IRRI

Research at IRRI and GMOs issues

Dr. Tanguy Lafarge

with much thanks to Bob Zeigler, Gerard Barry, Philippe Hervé, Inez Slamet-Loedin and Sophie Clayton

French School of Manila, 18 March 2009

Rice Science for a Better World

IRRI

INTERNATIONAL RICE RESEARCH INSTITUTE
Los Baños, Philippines

The largest non-profit agricultural research center in Asia

Mission:

Reduce poverty and hunger,

Improve the health of rice farmers and consumers,

Ensure environmental sustainability

Home of the Green Revolution

Established 1960

1200 Staff

Offices in 15 countries

Annual Budget of ~ $60 M

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40 years ago (28 Nov. 1966), IRRI released and distributed IR8 as the first modern semi-dwarf rice variety.

It jump-started Asia's green revolution in rice.

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IR varieties and their impact

- >330 IR breeding lines have been released as >650 varieties in 75 countries
- 60% of the world rice area is now planted to IRRI-bred varieties or their progenies
- World rice production increased from 255 Mt in 1966 to 600 Mt in 2000

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The problem of too much water

- **20 million ha affected in South and Southeast Asia.**
- **Growing problem with climate change.**
- **Rice is only crop suitable, but ‘drowns’.**

Submergence tolerant varieties offer great hope for food security of millions in Asia and Africa

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Rice Germplasm will play a critical role in meeting the needs of future generations.

IRRI holds in trust the world's largest collection of rice genetic resources (>110,000 accessions).

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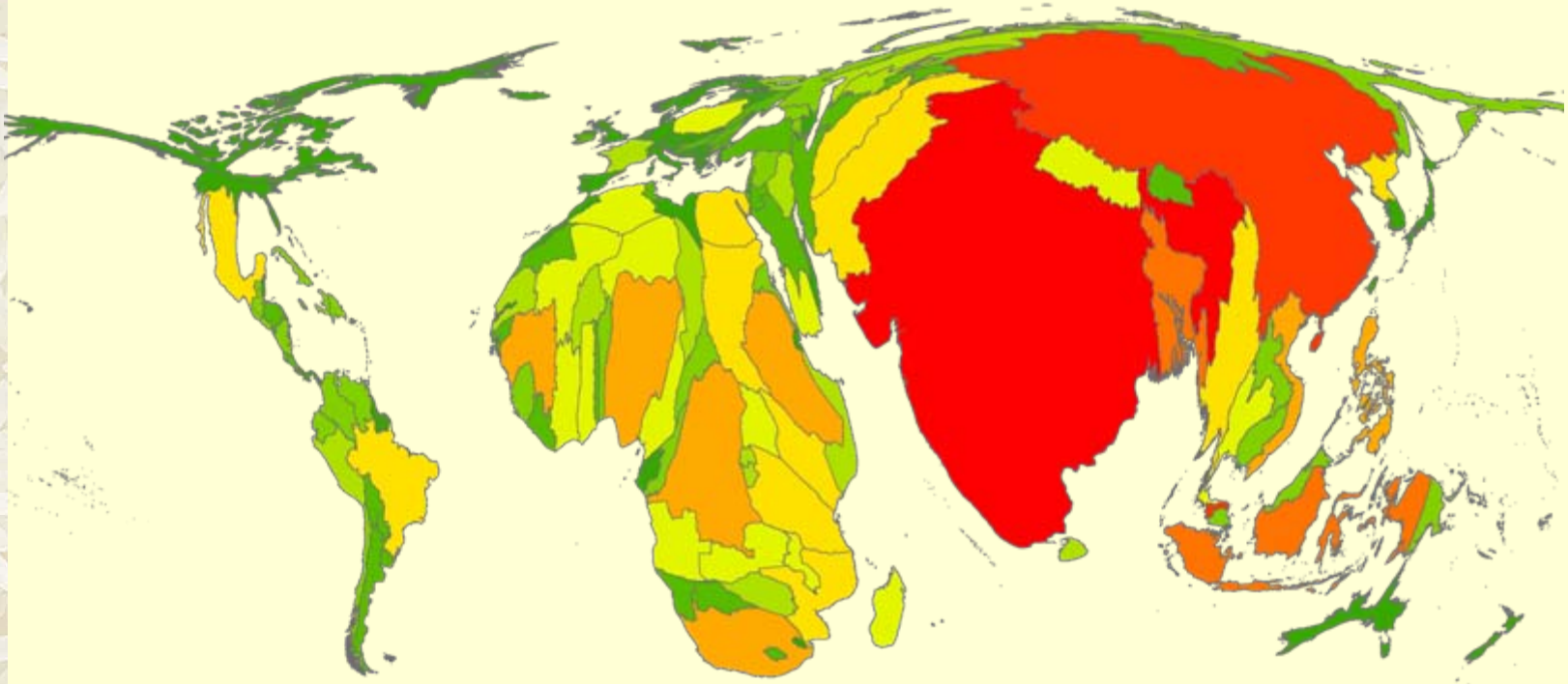
While much better off than 25 years ago, over one billion remain desperately poor

Country size shown as a function of the number of people living on less than one dollar per day



<u>IN FACT:</u> **Of the more than 1 billion poor in Asia and Africa, nearly 70% are in Asia … and more than ¾ of these people live in rural areas.**

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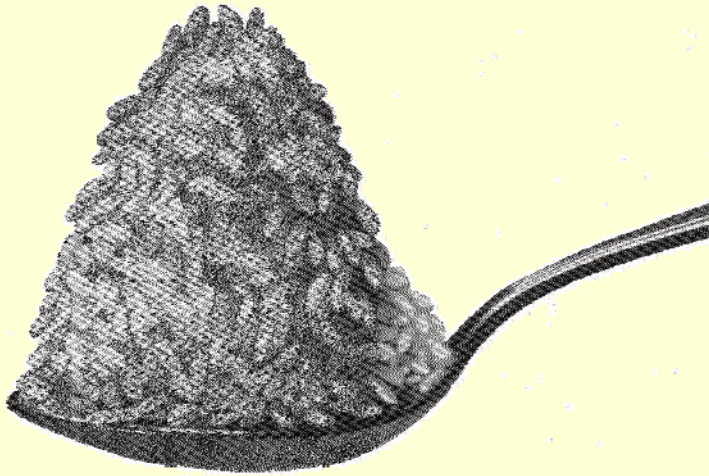
90% of the world's rice is produced and consumed in Asia.

- *around 70% of the world's poor live in Asia.*
- *and nearly all of them eat rice two or three times a day!*



By 2015 the world will need to produce at least an additional 50 M tons of paddy rice EVERY YEAR

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IRRI's Environmental Agenda

To assure that environmental sustainability will always be central to IRRI's research projects and day-to-day operations, we have codified our longstanding commitment to environmental protection and sustainable rice production.

