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Bioethics

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Ethical Applications of Plant Breeding and Biotechnology

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Crop plants have been – and must be – altered

- 11 000 years ago the start of agriculture and plant breeding enabled the genesis of modern human civilizations
- Vital staple crops were not donated ready and waiting for us
  - ...but were conquered by hard work through millennia
- Natural plants are adapted for their own and not human benefits
- Plants defend themselves against pests (including man) with a multitude of chemical weapons
- Human-directed evolution (plant breeding) has changed crop plants to suit human needs better
- Yields have increased by orders of magnitude (often 10–30-fold)
- Toxic and harmful chemicals have decreased in food crops
- Nutritional contents (e.g. essential amino and fatty acids) have been adjusted towards human requirements
  - ...though great improvements are still necessary

Art of breeding

- Great improvements still need be done in many old traits
  - ...and novel traits are necessary in the changing world
- Art is artificial beauty
  - ...and plant breeding was traditionally praised as classic art by the breeders themselves
- Recent breakthroughs in molecular biology and genetic understanding have
  - *evolved* plant genetics, physiology and breeding to true sciences
  - *improved* both precision (100–100 000-fold) and predictability (thus safety as well), efficiency (often 30-fold), and application potentials of plant breeding
  - *lowered* the cost of breeding new crop varieties quite a lot (apart from undue costs of approval owing to non-scientific GM legislation)
- Consequently, hundreds of biological inventions now lay (growing dusty) on university shelves
- …waiting for financial and social support
  - to push their way through the obstacles of GM and product legislation (to obtain permissions for their cultivation and use)
- ...to be finalized and made good use of for the prosperity of man and nature

Novel prospects and challenges

- **Quality, Nutrition, Health, Environment, and Bio-economy**
  - five core drivers in the rapidly changing world
- For the past 11 000 years, plant breeding has generated about one half of the progress in the productivity of agriculture
  - other half is owing to improved cultivation technologies
- ...but now it shall meet even bigger challenges
- Climatic change alone (direction disregarded...) would call plant scientists for a herculean task:
  - ✓ Update the existing thousands of core plant varieties to be suited to changed conditions
  - ✓ Breed a new generation of staple crops provided with crucial new traits, such as
    - radically enhanced nutritious qualities (for better growth and health with even less feed)
    - drought, heat, frost, salt or flooding tolerance
    - much more solid resistance to possibly ever more prolific plant pests and diseases
- Such updatings are vital just for retaining our current yield levels and efficiency in cultivation
  - ✓ ...but really improving food security would call for true (no-nonsense) attitudes towards life sciences

Edible cottonseed – high-quality protein to feed half billion people in developing countries

- Protein deprivation damages human health among the poor in the Third World
  - ...where 'hunger' often translates to shortage of protein
  - For example, it hurts brain development in children
- Cotton is very toxic due to gossypol, a terpenoid aldehyde
  - 2,2′-bis-(Formyl-1,6,7-trihydroxy-5-isopropyl-3-methylnaphthalene)
  - ...which can only be digested by ruminant microflora, but only to a certain level
- Cottonseed is rich in protein (22 %) of very high quality
  - ... gone to waste hitherto, due to its high gossypol content
  - ...though cottonseed (44 billion kg/year) could provide new, high-protein food for 500 million people annually
- Edible cottonseed has now been bred using RNAi
  - ...a gene silecing method awarded with Nobel prize in medicine in 2006
  - ...though it has been used in plant GM since decades ago
- Production of gossypol was only silenced in the seed
  - ...so that the indigenous chemical defence against pests was successfully retained in other plant parts
- That is not possible applying "traditional" breeding methods
  - Gossypol production was silenced by traditional mutagenesis in experimental cotton lines already in 1970's
  - …with the consequence that such defenceless plants were destroyed altogether by pests and diseases in the field

- Sunilkumar et al (2006). Engineering cottonseed for use in human nutrition by tissue-specific reduction of toxic gossypol. PNAS 103: 18054–18059
- Field trials: http://agnews.tamu.edu/showstory.php?id=1399

Harnessing bio-economy calls for new achievements in biological efficiency

- Achieving high productivity is the key question for reaching true sustainability in bio-economy
  - ...biofuels included
- Or else huge impoverishing automata are being constructed for ruining our civilization
  - ...duly comparably with the perpetual-motion economical machine in Stalin's agriculture which sucked Soviet national economy dry during a few decades:
    - ✓ E.g., nourishing swine and cows with bread instead of feed was made apparently "profitable" (but surely not sustainable)
- Biotechnological solutions beating old technologies in yield, energy use and costs
- ...must be created during the upcoming few years
  - ✓ ...which means troubled waters for EU, mixed-up with its occult movements and firmly established anti-science policies
    - ...petrified in its biologically untenable GM legislation
- E.g. oilseed rape should be bred resistant to clubroot, so it could be grown in successive years
  - ...increasing its potential cultivation area fivefold in EU

Inefficient biofuel plants risk food security?

