Can GM crops help to feed the world? Hopes and fears

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What is the challenge?

Can the science of genetic modification help?

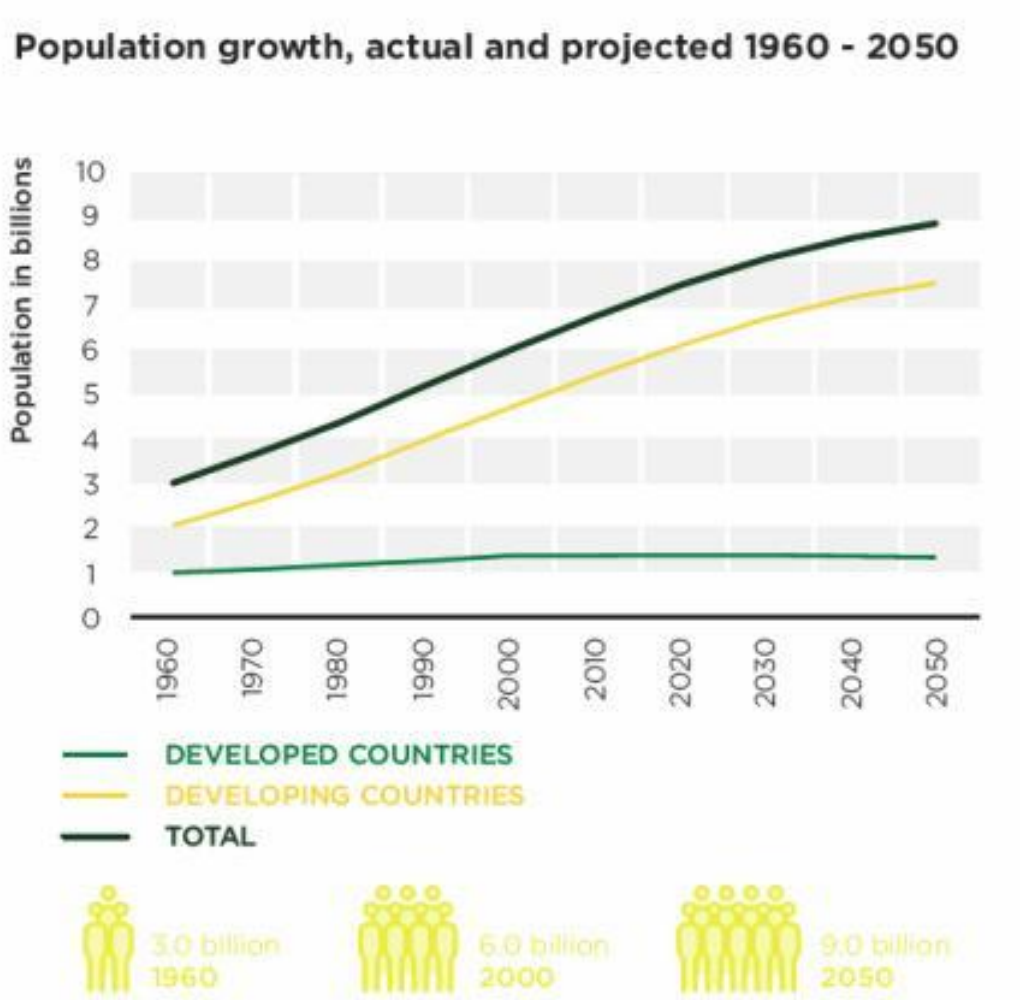
Hopes and fears – known and unknown?

Declaration: I do not hold any grants or consultancies from Monsanto or any other plant breeding organisation, and no industrial funding; first degrees in animal physiology; research career in endocrine physiology, biotechnology and scientific advice to policy makers.

We face increasing demand for the world's finite resources…

The global picture:
We face increasing demand for the world's finite resources

Population growth
From 1960 to 2007, the global population grew from 3 billion to over 6.5 billion. Projections for future growth take that number to nearly 9 billion in 2050. The UN Food and Agriculture Organisation (FAO) estimates that **food production must increase by 70%** if we are to feed the world population.



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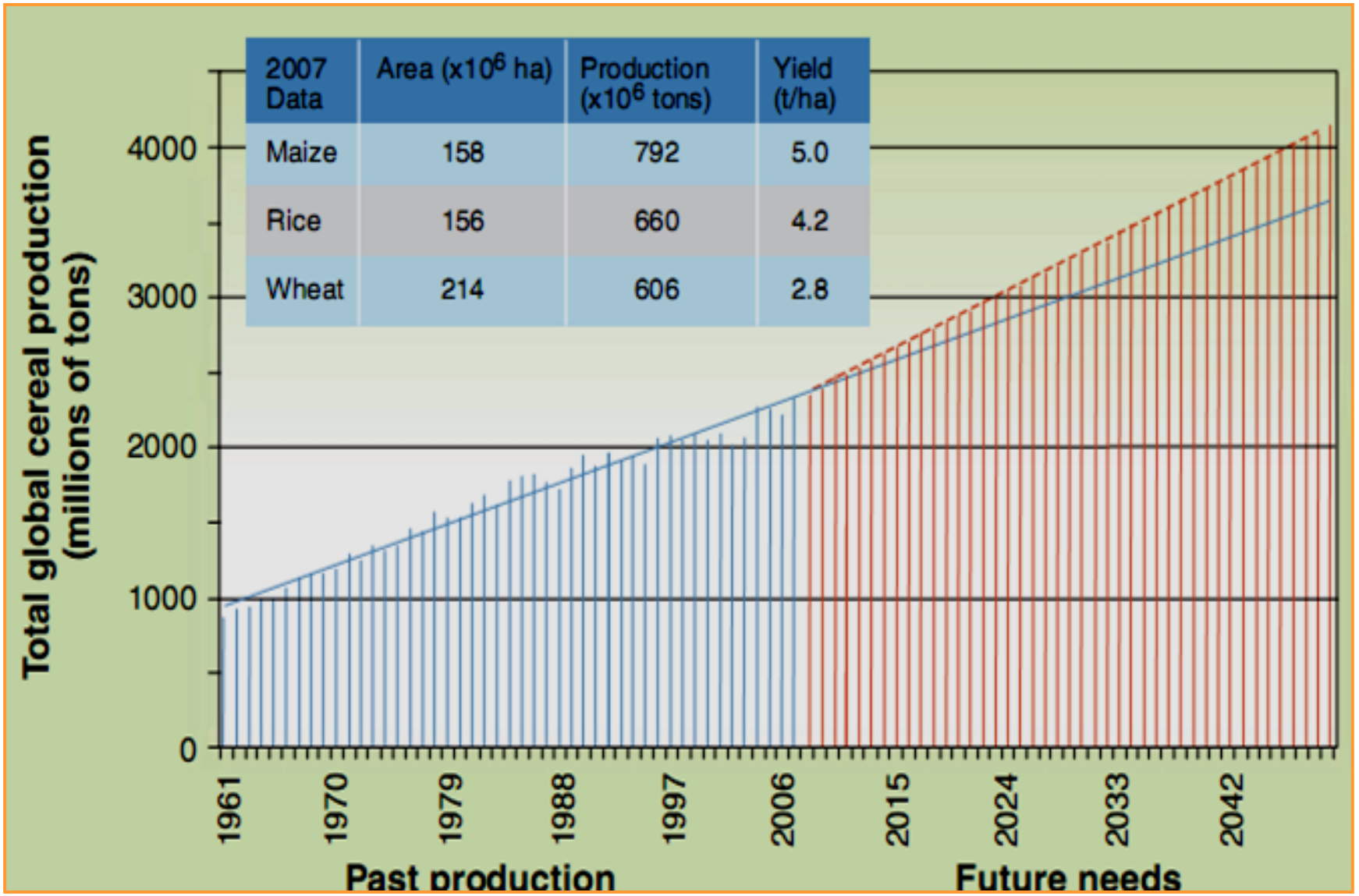
Increase of world demand for food….