Negative impact of farm chemicals

- Pesticides become costly replacements for natural control mechanisms.
- Farmers' health is compromised.
- Soil and water are polluted.
- Farmers develop high dependence on these products.

GMO: an organism that contains recombinant DNA in its genome

Human Genome (2001)

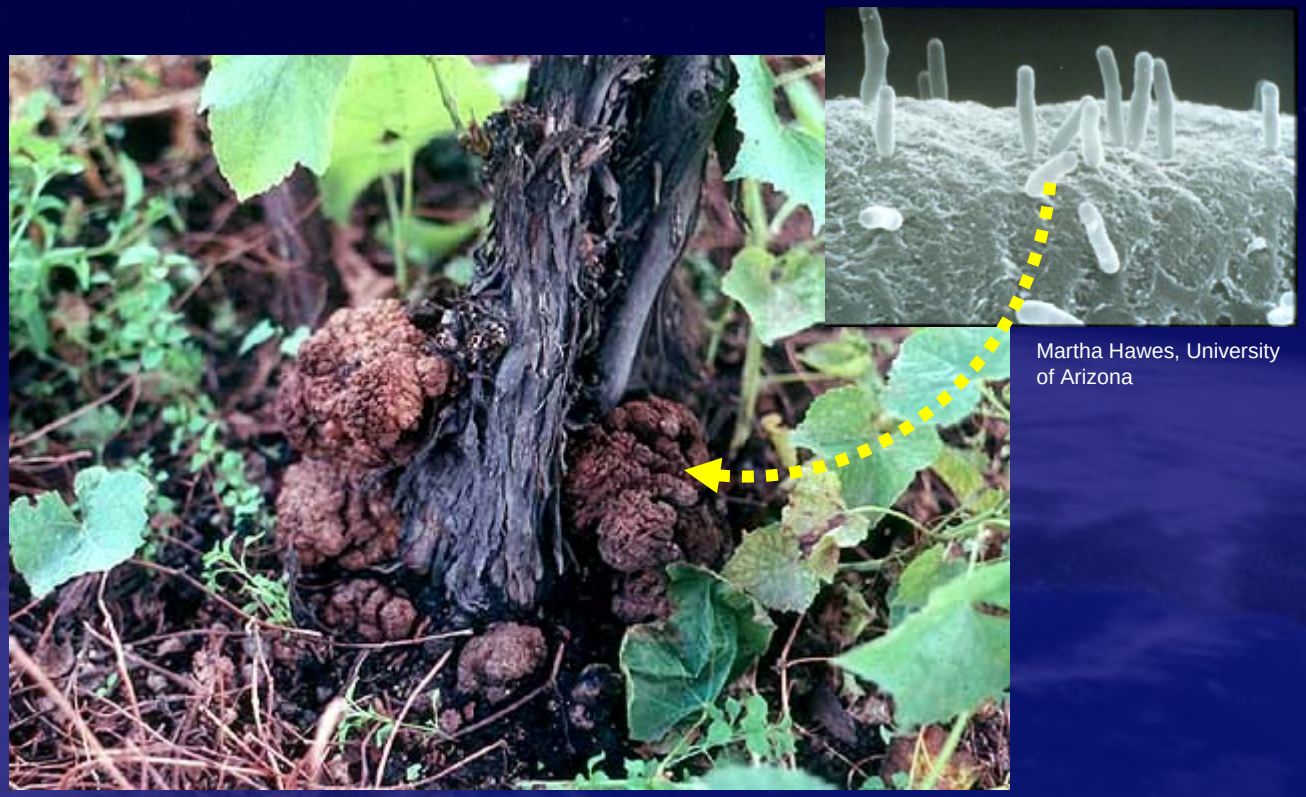
1. 99.9 % human genes are identical
2. 40% of human genes similar with nematode
3. 60% with Drosophylla, 90 % with rats
4. 99% similar with chimpanzee

Recombinant DNA: DNA fragment obtained by combining several DNA fragments from different source(s) (copy / paste)

DNA: DeoxyriboNucleic Acid molecule that is the chemical basis of any inherited trait or characteristic of an organism

Genome: The total DNA in a single cell

Crown Gall Disease caused by soil bacteria *Agrobacterium tumefaciens*



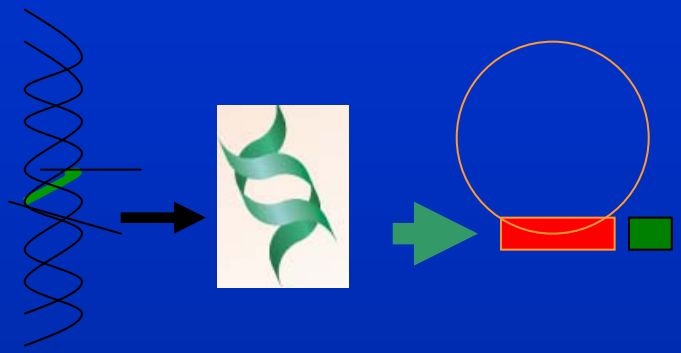
Martha Hawes, University of Arizona

Crown gall on wine grape

apple,
blackberry,
cherry,
euonymus,
forsythia,
grapes,
peach,
pear,
plum,
poplar,
raspberry,
rhododendron,
rose
...

These Bacteria transfer **naturally** a bacterial DNA fragment to the plant DNA

How to make GM plants?