- Regarding transport biofuels, just bioethanol from tropical *sugarcane* is reasonable in terms of carbon balance and economy (IEA 2007)
  - sugarcane is grown on more than 20 million hectares, one third of that in Brazil
- Maize yields very little of ethanol per ha
- Poor efficiency in biofuel production deprives food production of its field area
  - ...or extra land for cultivation must be cleared from the Nature in a large scale
- Pursuing ecological and economic sustainability in biofuels, the productivity and eco-efficiency of biofuel crops must be greatly enhanced (EPSO 2007, Tammisola 2010)
  - in a short time, and consequently
  - ...based on modern plant breeding, especially genetic modification

Why is it hard to breed sugarcane by traditional means?

- Cultivated sugarcanes are
  - Highly polyploid (ploidy levels 5x–14x) and even aneuploid plants (i.e. contain extra or missing copies of chromosomes)
  - Species hybrids: *Saccharum officinarum* (2n=80) *x S. spontaneum* (2n=40–128)
  - Highly heterozygotic ”jackpot hits”, cloned to millions of copies for cultivation
  - ...because their superior genotype would be lost in sexual reproduction (especially crosses)
  - Slow to grow from seed to maturity
  - ...and mostly almost sterile in practice
- Accordingly, improving an elite variety further with crosses translates to a fairly desperate ”Sisyphos”-affair statistically
- Thus e.g. sugar content has not improved much at all in 40 years (Jackson 2005)
  - ...despite heritability occurring in the trait

Too little progress in sugar content

- Sugar content is influenced by a multitude of genes (each one with a small effect as a rule)
- High-sugar genes (alleles) derive from *S. officinarum*
- Enriching such profitable genes together in a single superior genotype is very hard work by old means in polyploid hybrids
  - …because each basic chromosome type may occur in up to 14 (related) copies in the cell
  - ...and because all the other important traits shall also be kept unimpaired in the process
- Crosses break up the elite genotypes
  - …to a (”creative”) statistical chaos
  - ...and at the same time, arrays of poor alleles (once already screened out with hard work) make re-entry to the breeding lines once again

Sugar content was doubled with one step of genetic modification in sugarcane

- By applying GM to an elite cane variety, its sugar content could be doubled (Wu & Birch 2007, Birch 2006)
  - ...without compromising its unique genotype
- A bacterial gene for sucrose isomerase enzyme was inserted in the plant
- In addition to normal amounts of sucrose, GM sugarcane yields similar amounts of its isomeric form (isomaltulose)
- Isomaltulose is a health-promoting polysaccaride
  - produced for funtional foods by bacterial fementation
  - ...and also suited for being fermented to alcohol
- That sugar isomer is not utilized by the plant itself, and hence it is accumulated without loss in sugarcane cells
  - ...where it was channelled to find its way into vacuoles
- Field trials are going on in Australia (OGTR 2005 a, b)

The livelihoods of half billion people depend on banana, the most important fruit in the world

Juvenile banana fruits, trailing the male inflorescence. Rhodes, Greece, 2009. © J.Tammisola

- In Uganda, Burundi and Rwanda people eat 250–400 kg of bananas a year (BI 2010)

Is the evolution of devastating new races of fungal diseases going to eradicate our current commercial banana varieties?

Black Sigatoka ruins banana leaves

- ...just as that destroyed the far better and sweeter ”smiling banana” (’Gros Michel’) half a century ago (Ploetz 2001, Pearce 2003, Molina 2009 Keynote 2)

…though, in rich countries, these novel pathogens can still in part be controlled with frequent fungicide sprayings

- 20–40 (up to 70) sprayings per year may be required in banana plantations
  - That is too costly for small producers in the Third World
  - ...since fungicides are expensive and should preferably be spread by plane
  - Sprayings also burden the environment
- Furthermore, the efficiency of the fungicides tends to impair with time
  - ...due to resistance evolving in the pest
- Accordingly, developing disease resistant banana varieties would be fundamental to the livelihood
- Anyway, owing to the sterility of edible banana varieties, hardly any progress could be achieved with four decades of conventional breeding (Pearce 2003)

Could grocery store bananas (’Cavendish’) be saved with wild bananas?

