenya
CIFOR
Bogor,
Indonesia

Each country has its own major



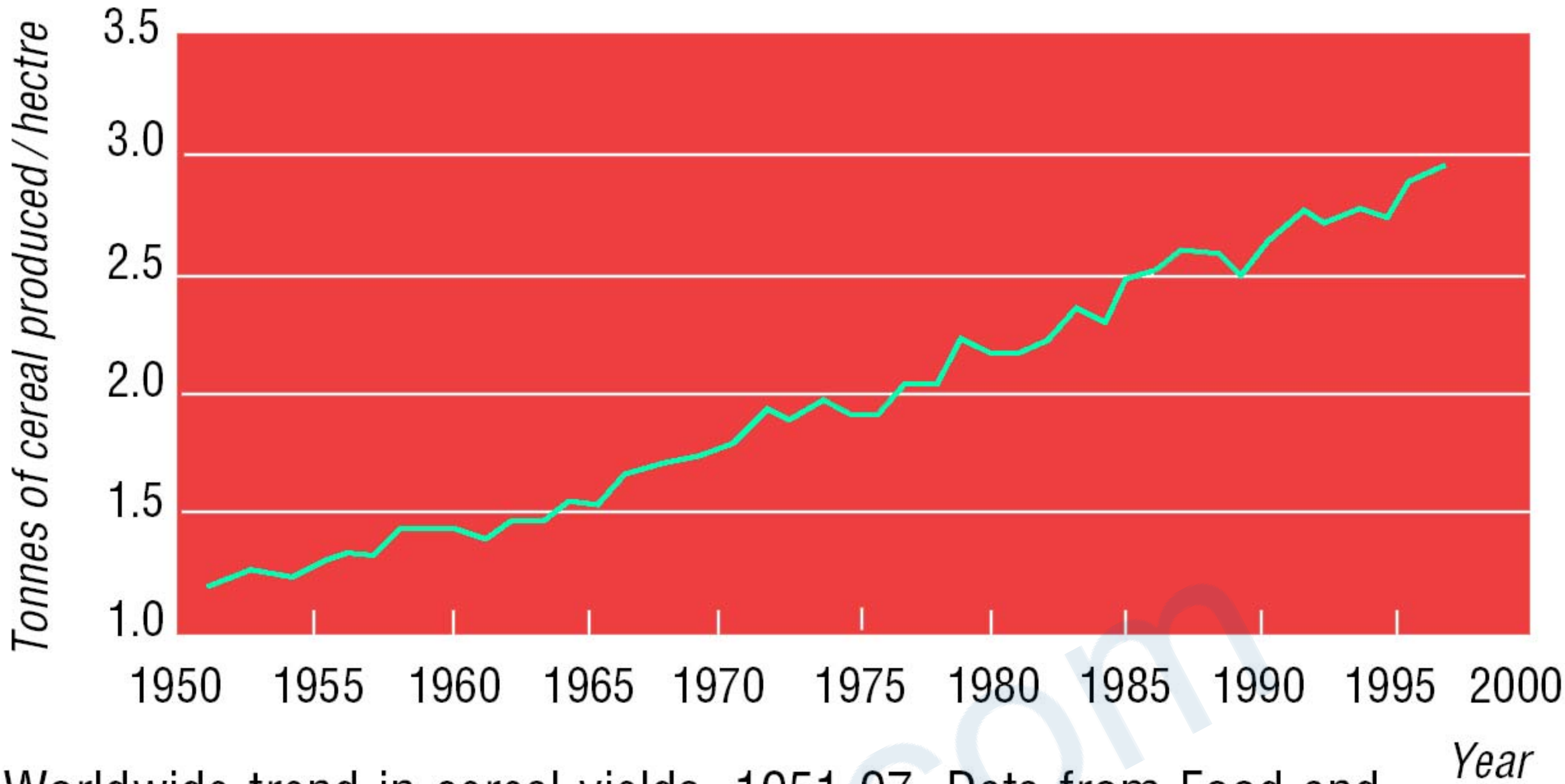
However, yield improved with breeding strategies, but it seems not as high as expected.