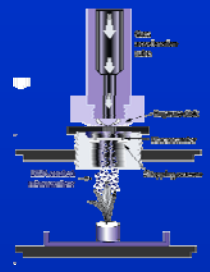


Gen is isolated

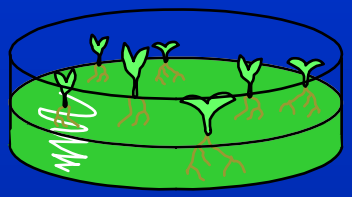
From organism

Connected to

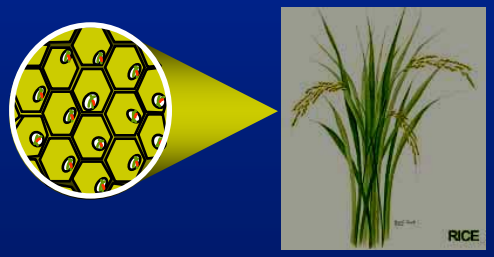
The plant promoter



DNA is transferred usingbiolistic, protoplast system or through *A. tumefaciens*

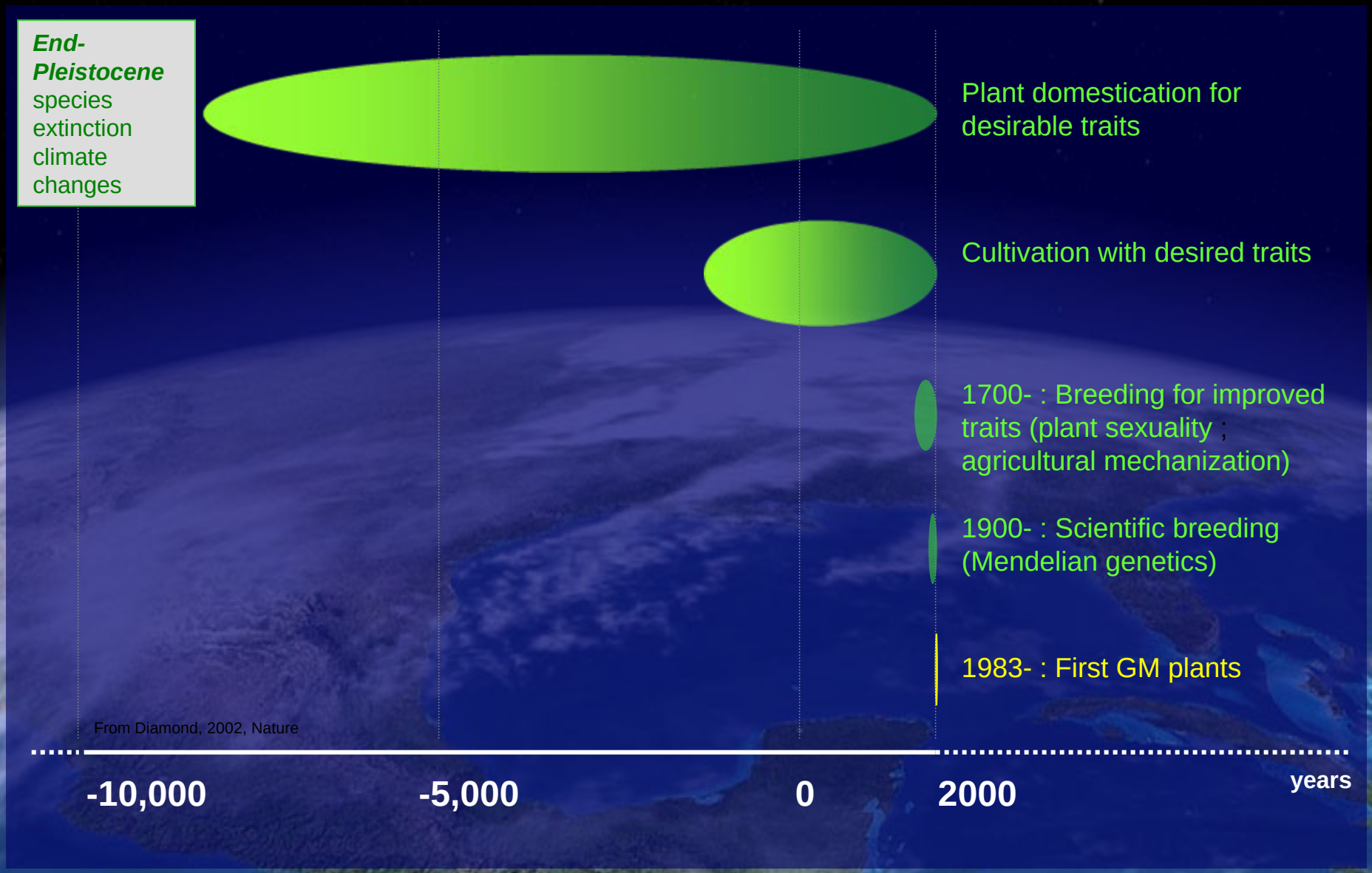


From cell to plant using Tissue culture



New organism with additional 1/ a few genes

Selection and crossing when needed



Plant domestication and breeding

1957

1973: First Network Protocol
Vinton Cerf, Robert Kahn

1971: First Email, Ray Tomlinson

1983: TCP/IP Protocol

1989: World Wide Web , *Timothy Berners-Lee*

1998 Google

>1 billion Internet users

>100 million Web sites

1947

1973: First modern portable handset, *Martin Cooper*

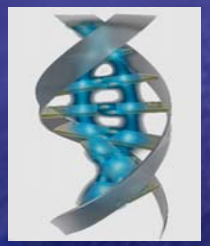
1983: First Commercial Advanced Mobile Phone Service , *Ameritech* USA

First generation of cellular and car phones

Second generation or 2G phones

2 billion Cell phone subscribers

Third generation or 3G phones



1953

1973: First successful recombinant DNA organism, Herbert Boyer and Stanley Cohen

1983: First GM plants

1982: First genetically engineered drug (Humulin), Genentech

1994: Commercial GM Tomato product (*Calgene*)