Wild bananas are packed full with hard seed

- Commercial banana varieties are seedless, parthenocarpic triploids
- ...whilst wild banana species carry inedible fruits (virtually devoid of flesh but full of seed)
  - ...called ”tae manu” (animals feces)
- Anyhow, wild bananas hold resistance genes
- ...which could be utilized in commercial banana varieties
  - ...though, in practice only with genetic modification

Forty years of wasted efforts in disease resistance development using retarded breeding methods

- 10 hectares of ’Cavendish’ bananas were force-crossed by hand pollinations with resistant Asian wild bananas
  - 400 000 kg of banana fruits were mashed through sieves
  - In total 15 seeds were found
  - ...of which 4 ones could be germinated
- These few species hybrids were then backcrossed with wild bananas
- ...finally yielding one seedless hybrid banana resistant to two severe diseases (Black Sigatoka & Fusarium wilt)
- Not quite unexpectedly:

  (given the thousandfold unnecessarily dirty, ”conventional” method, i.e. crosses)

  ❖ That flagship of traditional plant breeding
  - ...is sour, and
  - ...primarily tastes of apple (!)

Old top varieties: to be lost with crosses, or fixed with genetic modification?

- The fiasco of ”Sour Banana” came of inserting thousands of unknown, unnecessary and disadvantageous genes in banana genome
  - ...though only certain prescribed genes (for disease resistance) would have been needed
- Thus, no responsible plant biologist would apply such dirty and unpredictable, traditional ”black box” methods of breeding for the problem any more today (Tammisola 2006)
- Instead of a cacophony of genes, only the chosen few useful ones should be transferred in crops
  - ...purified from any hitchhiker genes whatsoever
- ...using latest precise genome modification methods such as gene targeting (Shukla et al 2009, Townsend et al 2009, Porteus 2009)
- Popular old varieties, such as ’Gros Michel’, could be resurrected on grocery store shelves by fixing their faults (whilst retaining their top qualities intact) with genetic modification

’Gros Michel’ banana modified with two rice genes for resistance against Black Sigatoka: Field tests are going on in Uganda

- Chitinases are involved in plant defence: they have anti-fungal properties
- ’Gros Michel’ banana variety was modified with chitinase genes Rcc2 and Rcg3 from rice
- Laboratory evaluation of GM banana showed very high resistance to Black Sigatoka (Kiggundu et al 2008)
- GM lines are being tested in the field for the stability of chitinase expression in different environments (Dauvers 2007)
- Meanwhile, progress in genomics by initiatives such as the *Global Musa Genomics Consortium*
- ...raises the possibility of using genes found in wild banana species instead of ‘borrowing’ genes from more distantly related organisms
- Such ‘cis-genic’ bananas may be more passable to laymen regarding species borders sacred
  - though such borders are commonly crossed in the Plant Kingdom (Tammisola 2006)

Genetics of aromatic cereals was resolved

- Thai scientists found out the genetic basis of fragrance in cereals in 2005 (Bradbury et al 2005, 2008, Kovach et al 2009)
- In ordinary cereals, the gene for non-fragrance is functioning
  - whereas in aromatic rices (basmati and jasmine) it is silenced by a mutation
- The gene was purified
  - and patented: for keeping its intellectual property rights in the developing country
- Wheat has altogether 6 non-fragrance genes, and consequently all of these cannot be silenced by old means:
  - Breaking one specific gene traditionally with chemicals or radiation may succeed, by investing plenty of time and efforts
  - ...but breaking all 6 ones by blind chance is simply not possible

Breeding aromatic wheat

- ...whereas aromatic wheat can be bred at a couple of steps with genetic modification
  - all 6 non-fragrance genes can be silenced in a focused way simultaneously
    - » with RNA interference (Vince 2006)
  - or sequentially in groups, at a few steps
    - » with targeted mutagenesis (Shukla et al 2009)
- The real challenge may be obtaining EU clearance for importing fragrant wheat
- Such permission is obligatory in practice
  - even if the product is not aimed at EU markets
  - namely, without such prior permission, import bans are launched even if minuscule amounts of the fragrant crop is mixed with the wheat imported in EU (Tammisola 2006, chapter 10)

Sufficiently of vitamin A from rice-based diets for billions of people

Conventional rice **Early *vs.* Current Golden Rice**

- Greenpeace insists that 9–14 kg of Golden Rice should be consumed every day in order to gain any remedy for A-vitamin deficiency
  - that is unethical ”campaign” nonsense , however (Tang et al 2009, *Am J Clin Nutr* 89: 1776–83)
- Clinical studies confirm that Golden Rice is more potent than even researchers could anticipate:
  - **72g** of GR per day supplies 50% of RDA of vitamin A for 1–3 year old children
  - ...so that it prevents the injuries due to vitamin A deficiency
  - ...which give rise to more than million deaths and up to 500 000 blinded children in developing countries every year
  - ☞ http://www.goldenrice.org
- Current Golden Rice lines contain up to 20 times more β-caroten than the early GR prototype in 1999
  - ☞ Paine et al. (2005), *Nature Biotechnology* 23: 482–487

Anthocyanin tomatoes prevent cancer

- Two genes from snapdragon were bred in tomato
  - transcription factors (regulate functioning of other genes)

- Anthocyanins were accumulated in tomato fruits to as high concentrations as in blueberries
- Blue tomatoes helped cancer mice live one quarter longer than red ones did (Butelli et al 2008)
- ...though also red tomatoes are known to prevent cancer
  - owing to their red pigment (lycopene)

Breeding long-chain ω3 oils into crop plants – health for the needy 1.