Yields of main crops in Kg / ha.

WHEAT

Source: SAGPYA



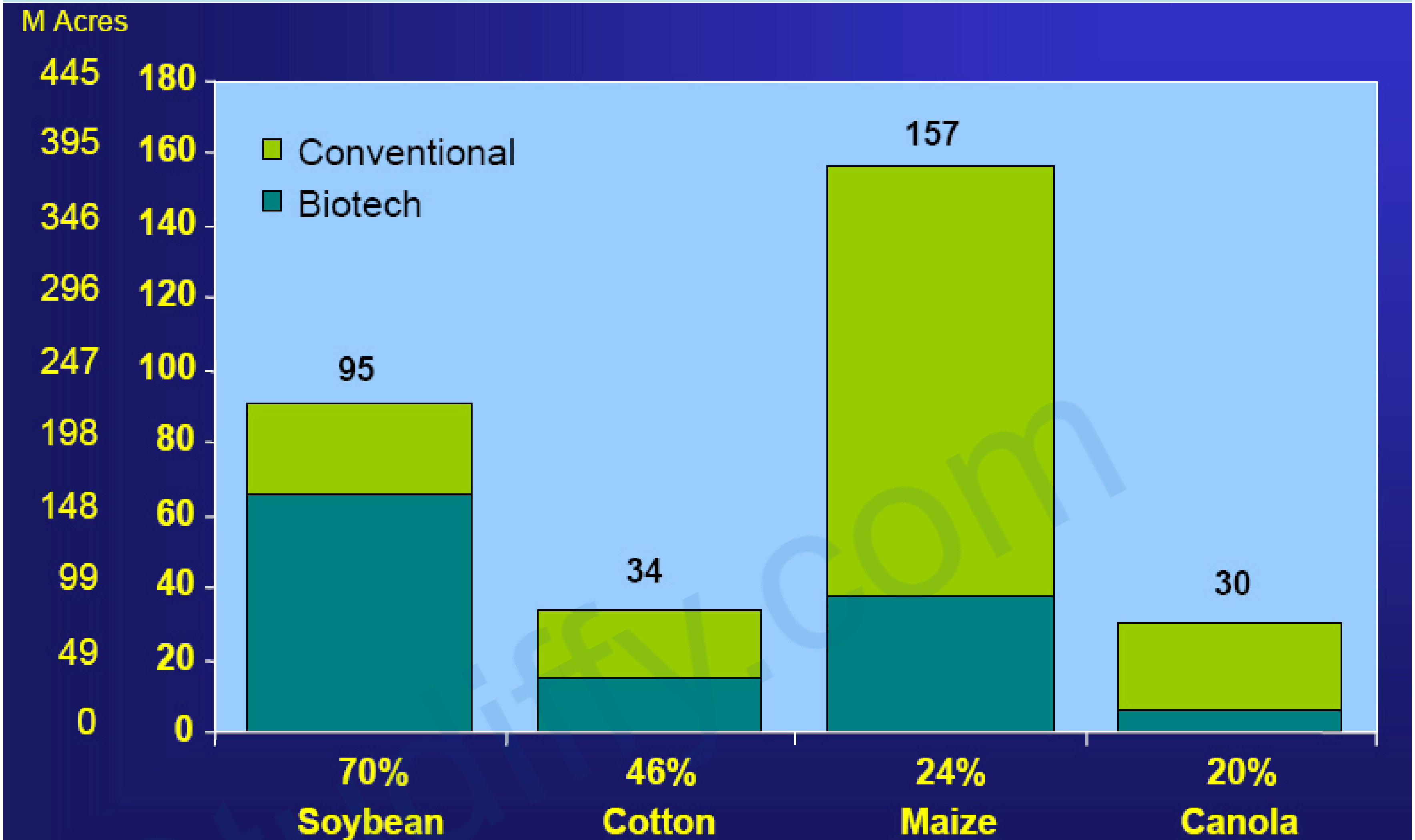
Worldwide trend in cereal yields, 1951-97. Data from Food and Agricultural Organisation[12]

How to keep the growth without any breakthrough?