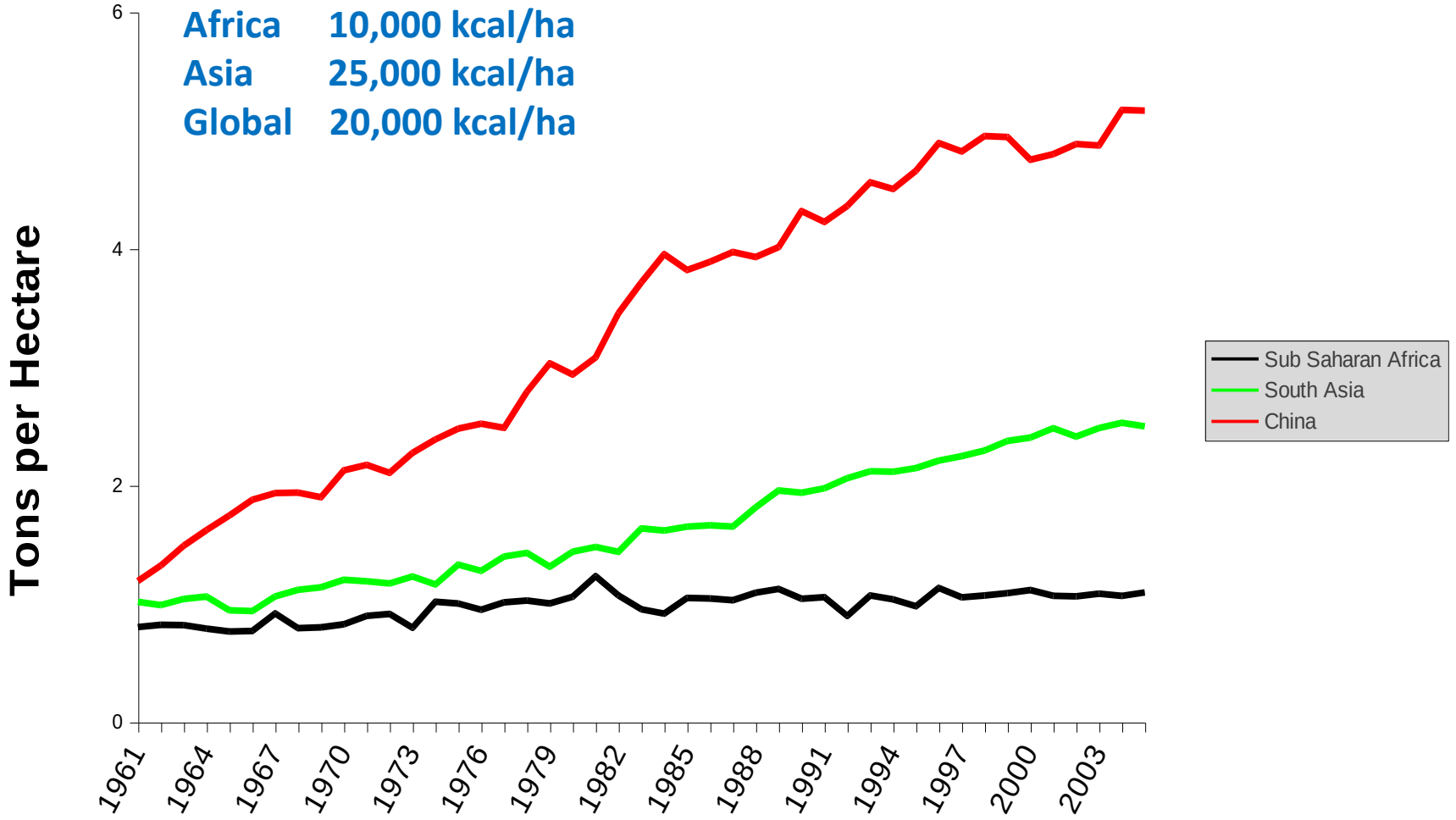


Science (2010) 327:818

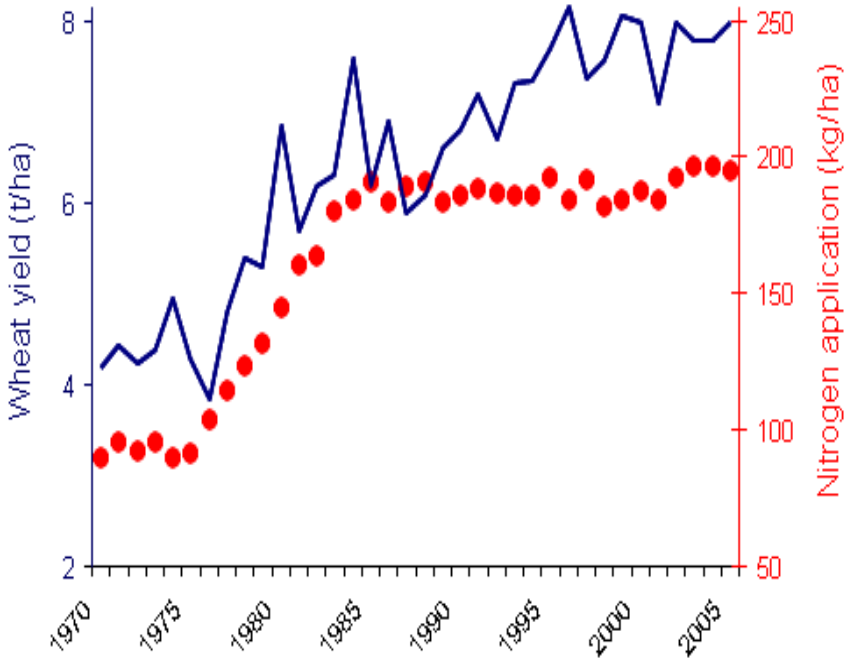
Africa is slow in moving toward higher crop yields

Agricultural productivity:

Africa	**10,000 kcal/ha**
Asia	**25,000 kcal/ha**
Global	**20,000 kcal/ha**



UK wheat yields have levelled-off



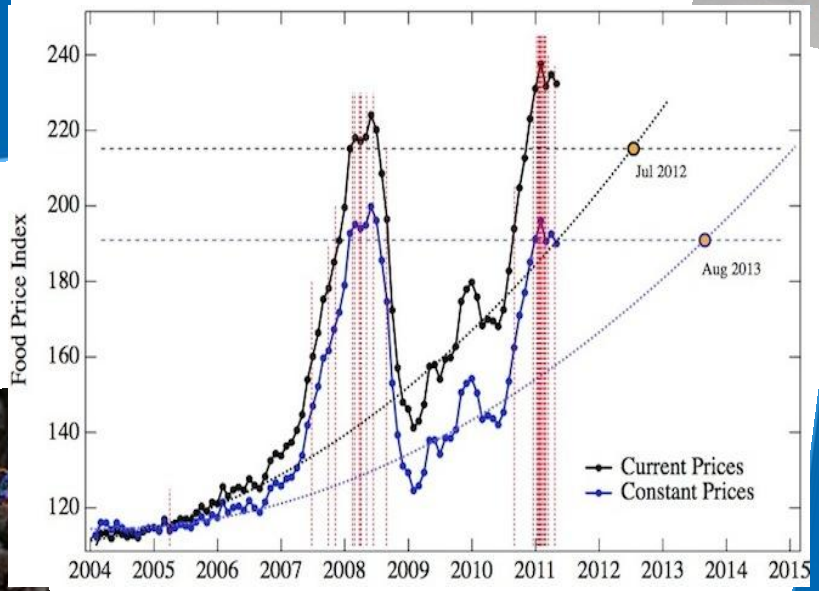
UK's national average yields have increased from 2.8t/ha in 1948 to 8t/ha now. Proportion of increase due to plant breeding was about 50% between 1948-82, rising to more than 90% over the last 25 years

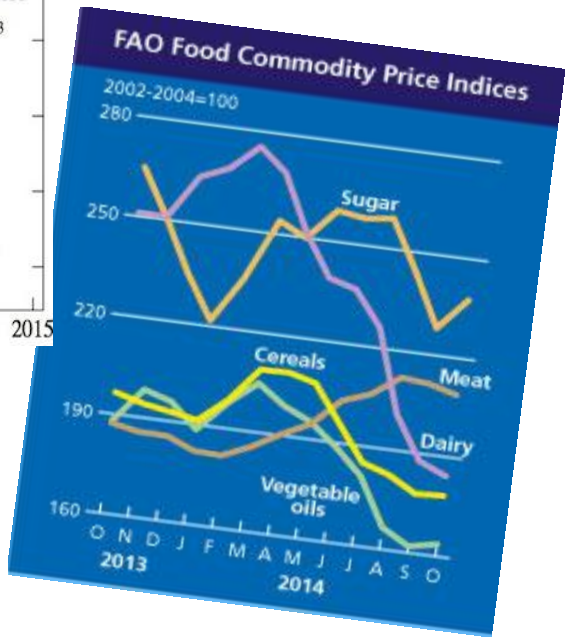
.....the current rate of progress in varietal yield can be maintained for 'some years' by extension of the current gene pool and more intensive use of genetic markers.