- Long-chain ω3 fatty acids (EPA, DHA) prevent heart diseases
  - ...and may even reduce death rates as much as statins do (Stanley 2006, *Lipid Tech.* 18: 158)
- Fish products alone have so far been the dietary source of these healthy fatty acids
- ...but supply of fish is declining in the world
  - due to exhaustive fishing and consequent restraints
- Hence, plant breeders are developing oil crops that could provide recomended daily allowance (RDA) of long-chain ω3 fatty acids for all people, especially
  - the poor ones, often relying on plant-based diets
  - vegans
  - people allergic to fish

Breeding long-chain ω3 oils into crop plants – health for the needy 2.

- In fact fish cannot produce EPA or DHA but receive those fatty acids from sea algae
- Mosses and algae can make long-chain ω3 fatty acids but flowering plants cannot
  - crop plants can only synthesize short-chain types of ω3 fatty acids
  - ...with merely scanty benefits to human health, because only a negligible fraction of those acids is converted to the long-chain ones in our cells
- The key gene was purified from a seaweed and inserted in soybean and oilseed rape
- Field trials proved that high amounts of EPA and DHA are generated in the crops
  - 1 ha of GM soybean yields as much of these as 30 000 salmon
- Clinical trials proved the efficiency of heart-nurturing long-chain ω3 soy oil in human use (American Heart Association 2009)
- Awaited dates of release in grocery stores: 2011 in USA, 2015 in Australia (CSIRO 2009)

Relieving allergies with plant breeding 1.

- One fifth of people living in industrialized countries suffer from pollen allergy
- Birch pollen is the main allergen in the Nordic countries
- ...whereas Japanese cedar (*Cryptomeria japonica*) commonly causes much more severe symptoms in Japan

Japanese cedar in Azores. Dec. 3, 2006. ©Gaspar Avila

Crops preventing or curing allergy or asthma... 2.

- In industrial countries, one in five persons suffer from pollen allergy
- Birch pollen is arduous in the North, whereas Japanese cedar causes strong symptoms in Japan
- A peptide combining the immunologically most essential patches of two major allergens in cedar pollen was synthesized (by gene technology)
- A synthetic gene coding for the peptide was then bred to rice, and the peptide was produced in rice seeds
- Cedar allergy was prevented in mice, when they were fed in advance with such seeds
- ...signifying edible vaccine against pollen allergy, without the danger of anaphylactic reactions

☞ Takagi et al. (2005). *PNAS* 102: 17525–17530

❖ The safety of the cedar allergy vaccine in development has recently been proved with Macaques (Domon et al 2009)

...without injection needles 3.

- Similarly, onset of experimental asthma (caused by sunflower seed albumin) could be prevented by oral vaccination
  - mice were fed in advance with lupin seeds, which were bred to contain sunflower seed albumin
  - such edible vaccine prevented the onset of sunflower asthma in the mice...
  - ...even after heavy dusting with the asthma launching protein at issue

☞ Smart et al. (2003). *J. Immunol.* 171: 2116–2126

Soybean allergy is common 4.

- Soybean is one of the ” big eight” food allergen sources
- Soy occurs in many processed foods, and it is hard to avoid
- A severe but rare reaction is anaphylactic shock
- Soybean seeds contain 1 400 different proteins
- About 7 of these seed proteins commonly cause allergic reactions in adult human population in USA
  - still extra ones may rise antibodies in babies (but do not cause symptoms in adulthood)

Breeding less allergenic soybeans... 5.

- Scientists try to remove the core of allergenic proteins from soybeans
  - onset of new allergy cases agains such proteins could be decreased or prevented
  - regarding inadvertent soy exposures, the allergic reactions of sensitized persons would be less severe
- The immunologically most dominant allergy protein (P34) in soy was removed by silencing its gene with gene technology
  - P34 protein causes more than 65 percent of soybean allergy reactions in USA
  - silencing the undesired gene did not harm the plant's agronomic characteristics

☞ Herman et al. (2003). *Plant Physiol.* 132: 36–43

☞ Herman (2003). *J Exp Bot* 54: 1317–1319

...gene by gene 6.