2009: The scope of plant biotechnology

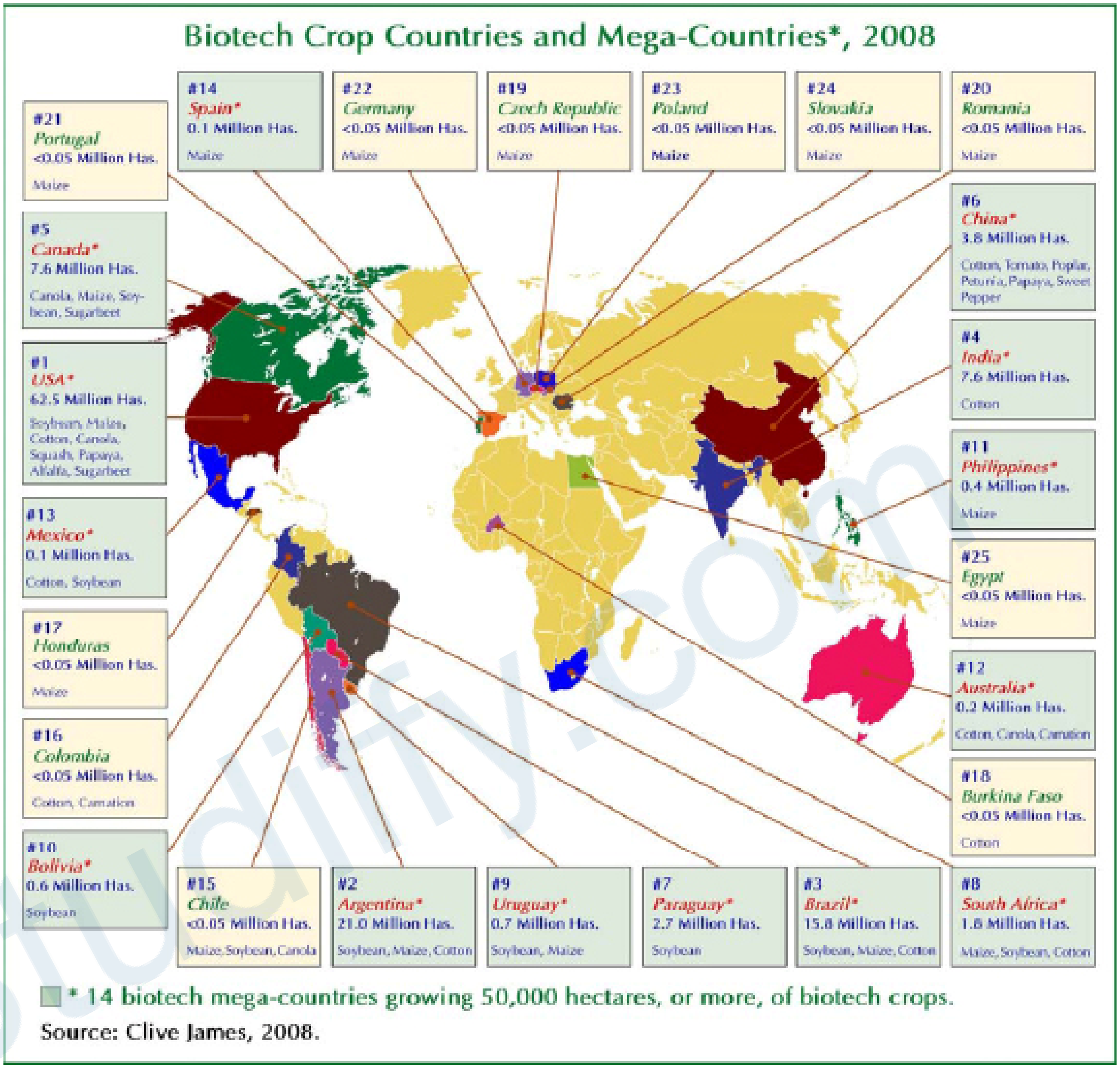
Plant genetic engineering
Plants micropropagation
Plant mutation cloning
Plant cells technology