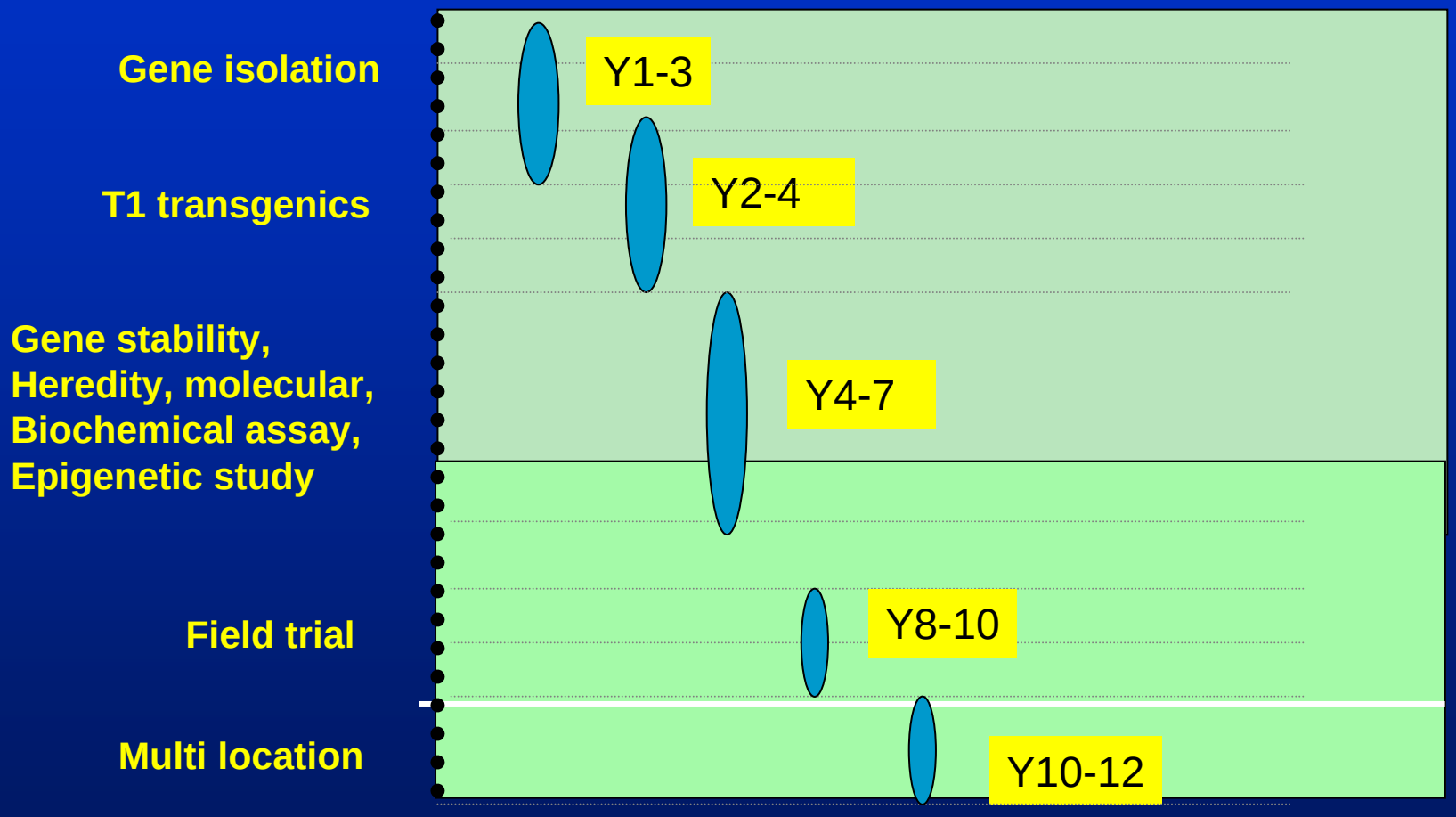
>100 approved biotech drugs

>100 million Ha GM crops

1970 1980 1990 2000

Modern Technologies

Time frame for transgenic product development



Comparison of transgenic breeding and conventional plant breeding

Conventional breeding

- Genes are transferred
- All parental genes are combined
- Unwanted characters have to be eliminated
- Effective for traits encodes by multiple genes
- There is risk

Transgenesis

- Genes are transferred
- Only 1-2 specific genes are introduced
- Effective for trait encodes by single gene or a few genes
- Gene can be transfer from other plants or organism
- There is risk

Transgenesis can be seen as part of plant breeding

Application of genetic modification in crops

- Insect and disease resistant
- Tolerance to environmental stress stresses
- Improve agronomic trait
- Improve nutrition
- Improve post harvest quality
- Molecular farming : plant as bioreactor for polymers, vaccines/pharmaceutical products

Developing countries have already benefited from modern agricultural biotechnology products

Performance Advantage of Insect Resistant over Conventional Cotton

(expressed as a percentage)

	Argentina	China	India	Mexico	S. Africa
Yield	33	19	34	11	65
Revenue	34	23	33	9	65
Pesticide costs	-47	-67	-41	-77	-58
Seed costs	530	95	17	165	89
Profit	31	340	69	12	299

Based on peer-reviewed studies of 2-3 seasons of commercial farm production

Adapted from: Raney. T. (2006) *Economic impact of transgenic crops in developing countries*. Current Opinion in Biotechnology 17:1–5

Impact of Bt cotton on farmer poisoning in China

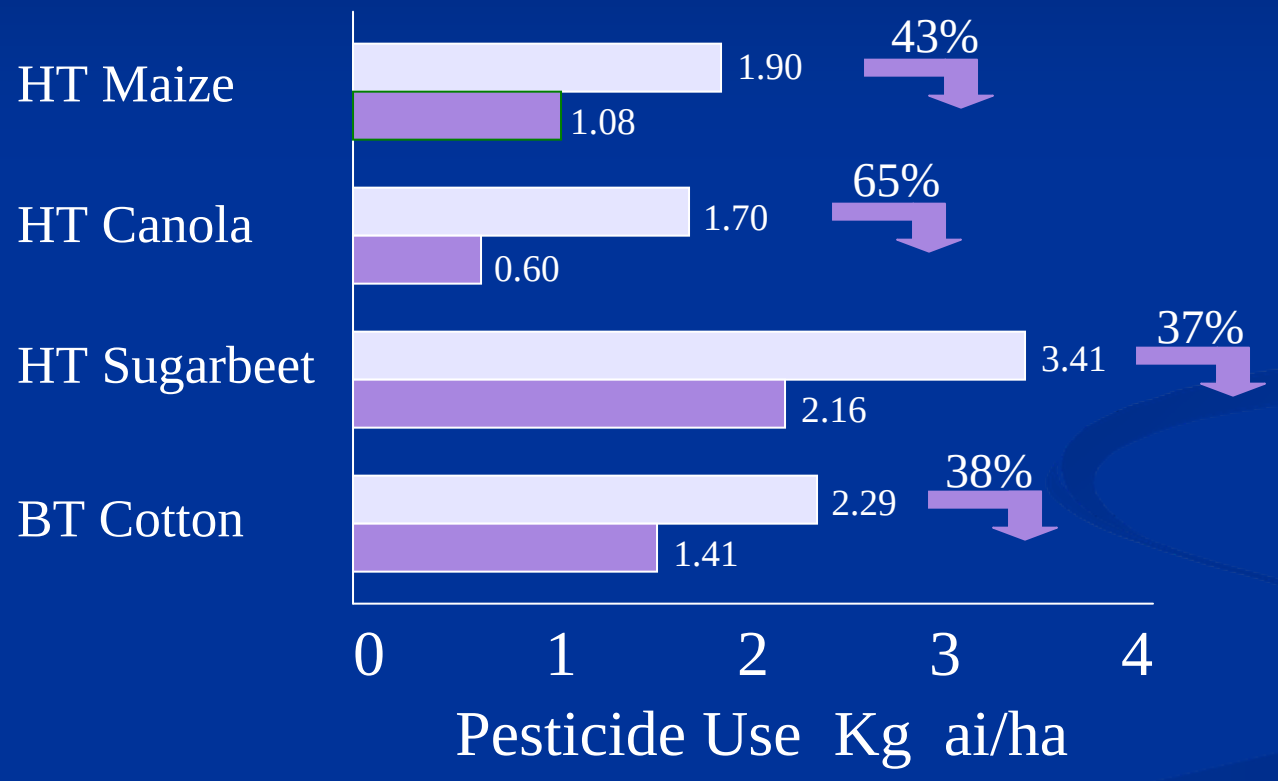
Farmers were asked if they experienced headaches, nausea, skin pain or digestive problems when they applied pesticides.