- Second most important allergenic protein was found lacking in one soybean line in gene bank materials
- The desired characteristic can be combined with the foregoing hypoallergenic trait
  - by classic crosses, because
  - soybean varieties are self-pollinated pure lines
- Work is underway for silencing the third most important allergen in soy (by gene technology)

GM vaccine against birch pollen allergy is in development 7.

- In the Nordic countries, 98 % of birch allergics only react to one birch pollen protein (Bet v 1)
  - In Central Europe, people may often react to Bet v 2 as well
- Thus, regarding vaccine development, the situation in birch is somewhat simpler than in Japanese cedar
  - ...from which at least four allergenic proteins have been reported so far
- No edible vaccine against birch pollen allergy is available yet
  - ...but efficient and safe injectable vaccine for Bet v 1 –caused birch allergy is already being developed
  - ... based on genetically modified vaccine protein (fusion peptide) (Mahler et al 2004)

Taming extra wild species for cultivation...

J. Tammisola©

- Arctic bramble (*Rubus arcticus*)
  - the most aromatic berry in Europe (Línné 1762)
- Rare species with declining populations
- First cultivation trials by Linné
- Breeding attempts since 1920's
  - with scanty results

☞ Tammisola (1988) *J.Agric.Sci.Finl.* 60: 327–446

...or achieving poor compromises by classic crosses?

- Arctic bramble is unreliable and tedious to cultivate, due to its ”primitive” features
  - it only thrives in the Far North (latitudes > 60º), and
  - cannot tolerate weeds (is a weak competitor)
  - is susceptible to fungal and virus diseases
  - is self-sterile (many varieties need to be grown mixed)
  - its soft berries cannot be picked mechanically
- More robust growth, ”tolerance to South”, and disease resistance could be gathered from the American-Asian sister subspecies (ssp. *stellatus*)

Distortion of the aroma by combining unknown genes at random

- Crosses and backcrosses between these two ”sister” brambles were made during decades in Sweden
  - resulting finally in a more southern, more robust and less disease-prone bramble type (”noble bramble”)
- Alas, the unique arctic bramble aroma was lost!
  - consequently, ”noble bramble” berries (albeit their still premium aroma) are not accepted to genuine ”Mesimarja” liqueur by the industry
- The lesson: saviour traits should, for caution, be introduced in a purified form (using gene technology)
- ☞ Pirinen et al. (1998) *Agric. Food Sci. Finl.* 7: 455–468

European Corn Borer increased mold toxins 100-fold in Italian maize cobs

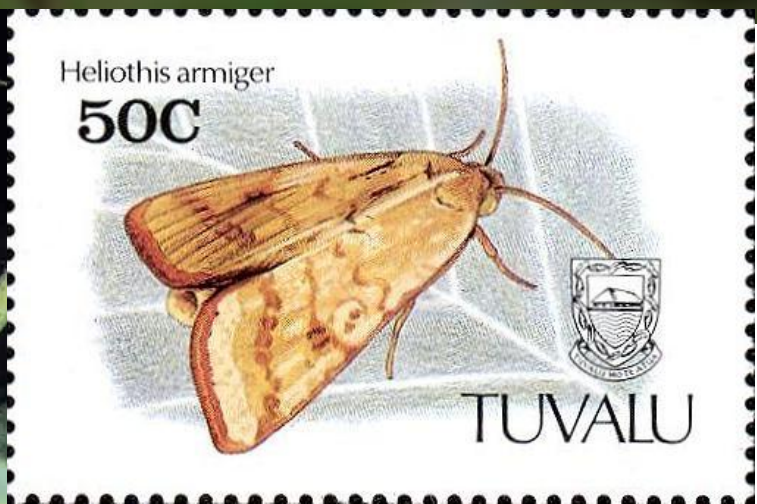
- Cobs damaged by ECB larvae are often conquered by poisonous molds (*Fusarium*)
- Their toxins (e.g. fumonisin) are deleterious to human health:
  - they cause cancer and damage liver, kidneys, nervous system and developing embryos (Marasas et al 2004, Gelineau-vanWaes et al 2005, 2009)
- Developmental disorders such as *hydrocephalus* and *spina bifida are* much more common among neonates in ”Tortilla-zone” countries
  - ...where their mothers are often exposed to poor-quality corn products during pregnancy
- Fumonisin toxin content is radically reduced in the cobs of ECB-resistant Bt-maize varieties
  - especially so in South Europe