Conventional Vs. Biotech crops



Global Adoption Rates (%) for Principal Biotech Crops (Million Hectares) 2009(Clive James)

Biotech Crop Countries and Mega-Countries, 2008



1.4. Impact of plant biotechnology

Economic impact


A GM cotton crop in the Kimberley

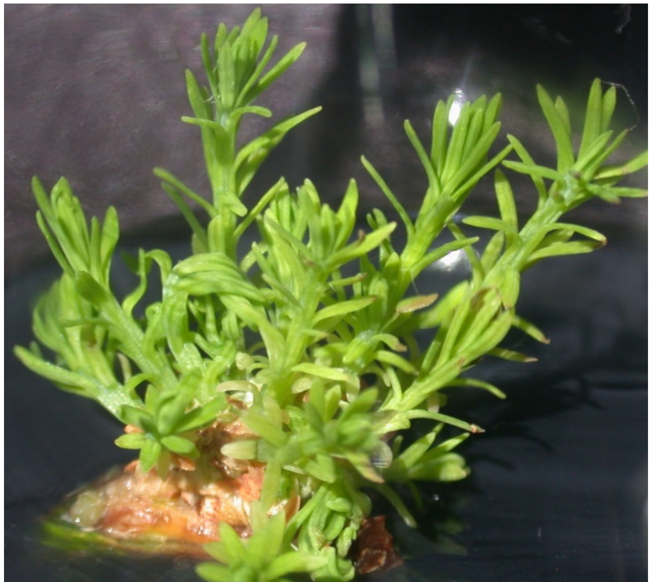
More crop

More money

With full adoption of biotechnology, aggregate income for all regions, measured by gross national product (GNP), is estimated to rise by US$210 billion a year, by the end of the period (2006-2015).