However, there is no prospect of a stepwise increase in yield equating to a second green revolution unless the physiology of the crop can be radically advanced

(Bingham and Summers, 2009)

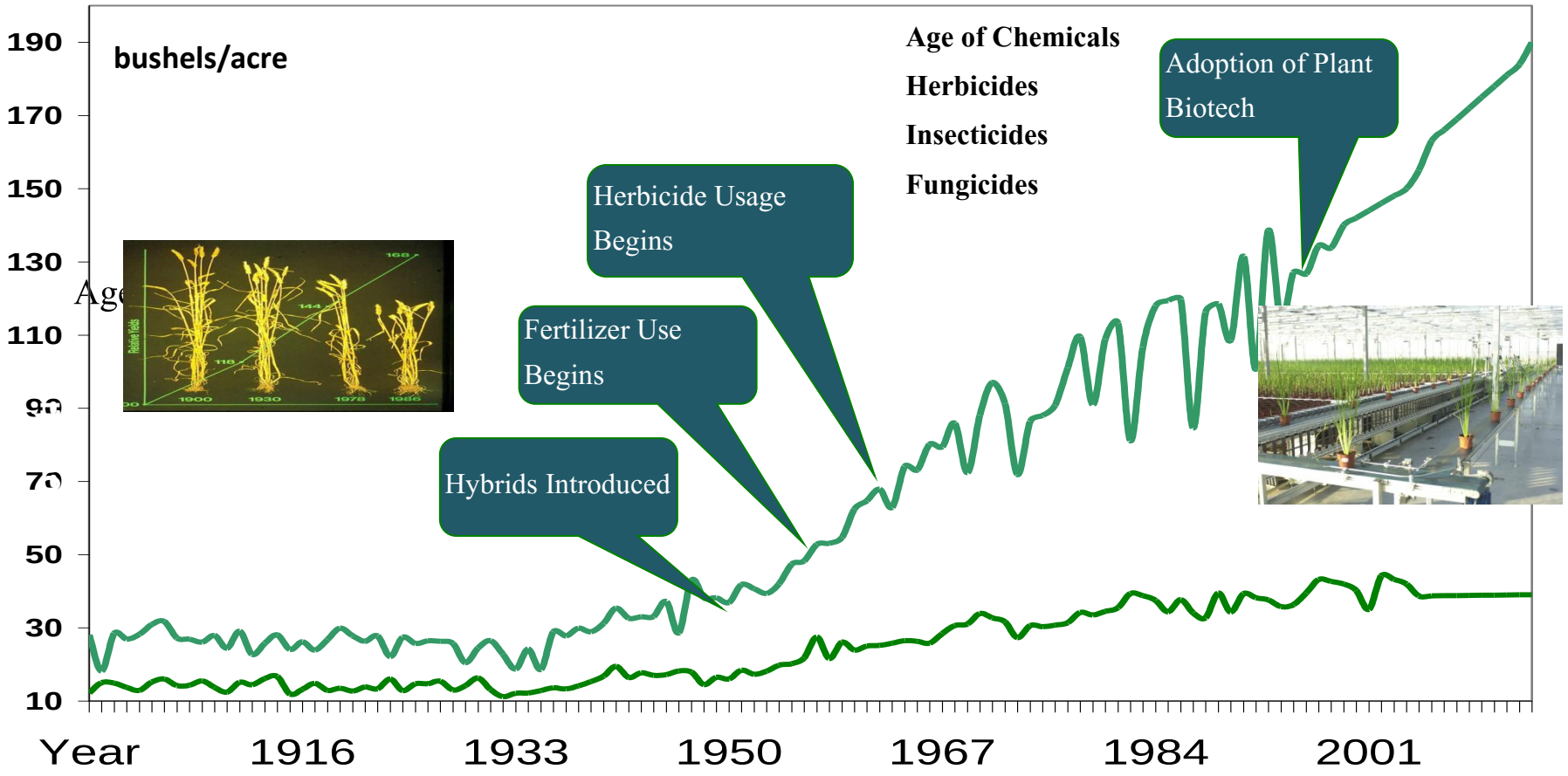
Impact





http://www.fao.org/worldfoodsituation/wfs-home/foodpricesindex/en/

How has agriculture historically risen to the challenge?



....with new technology.

Traditional and intermediate technologies (Conway 2010)

A home garden in Java

Drip irrigation

Irrigation pump, ***KickStart***
http://www.kickstart.org/products/super-moneymaker/

Conventional but more precise – controlling Striga (witchweed)

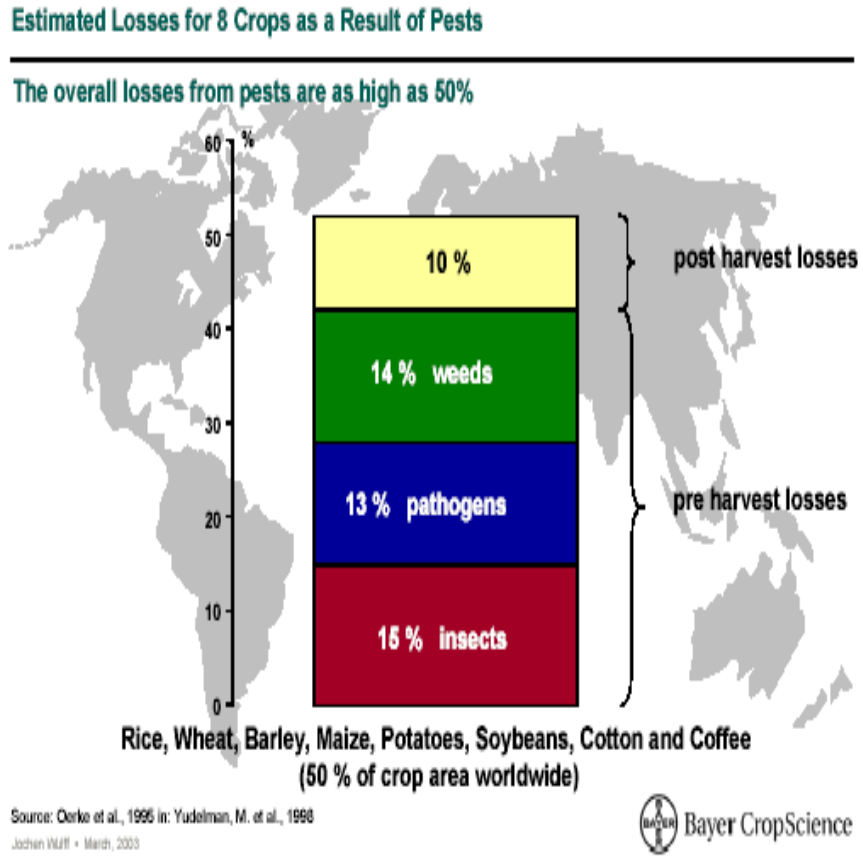
- 70% in W Kenya
- 100 m people affected
- $1 billion loss
- Maize resistant to Imazapyr (non-GM)
- Coat seed, herbicide kills Striga

Conway 2010

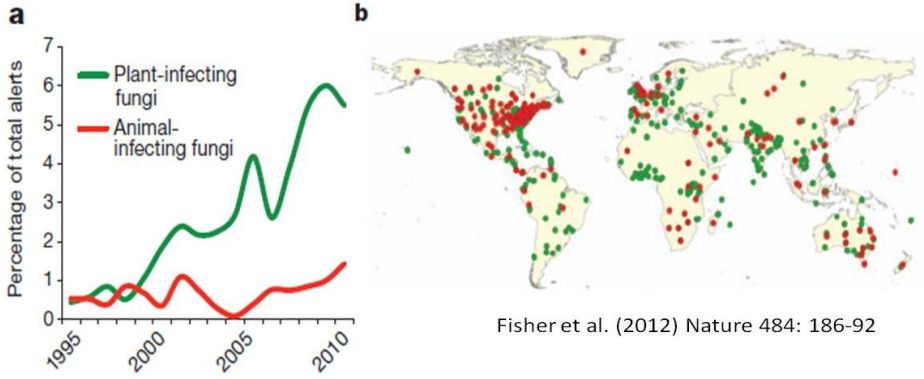
Plant breeding and biotechnology by – *building productivity and sustainability into the seed*

- **Increase nutrient uptake efficiency**
- **Improve nutritive value**
- **Increase drought tolerance**
- **Increase water use efficiency**
- **Counter the new pest and disease outbreaks**

(Conway 2010)