ECB damages corn fields and brings along toxic molds

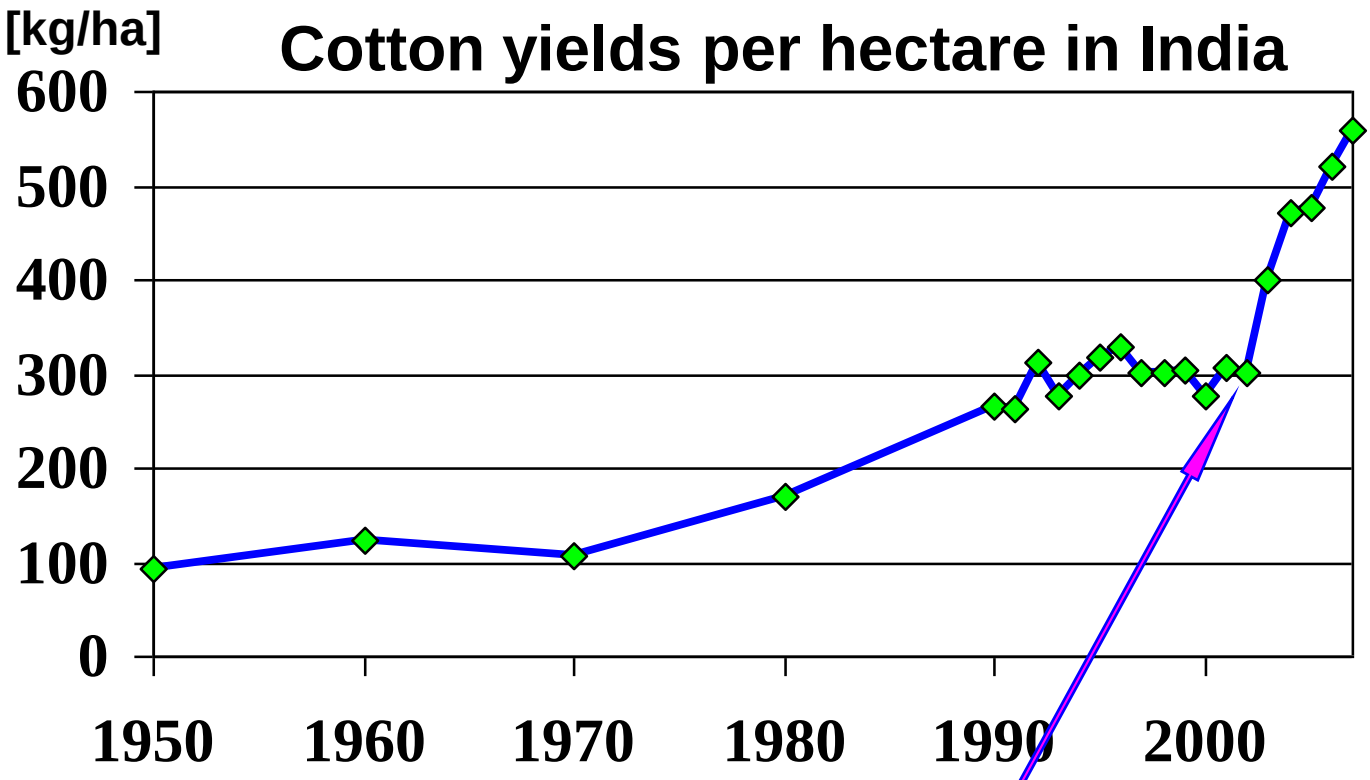
Results of field release in Italy, left conventional, right transgenic insect-resistant maize
http://www.agbioworld.org Data produced by the University of Milan, Italy

Producing cotton ...or bollworm?
(an invasive moth: *Helicoverpa armigera*)