	Non-Bt	Both	Bt cotton only
# of Farmers (1999)	9	37	236
Number of poisonings	2	4	11
Poisonings (as % of farmers)	22	11	5
# of Farmers (2000)	31	58	318
Number of poisonings	9	11	23
Poisonings (as %e of farmers)	29	19	7
# of Farmers (2001)	49	96	221
Number of poisonings	6	10	19
Poisonings (as % of farmers)	*12*	*10*	*8*

Adapted from: Pray *et al*. (2002) *Five years of Bt cotton in China - the benefits continue*. The Plant Journal **31**(4), 423-430

Potential pesticide reduction in Europe

Potential Pesticide Reduction in Europe from Biotech Crops



Total reduction in use of pesticides in Europe

14.47 million kg[1]

Source: Phipps. R.H., and Park, J.R. 2002. Environmental benefits of genetically modified crops: Global and European Perspectives on their ability to reduce pesticide use. Journal of Animal and Feed Sciences. Vol. 11(1) 1:18

[1]Based on 50% adoption of biotech maize, canola, sugarbeet and cotton

Late Blight Resistant Potato

- Potato is an important vegetable crop in India, Bangladesh and Indonesia, primarily grown by resource-poor farmers
- Late blight (responsible for the Irish Potato Famine in 1840s) is the most important disease; high fungicide use
- Some wild potato species are resistant to the disease.
- Attempts to breed the resistance gene from the wild potato failed after 35 years of efforts.
- Technology: Rb1 gene from wild species *S. bulbocastanum* introduced by GM technology into potato.

***S. bulbocastanum* Acc. # PT29**

From Des Hautea, UPLB

Field trial of transgenic *vs.* non transgenic potato cultivar (India and Indonesia)

Kufri jyoti and Katahdin (SP951).
July 2006 at CPRI, Shimla

Non-GM Katahdin and SP951. Early 2007 at IVEGRI, Lembang

From Des Hautea, UPLB

Biofuels and Biotech: need and possibility to improve productivity on the land being used today

The need for ethanol by 2020 could require an additional 20 Mi ha of sugarcane

<u>Target</u>: In 10 years,
- double the ethanol productivity per hectare,
- produce over 15 Bi L in the same area used today.

New GM sugarcane varieties developed by Brazilian private and public companies:
- 40% more sugar,
- Insect Resistant and
- Herbicide Tolerant

Adapted from: Alda Lerayer, August 21, 2008

- Gene technology in plant science is a new technology

- A biotech product requires about 10 years R&D and 5-10 years of market impact

- Farm-oriented products (productivity)

IRRI

Current facilities and on going research at IRRI

Facilities	Dimension/ capacities
Molecular Biology Laboratory and equipments	250 m2
Clean room 16 sterile work station	80 m2
Controlled growth chamber	50 m2
Transgenic green house – 8 glass houses	12,000 plants/year
Transgenic screen house	75,000 plants/year
Transgenic field	10,000 m2

Target trait	Variety
Nutrition: -Increased iron -increased free lysine -Pro-vitamin A	IR64, IR68144 IR64 IR64 (MAS)
Drought Hybrid rice C4 rice	IR64

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Rice Biofortification

2 of 3 infants (6mos.-1yr) have iron-deficiency anemia

1 of 3 Filipinos are at risk of low zinc intake

4 of 10 children are vitamin A deficient

The numbers are increasing since the 1990s

Micronutrient malnutrition is a serious public health problem

(FNRI, 2003)

Adverse health outcomes of micronutrient deficiencies for different target groups

Target group	Iron deficiency	Zinc deficiency	Vitamin A deficiency
Children	• Impaired physical ability • Impaired mental development • Child mortality (related to maternal deaths)	• Diarrhea • Pneumonia • Stunting • Child mortality	• Child mortality • Measles • Night blindness • Corneal scarring • Blindness
Women	• Impaired physical activity • Maternal mortality		• Night blindness in pregnant and lactating women
Men	• Impaired physical activity		

Source: Stein et al. (2005)

Transferring β-carotene loci into important Asian varieties at IRRI

- IR64 & IR36: Mega-varieties with broad Asian coverage (GR1 & GR2)
- BR29: The most popular and productive *boro* rice variety in Bangladesh (GR1 & GR2)
- An IRRI-bred line released as PSB Rc82: the most popular rice variety in the Philippines (GR2)
- Additional crosses into High Zn/Fe germplasm and those with important agronomic traits (i.e., submergence tolerance - Sub1)

IRRI
International Rice Research Institute

Risk assessment

- Aims :
  - to support decision making
  - to avoid potential adverse effect (there is no technology innovation and agriculture practice with zero risk)

- Risk assessment is required in the Cartagena Protocol on Biosafety (CPB) as part of AIA procedure (advanced informed agreement prior to transboundary movement of GMO) – exception of AIA pharmaceutical product and contained use.

- Standard practice worldwide for GM crops and food approval

Risk management

- appropriate mechanisms, measures and strategies to regulate, manage and control risks identified in the risk assessment (CPB Article 16)

- Risk management includes : all process aimed to influence avoidance of risk, perception of risk, acceptability of risk or the mitigation of risk

Biosafety is assessed throughout the life of a product… especially early on

discovery → **7-12 years** → **market introduction**

Product Concept	Gene Disc.	Transfor-mation	GH & Field Evaluation	Line Selection	Variety Devel.	Production	Market	Post Market

Safety of gene, protein, crop

- Choice of genes / proteins
  - mechanism of action
- Source of genes
  - history of safe use
  - ethics
- Environmental / ecological aspects of product concepts

Selection of line(s) with appropriate characteristics

- Stringent agronomic performance and efficacy criteria
- Greater than 99% of all events are eliminated
- Based in part on methods used to evaluate conventional varieties through traditional breeding

Detailed risk assessment for regulatory review

- **Food**
- Feed
- **Environmental**

Appropriate product stewardship

- Product performance
- Investigate complaints
- Support of academic research into applications

Adapted from Owens and Rogan, 2002

Environmental Risk Assessment

- Biology of host plant (natural range, reproductive method, viability, weediness characteristics).
- Novel trait(s) introduced
- Assessment on biodiversity – when relevant with the introduced trait
  - Safety to non target organism
  - Soil toxicity
  - Gene flow and its consequences
  - Weediness potential/invasiness

GM Food Assessment

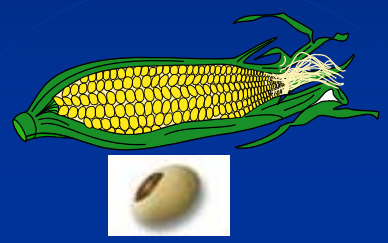
European Network on Safety Assessment of Genetically Modified Food (ENTRANSFOOD)