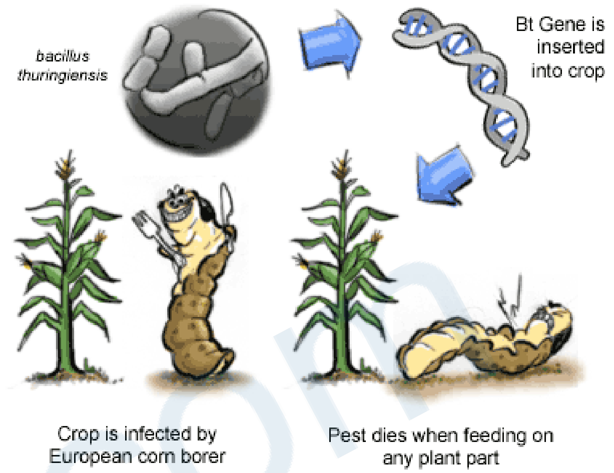
Environmental impact

In vitro conservation



Water pine – a dangerous extinct species

Pesticide reduction



GM oilseed rape

Health impact

More food

Better food

More healthy

Source: *www.vnexpress.net*

Society impact

Reducing

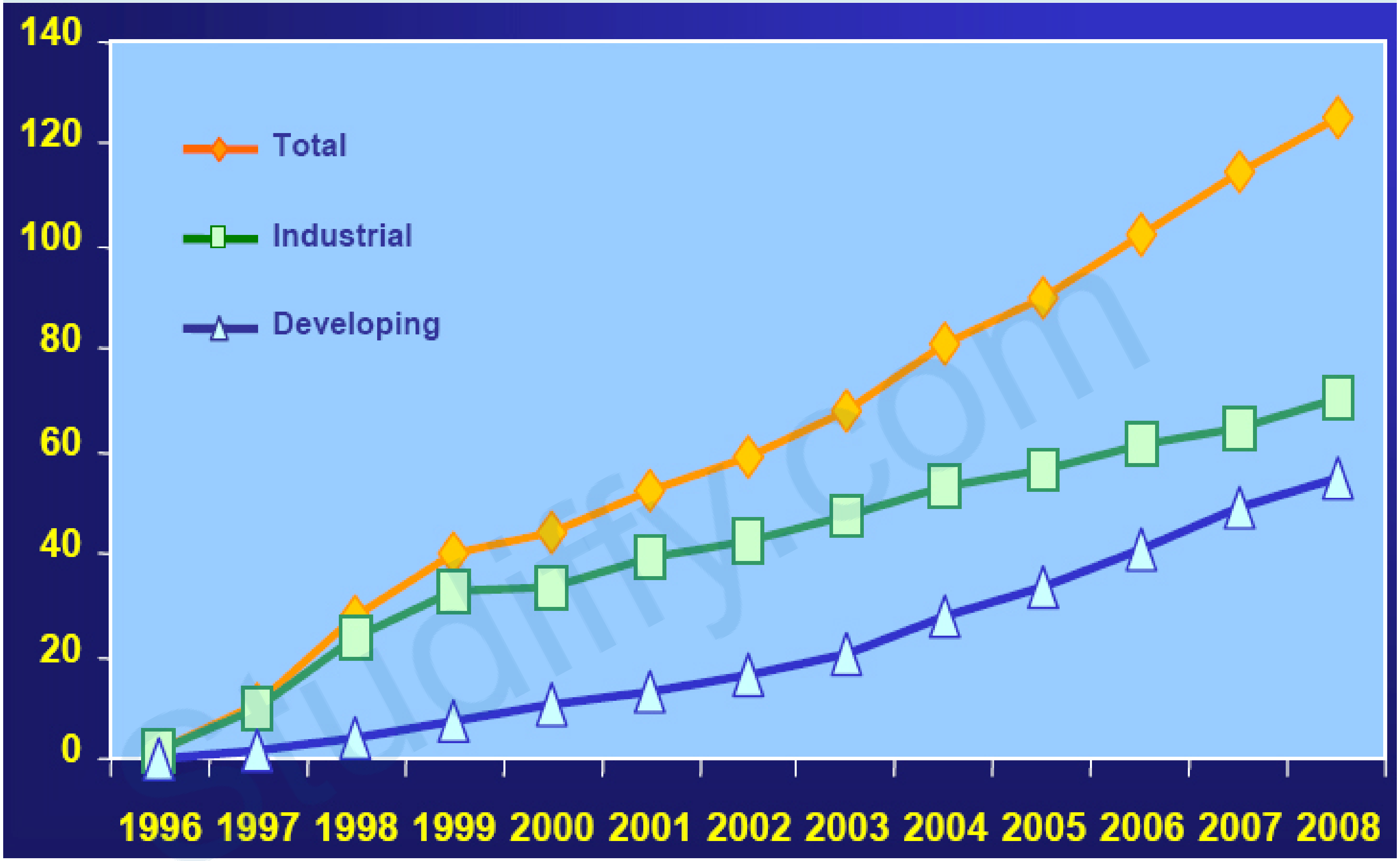
caloric under-nutrition

“food crisis”