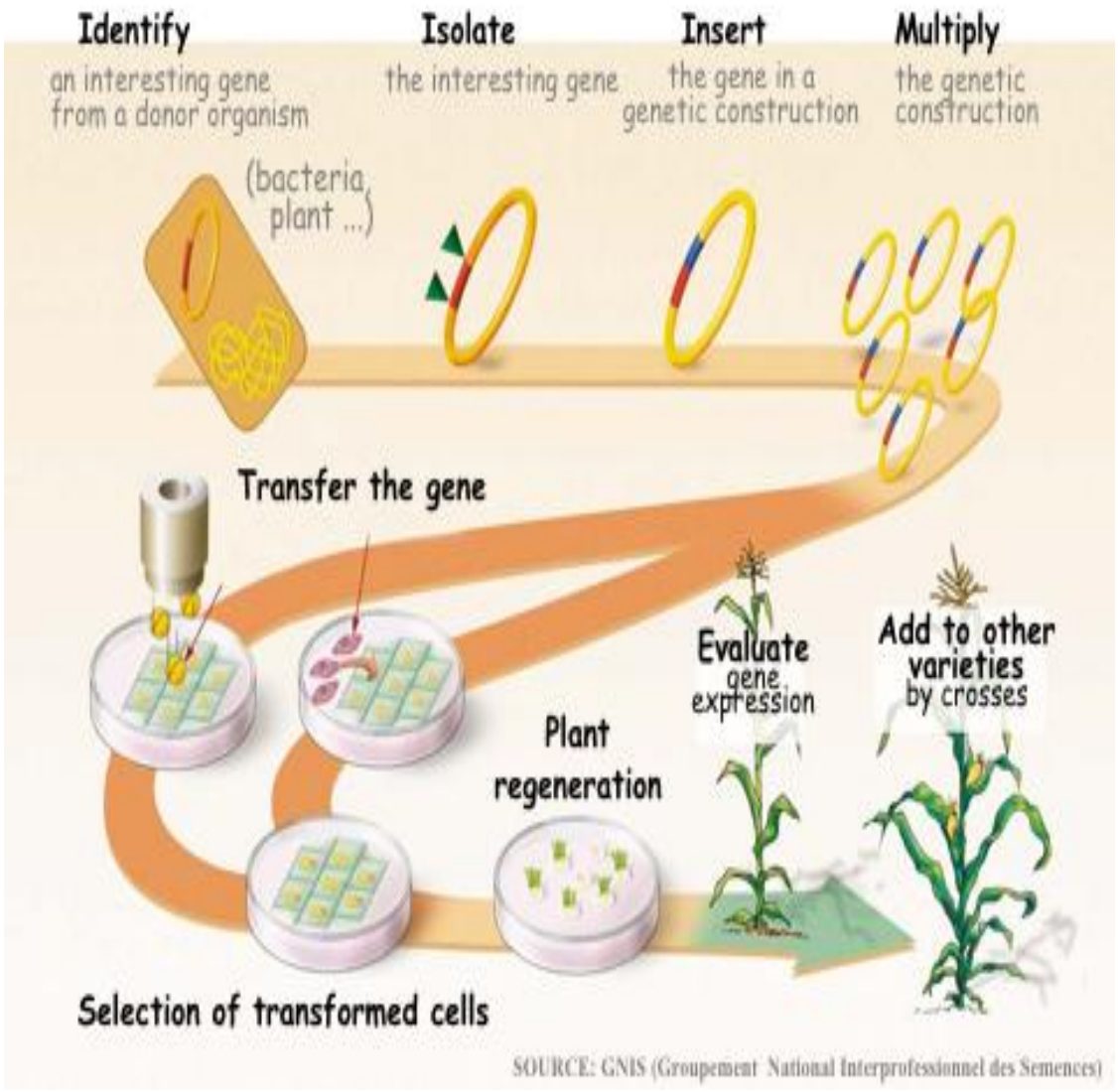


Emerging infectious diseases(EIDs) - pathogens that are increasing in: ***incidence***, ***geographic or host range***, and ***virulence***



Fisher et al. (2012) Nature 484: 186-92

Steps involved in genetic modification



Future technologies

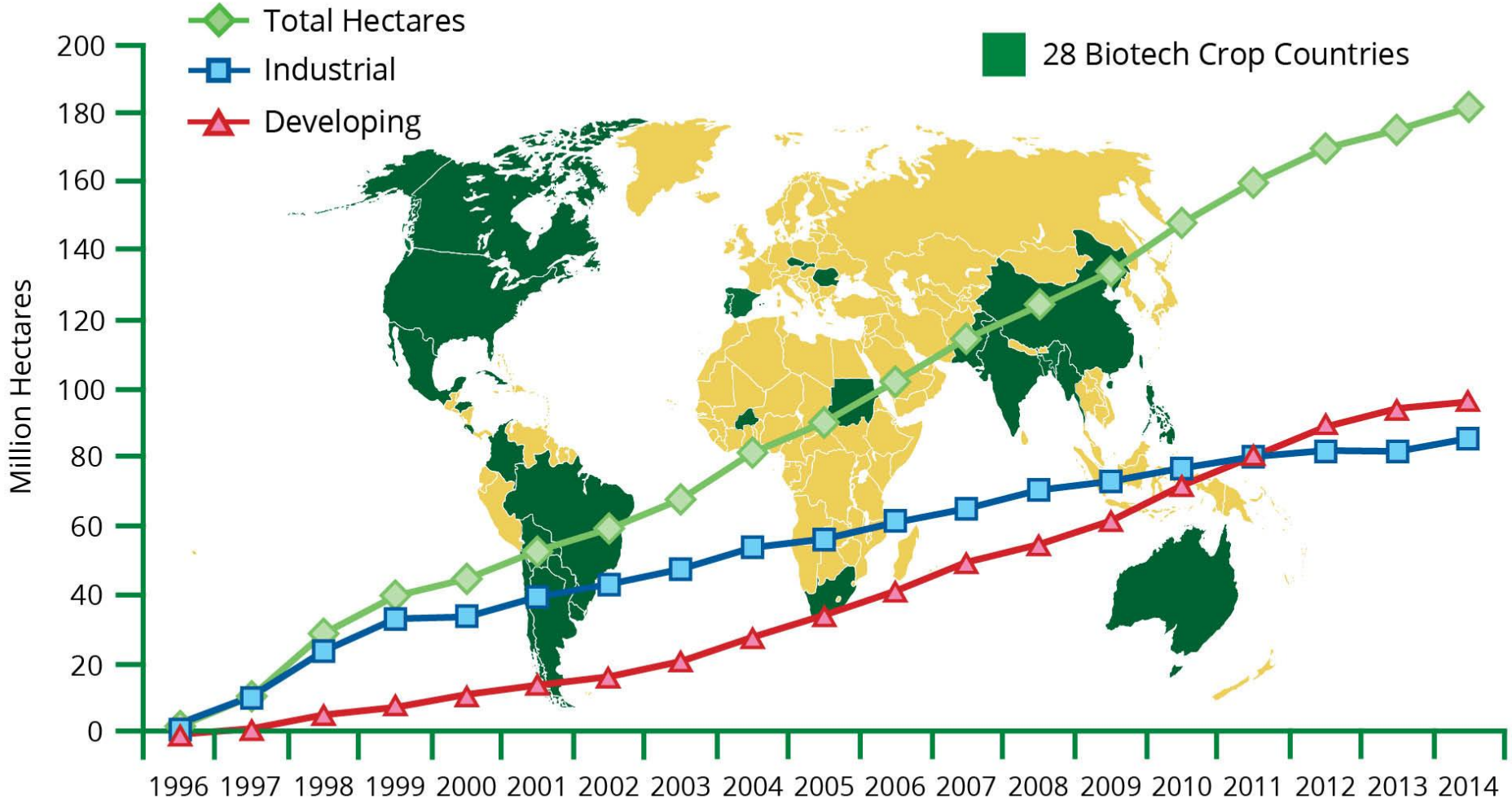
Cisgenesis and intragenesis (sequences from same or compatible species)

RNA-dependent DNA methylation (gene silencing, no DNA introduced)

Zinc finger nuclease (site-specific)

Oligonucleotide directed mutagenesis (induced mutations)

GLOBAL AREA OF BIOTECH CROPS
Million Hectares (1996-2014)