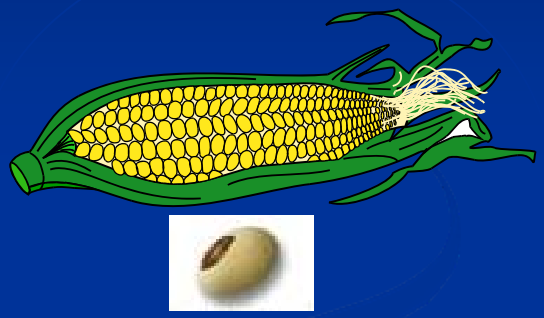
(sponsored by the European Commission)

- Underlying assumption:
  - Traditionally cultivated crops have gained a history of generally accepted use
  - These crops can therefore serve as a *baseline* for the environmental and food/feed safety assessment of GM crops

European Food Safety Authority Stakeholder Consultation: Draft guidance document for the risk assessment of genetically modified plants and derived food and feed. 25 May 2004, Brussels - Reports published in Food and Chemical Toxicology, 42 (7) 2004

SUBSTANTIAL EQUIVALENCE CONCEPT (OECD, 1993, FAO/WHO, 1996. Entransfood, 2004)





Non-GMO Counterpart

Comparative Approach focusing on their characteristics

The most similar food which has a history of safe use

To determine that, if a food derived from GMO is substantial equivalent, it is “as safe as” the corresponding conventional food item

POLICY ON RELEASE FOR PROPAGATION Philippines

"No regulated article shall be released for propagation unless:

(i) a *Permit for Propagation* has been secured from Bureau of Plant Industry(BPI);

(ii) it can be shown that based on field testing conducted in the Philippines, the regulated article will not pose any significant risks to the environment;

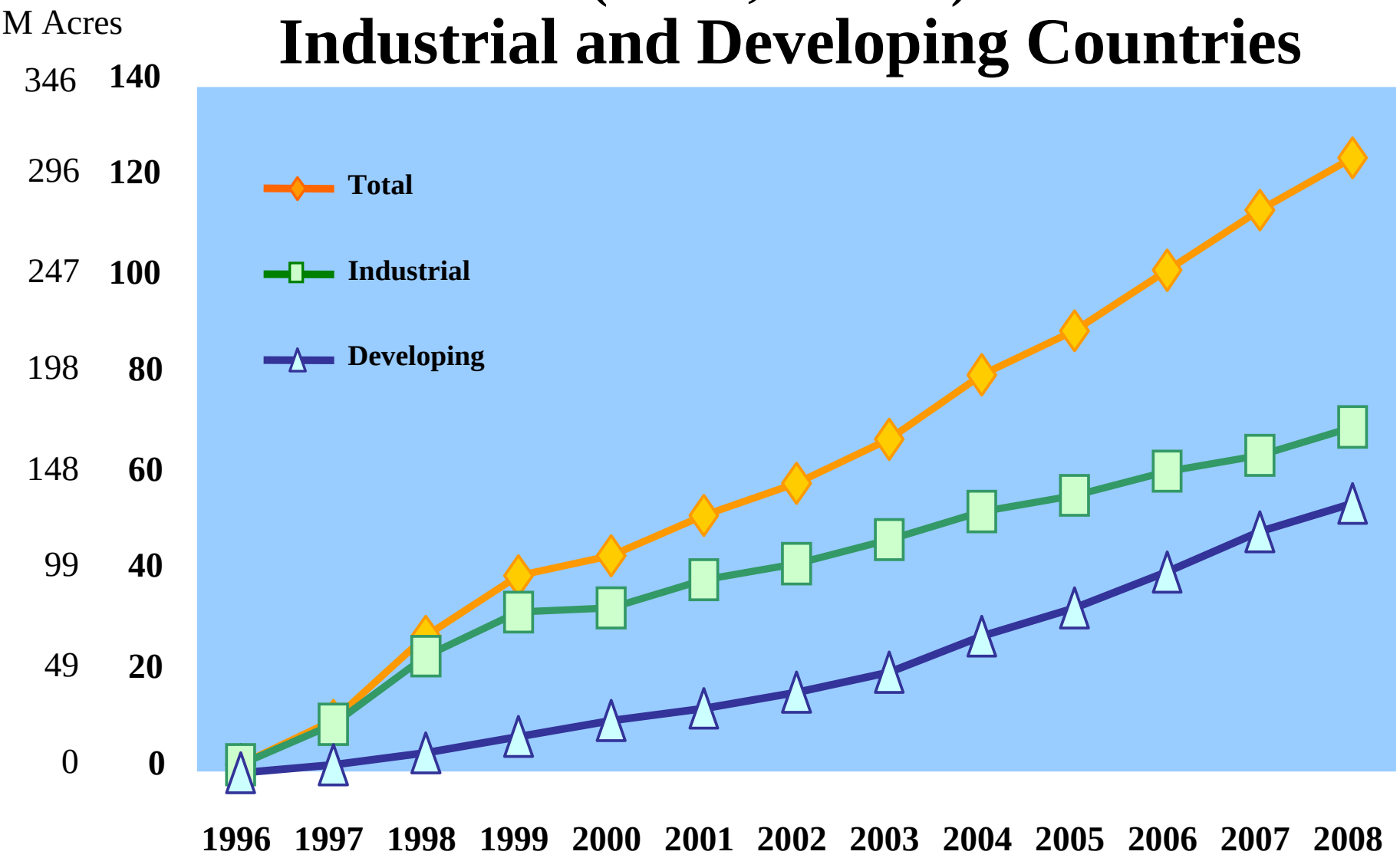
(iii) food and/or feed safety studies show that the regulated article will not pose any significant risks to human and animal health; and,

(iv) If the regulated article is a pest-protected plant, it has been duly registered with the FPA."