Boll is opening to Reveal the Cotton. Judy Baxter 2005



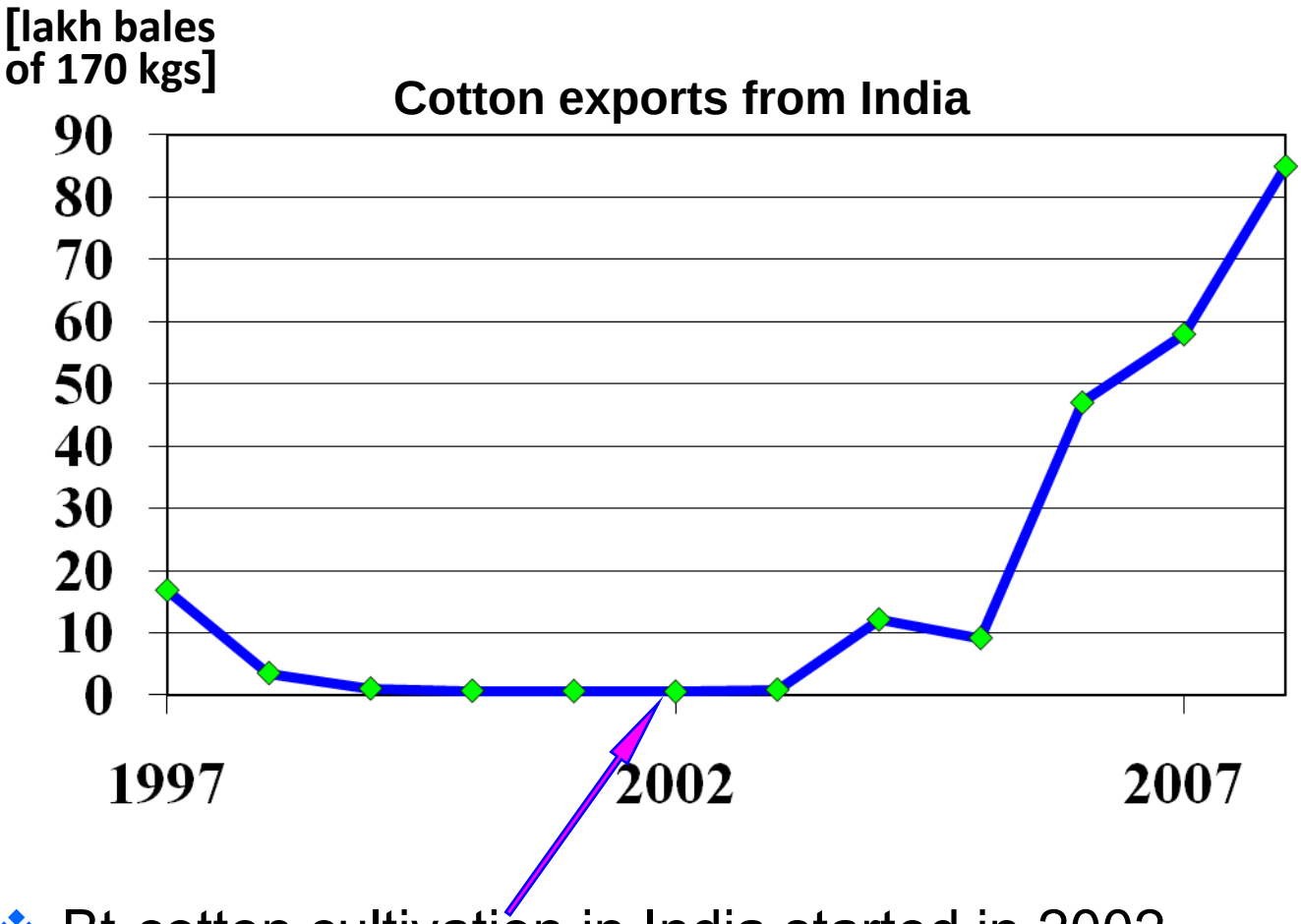
Bollworm-resistant GM cotton rescued Indian cotton livelihoods



- Bt-cotton cultivation in the country started in 2002
  - Varieties resistant to cotton bollworm are now being cultivated in over 80 % of Indian cotton acreage
  - Yields per hectare have risen 80 % in just six years (Official Cotton Statistics)