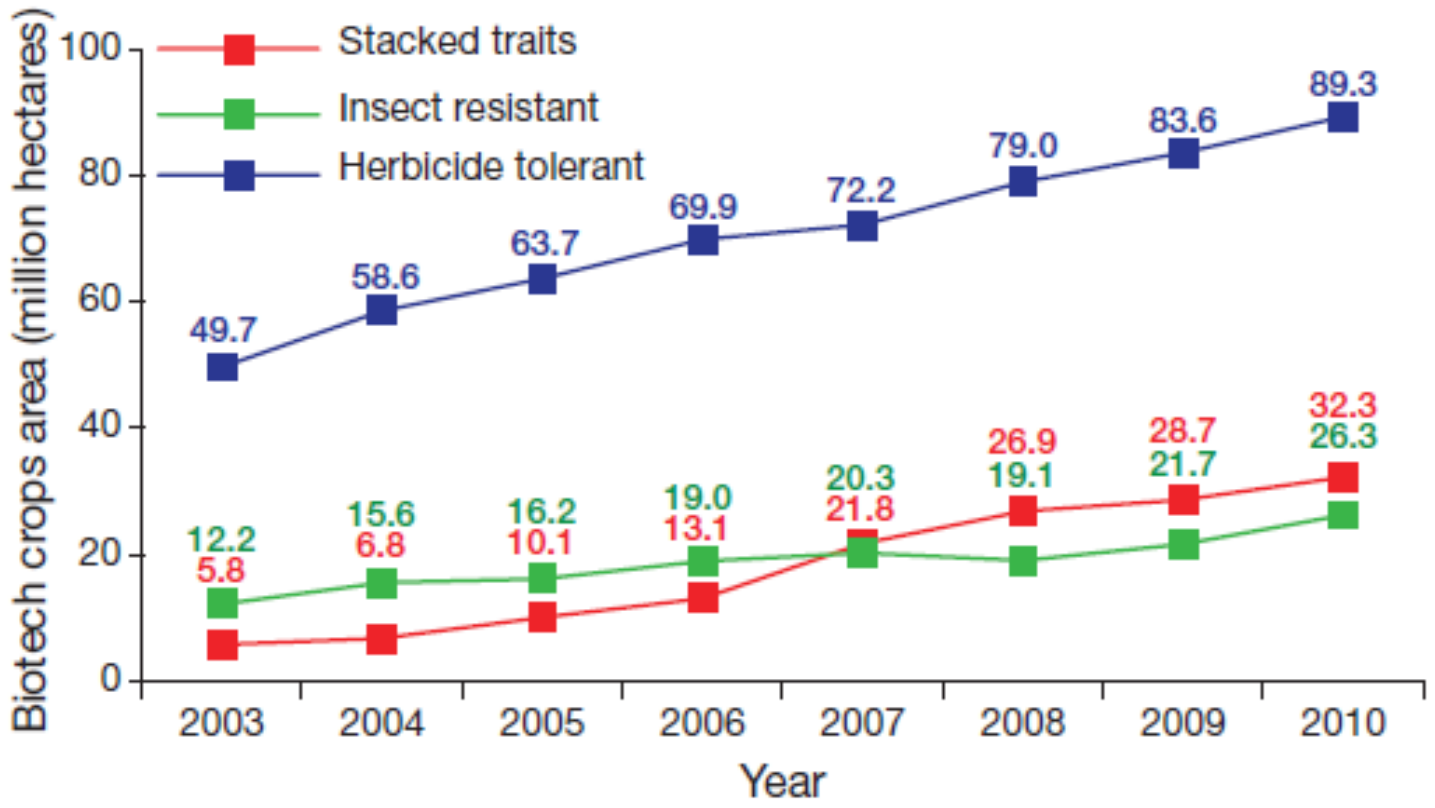
A record 18 million farmers, in 28 countries, planted 181.5 million hectares (448 million acres) in 2014, a sustained increase of 3 to 4% or 6.3 million hectares (~16 million acres) over 2013.

Source: Clive James, 2014.

GMOs – The Global Picture

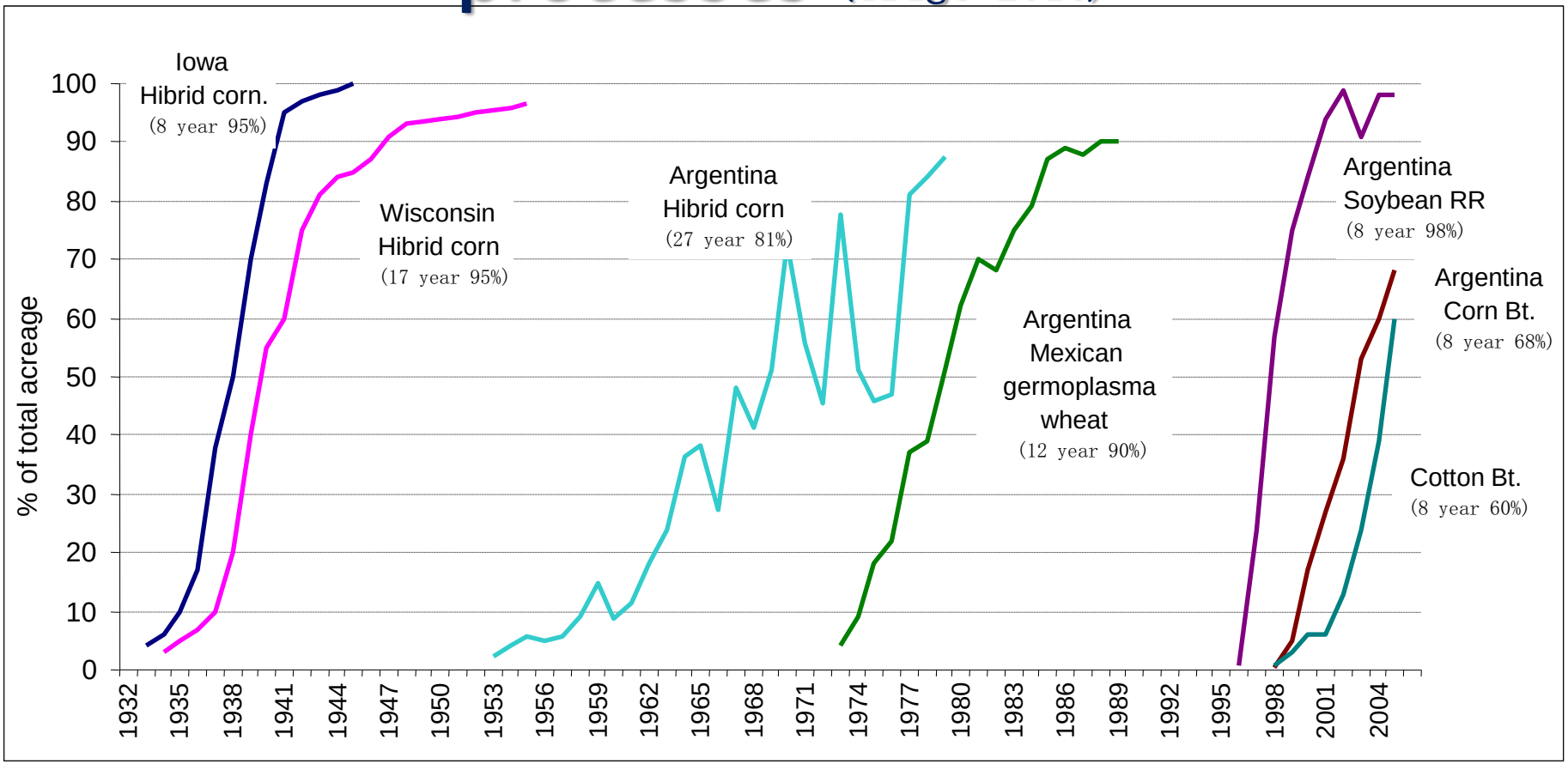
Global area by transgenic trait

Crops with two or more stacked traits continue to be popular.



Source: Peng, W. (2011) GM crop cultivation surges, but traits languish. *Nature Biotechnology* 29, 302

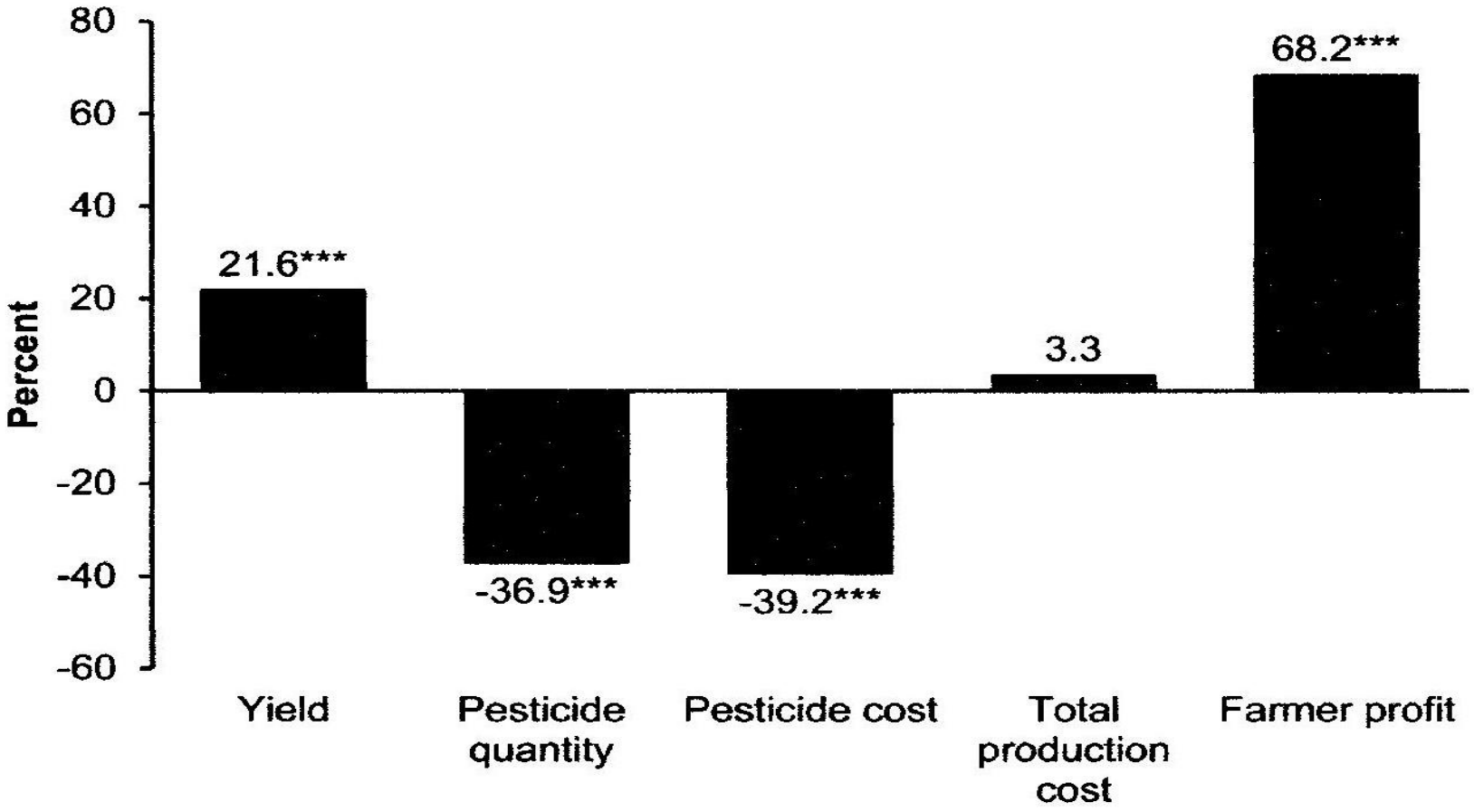
GMO technology adoption process compared to other major technological change processes (Trigo 2010)