Global Area of Biotech Crops, 1996 to 2008

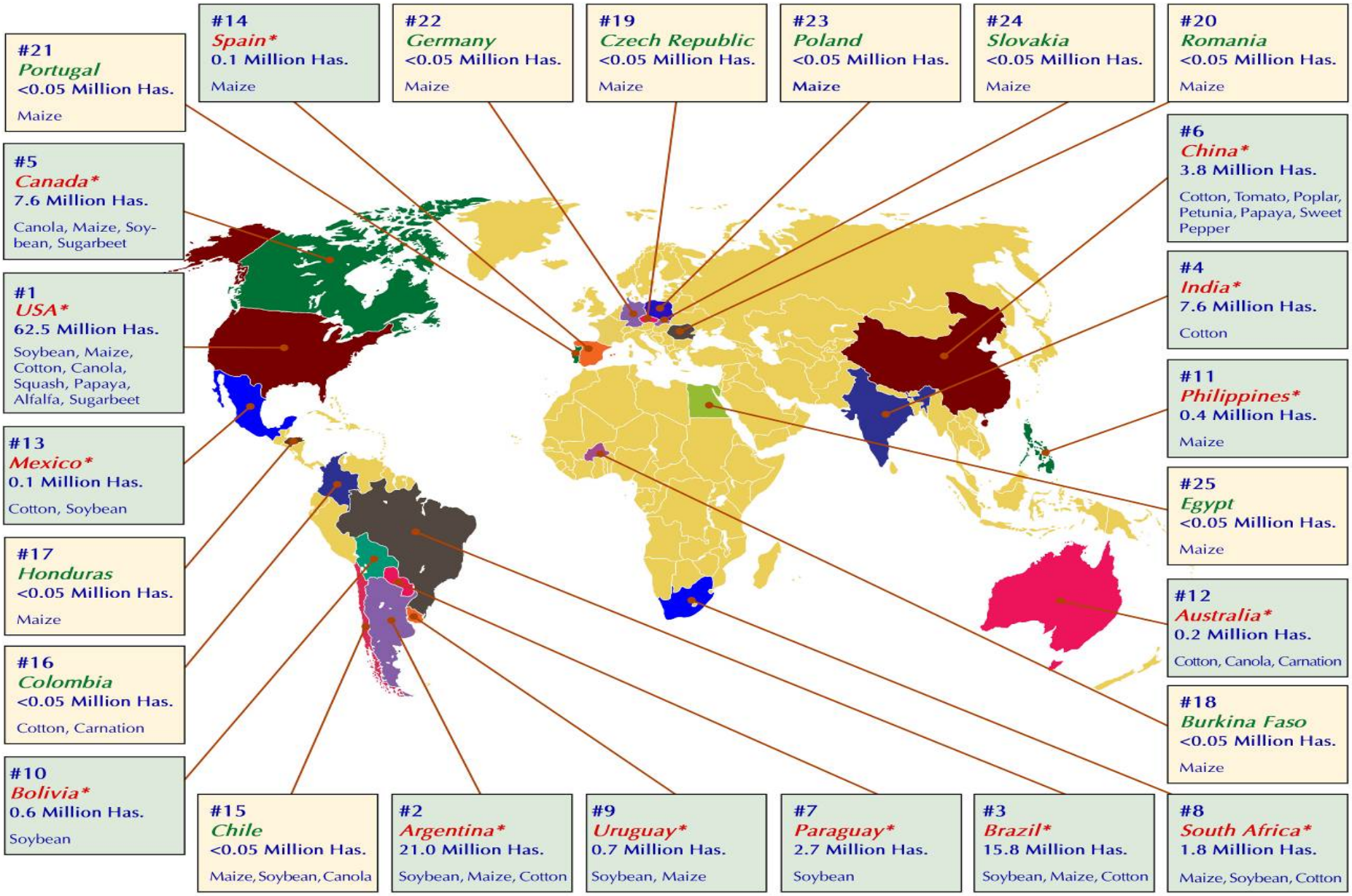
(M Has, M Acres):

Industrial and Developing Countries



Source: Clive James, 2009

Biotech Crop Countries and Mega-Countries, 2008



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

Source: Clive James, 2008.

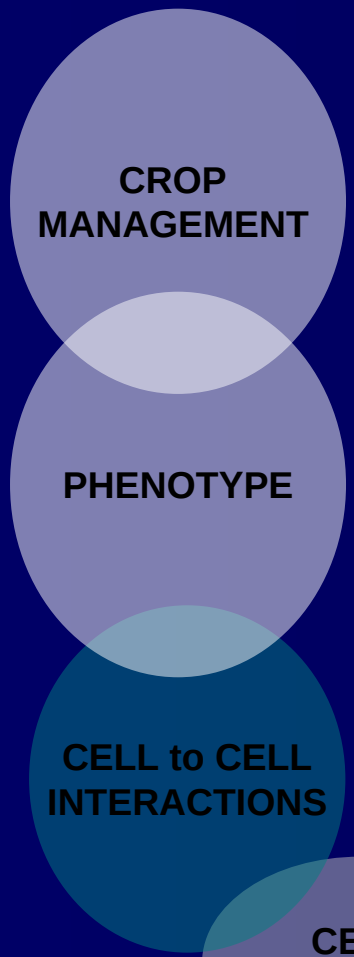
Scientific officials report on transgenic crops safety and benefits :

"…in those countries where transgenic crops have been grown, there have been no verifiable reports of… health or environmental harm."

- FAO

- World Health Organization
- Food & Agriculture Organization (FAO) of the United Nations
- National Academy of Sciences (USA)
- Royal Society (UK)
- American Medical Association (USA)
- French Academy of Medicine
- European Commission
- U.S. Food & Drug Administration
- Society of Toxicology
- Institute of Food Technologists

How to make the decision to use or not use Gene technology?

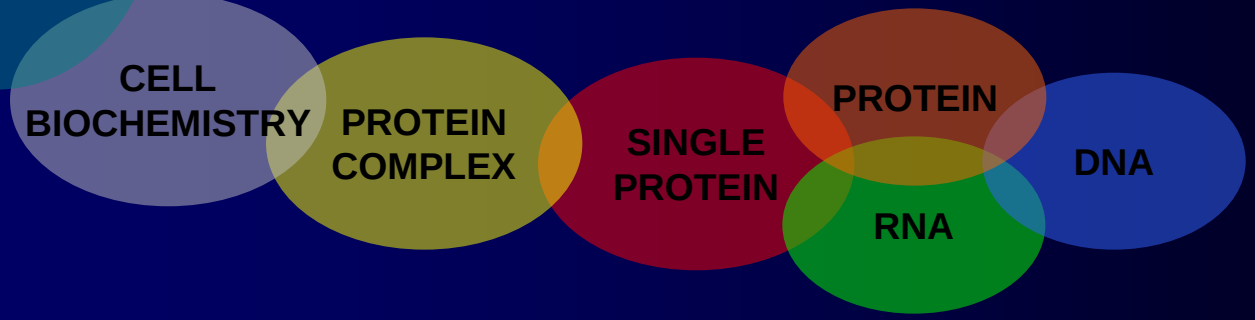


Technology is available

Molecular tool but the final product is not a GM product

GM varieties with a trait that cannot be obtained by other currently available breeding methodology

For a trait that can be improved by other methodology, what is the advantage of using gene technology?