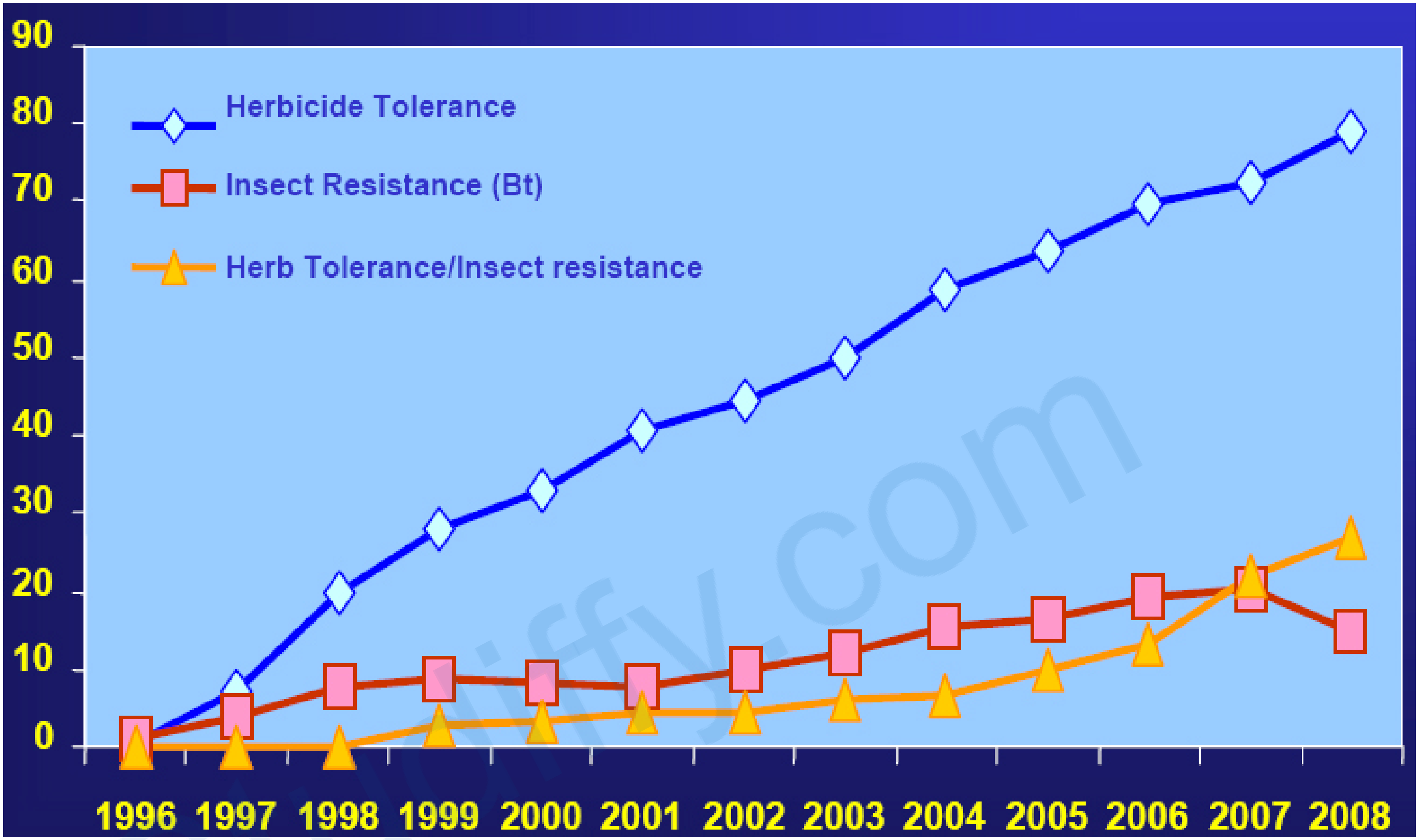
Source: *www.freemorpheus.altervista.org*

1.5.Current Status of GM Crops

Global Area of Biotech Crops, 1996 to 2008: Industrial and Developing Countries (Million Hectares). (Clive James,2009)