grupo CEO

A meta-analysis of the impacts of GM crops

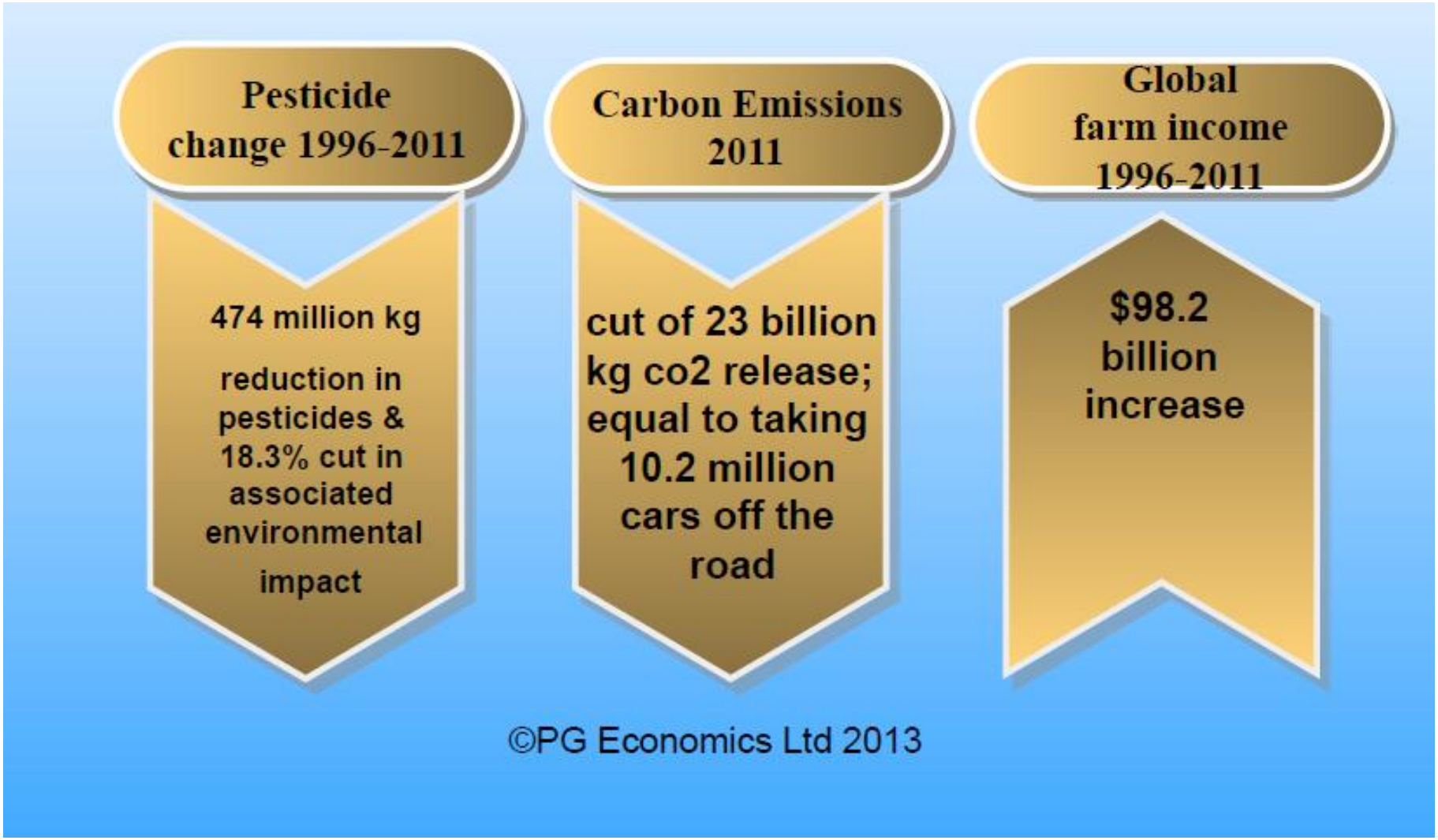
Klümper and Qaim, PLoS ONE 8 (11) 2014



Av % differences between GM and non-GM crops (herbicide tolerant and insect resistant); yield, n=451; pesticide quantity, 121; pesticide cost, 193; total production cost, 115; profit 136. *** P<0.001

How do we assess if modern genetics provide an appropriate intervention?

Does it add significant value to farmers?



But do consumers benefit....

- Yield increases ARE societal benefits
- Environmental benefits ARE consumer benefits

….Decreased sprayings, more efficient water use, less CO2, lower mycotoxins

Three products on their way:

Healthier soya oils = healthier consumers

- Trial plantings 2012 US, await EFSA approval
- 0 g trans fat, 20% less saturated

Late blight resistant potato = less sprayings

- Trials in Belgium, NL, UK
- Await EFSA approval

Drought-tolerant maize = more food

- US approval Dec 2011
- Commercialisation in US
- WEMA, Gates Foundation, private companies

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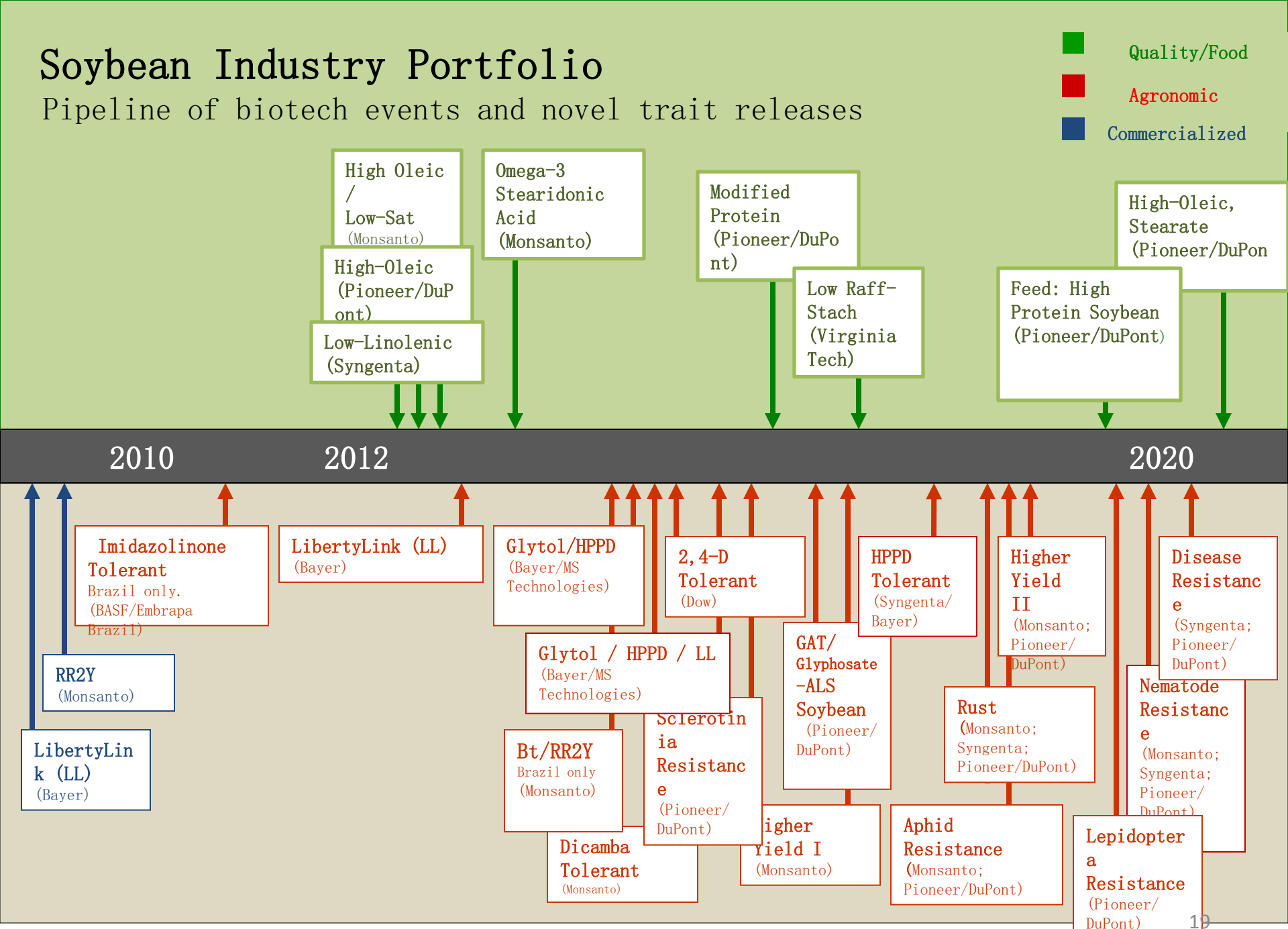
Soybean Industry Portfolio