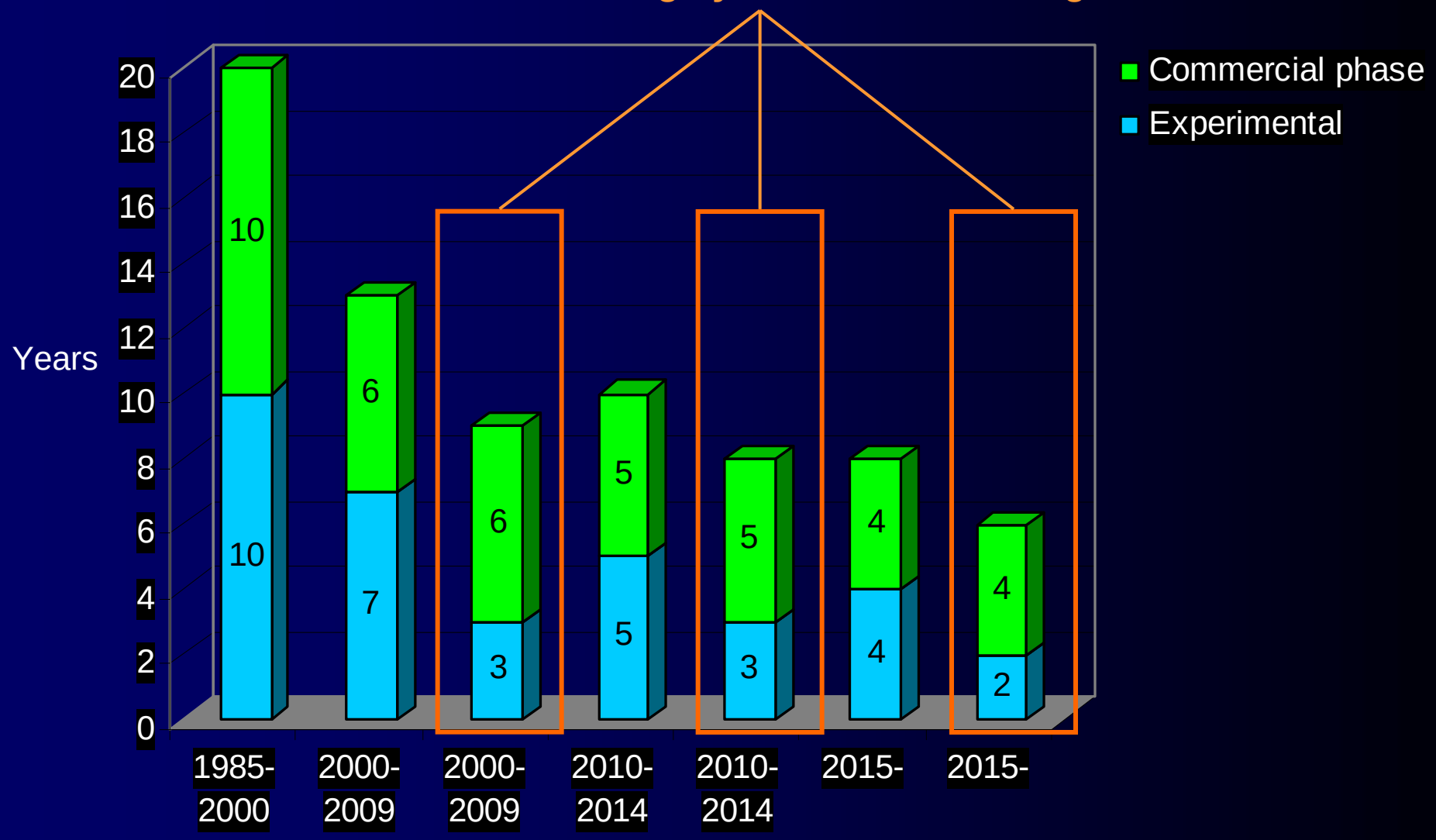
Shall we stop growing GMOs?

- Shall we stop driving because of global warming?
- Shall we stop using electricity because of global warming?
- shall we stop using cell phones because of pollution generated by their batteries?

And why not make better cars, better devices consuming less energy, using new sources of energy and recycling batteries?

Make better GM Ag products

Trait Stacking by molecular breeding



Faster delivery of new biotech products

Accepting or rejecting GMO

The same fears did exist for electricity, train, car, airplane, cell phone, internet, globalization !

- Gene technology is still a new technology that has not achieved its potential yet

- Avoid the 'opinion trap' and refrain sending the wrong message:

  Gene technology is the solution or Gene technology must not be used

'My argument rests on the assumption that doing nothing (when opportunity exists for doing something) might be worse for the current situation'

L. Carter, A case for a duty to feed the hungry: GM plants and the third world, Sci Eng Ethics, 2006

"**Rich People have got a lot of problems. Hungry people have got one**".
Jerry Caulder, Finistere Partners, PAG meeting 2008, Keynote lecture

IRRI

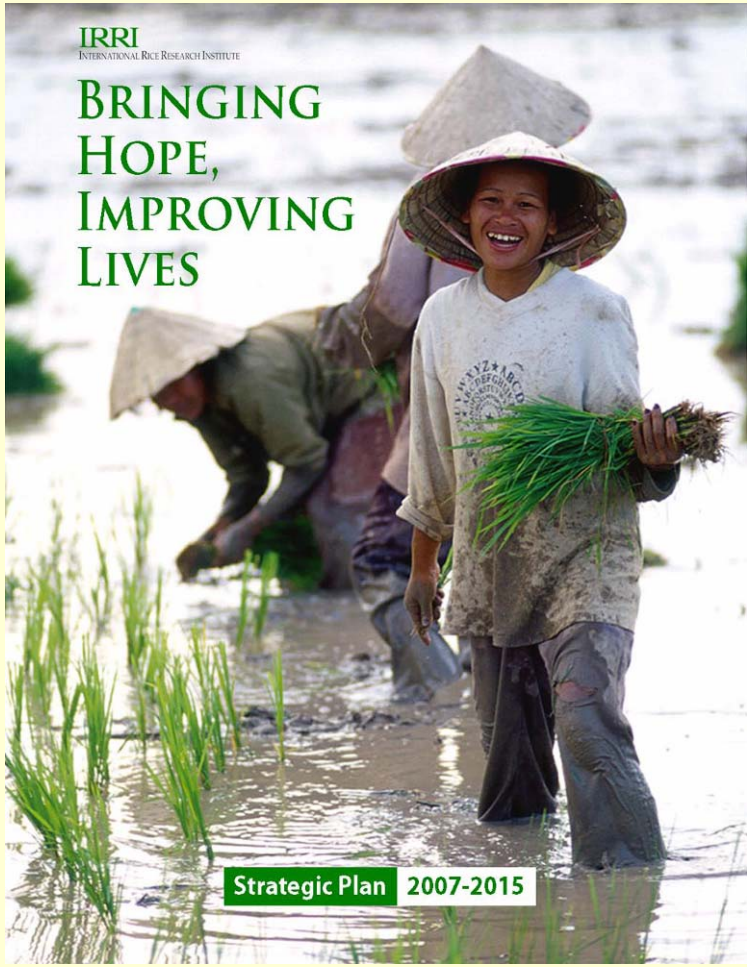
"Since the way to feed the world is not to bring more land under cultivation, but to increase yields, science is crucial."

The Economist, "The Silent Tsunami", 19 April 2008

HarvestPlus

Breeding Crops for Better Nutrition

www.harvestplus.org



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