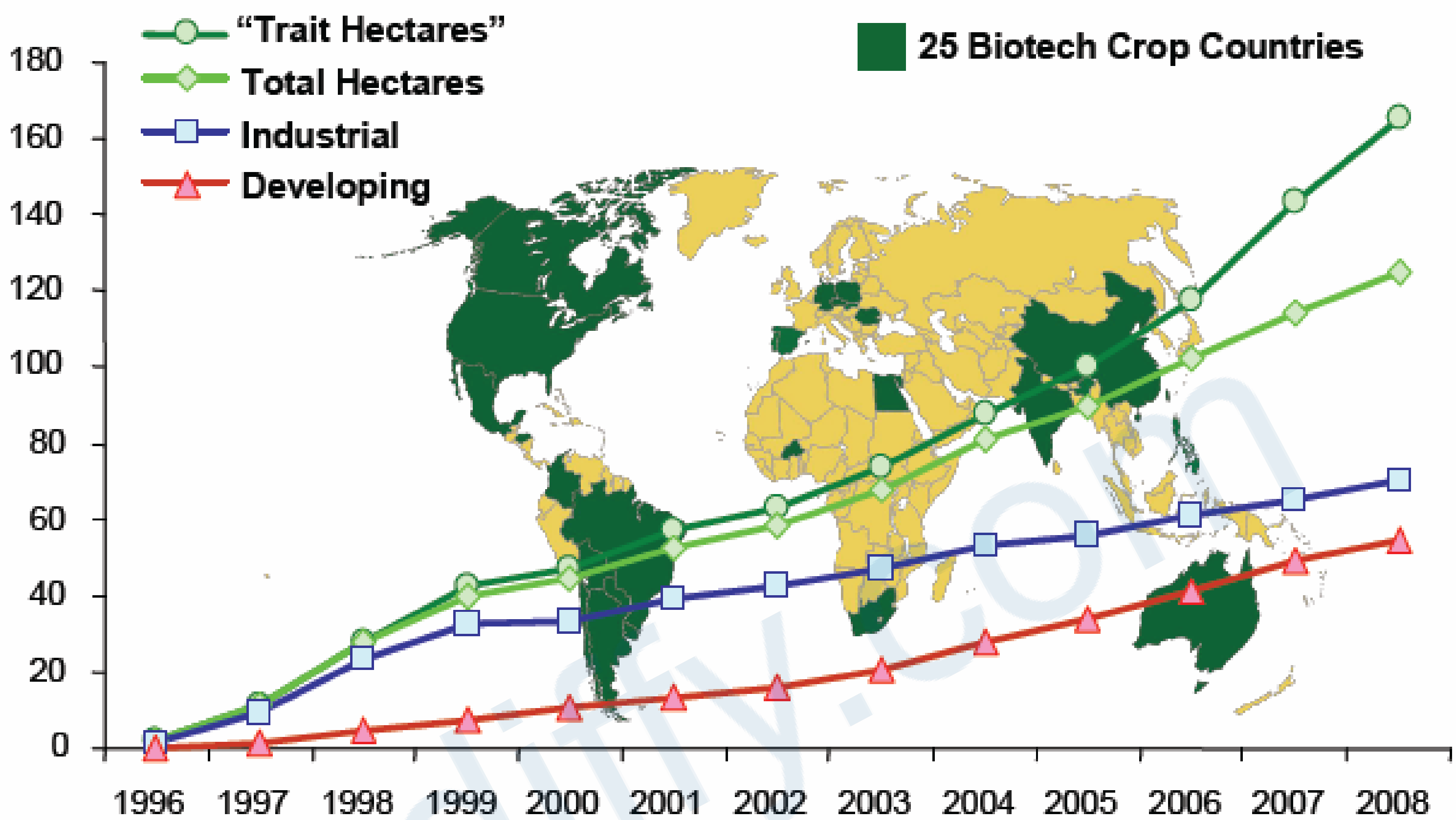


The better resistance, the higher the yield



Global Area of Biotech Crops, 1996 to 2008: By Trait (Million Hectares) (Clive James,2009)

GLOBAL AREA OF BIOTECH CROPS
Million Hectares (1996 to 2008)



An "apparent" increase of 9.4% or 10.7 million hectares between 2007 and 2008, equivalent to a "real" increase of 15% or 22 million "trait hectares"

Source: Clive James, 2009.