Pipeline of biotech events and novel trait releases



Source: Pipeline from Industry Sources; prepared by ASA, USSEC, USB. Updated May, 2011

Fears of the unknown – Is it safe?

Questions of risks and risk assessment are notoriously hard to discuss rationally

Risks and benefits to the environment and wildlife are no different from the introduction of any new plant variety or hybrid derived from the well-established methods of conventional plant breeding

Nicolia et al (2013) reviewed 1783 publications between 2002 and 2010 and concluded that there were 'no significant hazards directly connected with the use of GE crops' (*Critical Reviews in Biotechnology*).

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

Transparency…..

Food and Feed Safety risk assessment

- Differences between a GM crop and appropriate comparator
- Analysis of the gene and its expression as a protein
- Safety of the introduced protein for human and animal health
- Allergenicity assessment
- Assessment of unintended effects

Environmental risk assessment

- Persistence & invasiveness of the GM plant
- Impact on agricultural practices
- Potential horizontal gene transfer
- Interaction with target organisms
- Interaction with non-target organisms
- Effects on biogeochemical processes
- Long-term effects

Equitable…

Table 1 Compliance costs for insect-resistant maize

Cost categories	Range of costs incurred ($)
Preparation for hand-off of events into regulatory	20,000–50,000
Molecular characterization	300,000–1,200,000
Compositional assessment	750,000–1,500,000
Animal performance and safety studies	300,000–845,000
Protein production and characterization	162,000–1,725,000
Protein safety assessment	195,000–853,000
Nontarget organism studies	100,000–600,000
Agronomic and phenotypic assessments	130,000–460,000
Production of tissues	680,000–2,200,000
ELISA development, validation and expression analysis	415,000–610,000
EPA expenses for PIPs (e.g., EUPs, tolerances)	150,000–715,000
Environmental fate studies	32,000–800,000
EU import (detection methods, fees)	230,000–405,000
Canada costs	40,000–195,000
Stewardship	250,000–1,000,000
Toxicology (90-day rat)—when done	250,000–300,000
Facility & management overhead costs	600,000–4,500,000
Total	*7,060,000–15,440,000*

ELISA, enzyme-linked immunosorbent assay; EPA, US Environmental Protection Agency (Washington, DC); EUP, experimental use permit; PIP, plant-incorporated protectant.

Risk assessment harmonisation

- Codex Alimentarius: international food safety standards
- Cartagena Protocol
- OECD protocols
- Tried- and tested methodology

Extensive studies

- In-house and commissioned studies
- Harmonisation needed
- Long preparation phase
- High costs ($7-15 million)

EuropaBio 2012 by permission

Compliance costs for regulatory approval of new biotech crops. Nature Biotechnology 25: 509-511 (2007).

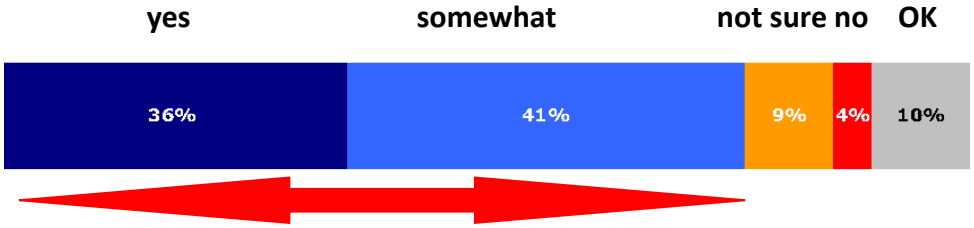
Power politics in Europe

Member States - attitudes to GM

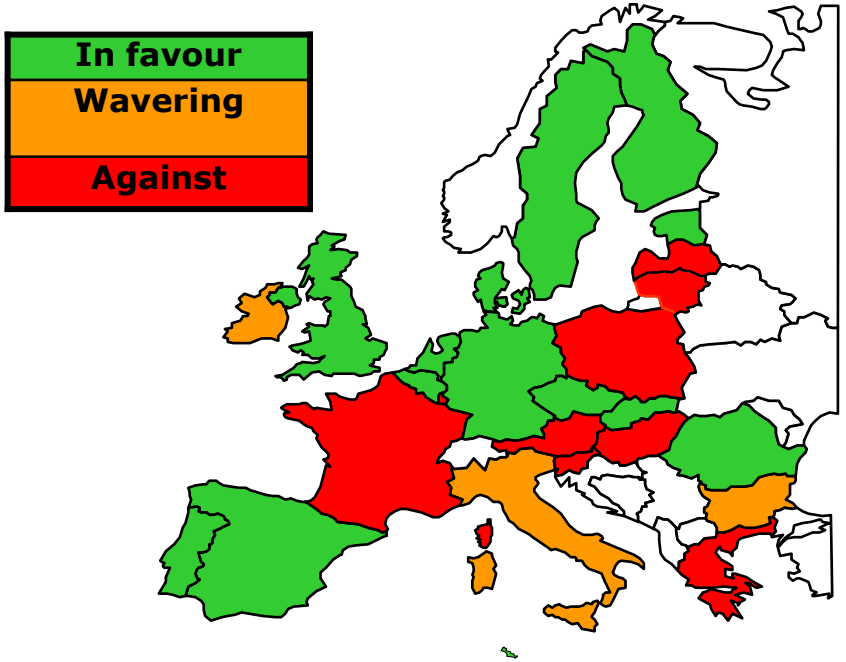
EU COUNTRY	TOTAL IMPORT OF SOYA BEANS & MEAL	IMPORTS PER CITIZEN PER YEAR	DID VOTING FOLLOW SCIENCE IN 2014?
AUSTRIA	0.6 MT	70 KG per Austrian per year	☹
BELGIUM			😐 +
LUXEMBOURG	1.5 MT	128 KG per citizen per year	☹
BULGARIA	0.1 MT	14 KG per Bulgarian per year	☹
CYPRUS	0.09 MT	81 KG per Cypriot per year	☹
CZECH REPUBLIC	0.4 MT	38 KG per Czech per year	☺
CROATIA	0.2 MT	47 KG per Croat per year	😐 -
DENMARK	1.6 MT	285 KG per Dane per year	😐 +
ESTONIA	0.03 MT	23 KG per Estonian per year	☺
FINLAND	0.2 MT	37 KG per Fin per year	☺
FRANCE	3.9 MT	59 KG per Frenchman per year	😐 -
GERMANY	6.4 MT	79 KG per German per year	😐
GREECE	0.5 MT	45 KG per Greek per year	☹
HUNGARY	0.4 MT	40 KG per Hungarian per year	☹
IRELAND	0.4 MT	87 KG per Irish per year	☺
ITALY	3.4 MT	57 KG per Italian per year	😐
LATVIA	0.1 MT	50 KG per Latvian per year	☹
LITHUANIA	0.1 MT	34.4 KG per Lithuanian per year	☹
MALTA	0.01 MT	25 KG per Maltese per year	😐 -
NETHERLANDS	7.9 MT	470 KG per Dutch per year	☺
POLAND	2 MT	52 KG per Pole per year	☹
PORTUGAL	0.9 MT	86 kg per Portuguese per year	☺
ROMANIA	0.5 MT	25 KG per Romanian per year	☺
SLOVAKIA	0.1 MT	18 KG per Slovak per year	☺
SLOVENIA	0.6 MT	300 KG per Slovenian per year	☹
SPAIN	5.3 MT	112 KG per Spaniard per year	☺
SWEDEN	0.2 MT	21 KG per Swede per year	😐 +
UNITED KINGDOM	2.8 MT	43 KG per Brit per year	☺

More info on www.europabio.org

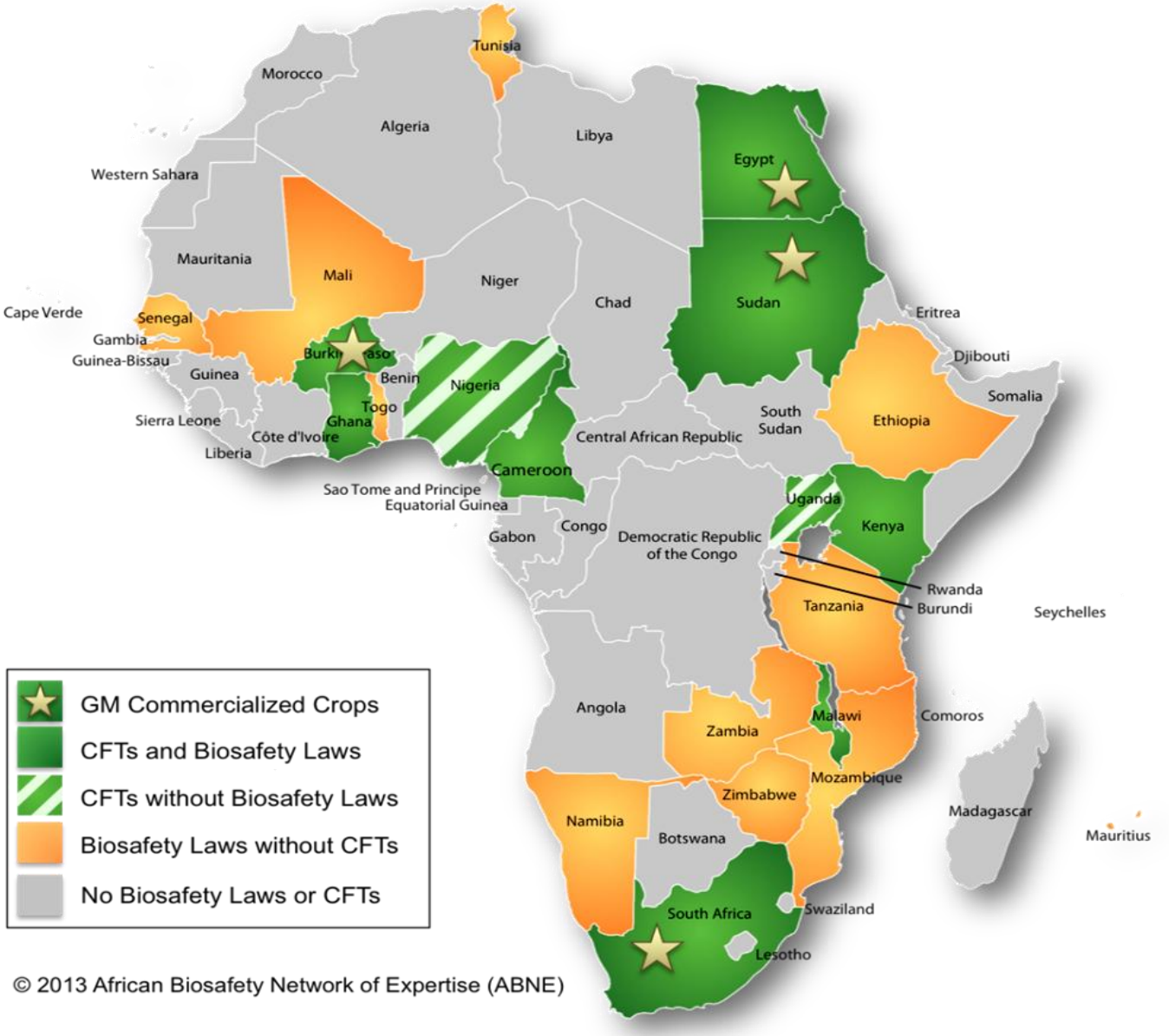
Do you agree or not with use of biotechnology for food security?



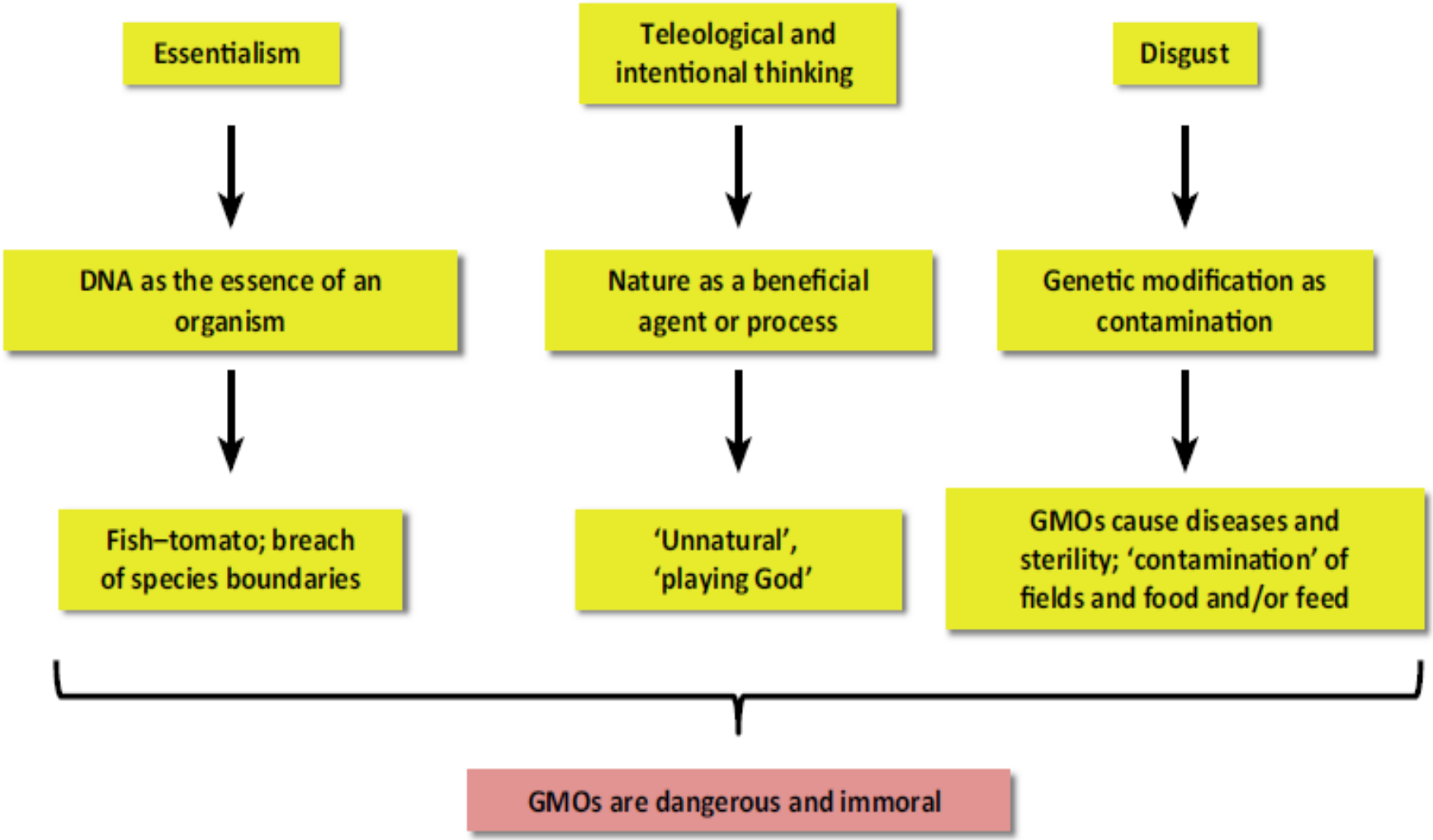
77% of EU citizens are in favour of taking advantage of biotechnology in agriculture



Current status of GM crops in Africa



Negative representations of GMOs tap into intuitive preferences



Blancke et al./*Trends in Plant Science* 2015
http://phys.org/news/2015-04-appeal-anti-gmo.html#jCp

Summary

- *Is it safe?* no effect on human health has been found; risks and benefits to wildlife are no different from the introduction of any new plant derived from the well-established methods of conventional plant breeding

- *Is it natural?* Humankind has been modifying plants by selection and seed collection for centuries; what we grow today does not resemble their natural origins.



- *Is it fair?* Developers need a financial return; developing countries need access to technologies with public-private sharing schemes and partnerships; public concerns expressed where they see science and its presentation shaped solely by commercial interests

- *Is it needed?* Maximising food security requires that benefits outweigh the costs; barriers may exist that prevent markets supplying resources and infrastructure to make food supply robust.