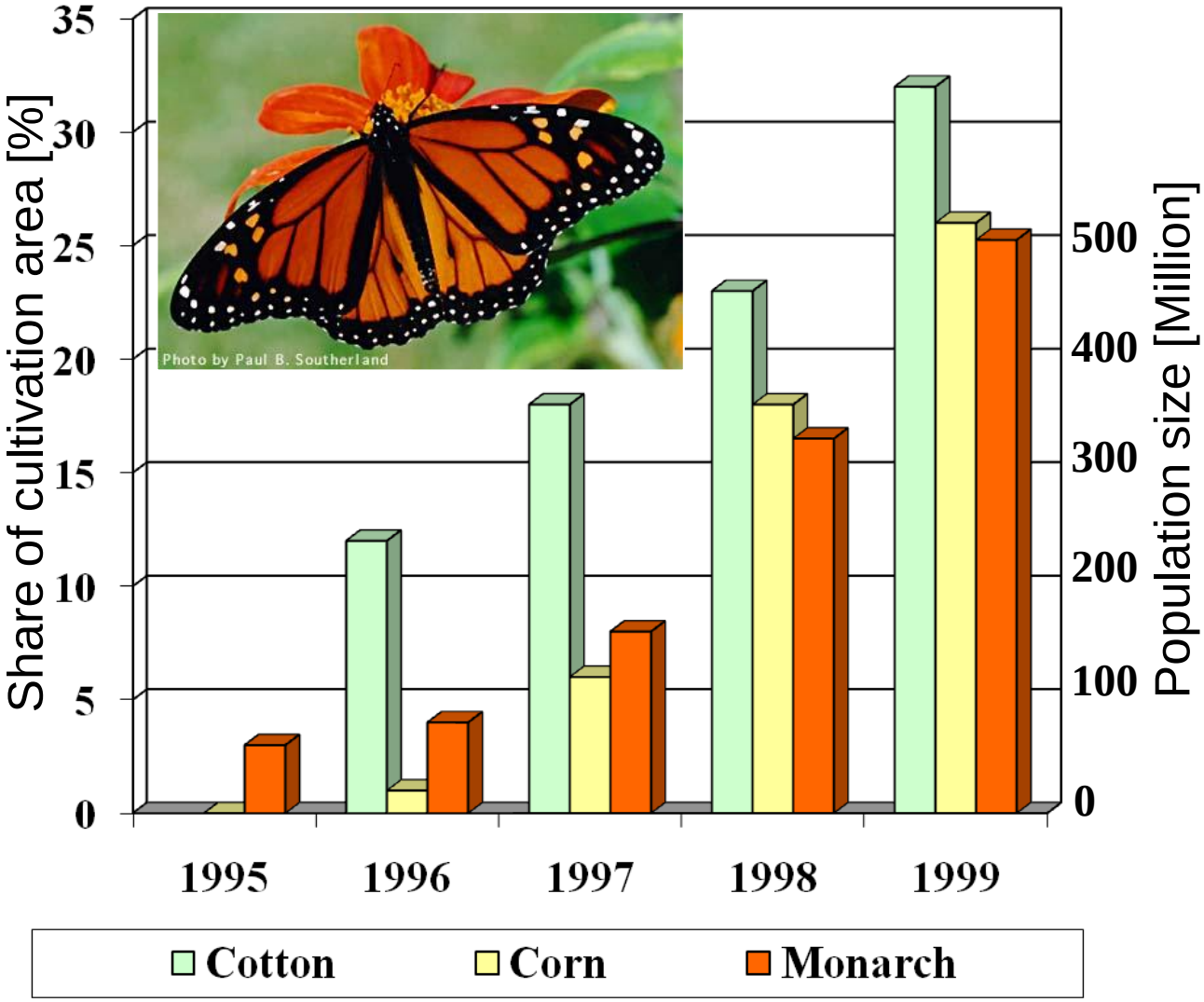
    ...and reduces farmer suicides in India
  - ...as is concluded in an independent study review: (IFPRI 2008)
- ...by diminishing their risk for crop failures
- ...and by improving their cotton yields, income and occupational safety & health (Tammisola 2006)
- Water shortages can be met with drought-resistant GM cotton (under development)

Bollworm-resistant Bt cotton revived Indian cotton industry



- Bt-cotton cultivation in India started in 2002
  - Now its share is more than 80 % of cotton cultivation acreage in the country
  - Accordingly, cotton exports from India have risen exponentially after their chronic stagnation
  - ...e.g. by **13 600 %** since 2000–2002
- Now Pakistan is starting its own ambitious program of Bt-cotton breeding as well
  - ...in order to reproduce the Indian success story

Insect-resistant Bt crops supported the growth of Monarch populations in USA in1996–99



• USDA (1995–2000)

• Carpenter JE, Gianessi LP (2001). Agricultural Biotechnology: Updated Benefit Estimates. Nat. Center for Food and Agric. Policy, Washington www.ncfap.org

• *Monarch Watch* vol. 3–8 (1995–2000), Univ. of Kansas www.MonarchWatch.org

Producing Autumn Blight ...or potatoes?

– Blight resistance is being introduced from wild potatoes with genetic modification (Song et al 2003)

Potato late blight – worst potato disease globally

- Killed million people for hunger in Ireland during 1845–50
- Received compatible mating partner from America a couple of decades ago
  - and started sexual reproduction...
  - so that its genetic diversity and evolution are enhanced, and
  - blight epidemics grow worse in EU
- No true resistance is available in cultivated potato (*S. tuberosum*)
  - but only diverse grades of vulnerability
- Race-specific resistance cannot sustain...
  - but collapses every time when new blight races are generated by evolution

Broad-spectrum resistance to potato late blight is on offer from a wild species

- A wild potato (*S. bulbocastanum*) is resistant to potato autumn blight
- Gene for resistance was searched for, purified, and bred in cultivated potatoes by gene technology
- Potato lines being tested showed resistance to all known blight races
  - including a ”super race” that can overcome all race-specific resistances
- The trait could not be retrieved by old means, because of
  - cross barriers (unequal ploidy levels)
  - exhaustingly long time to be needed
  - risk of toxins being generated in cultivated potato due to unwanted (hitchhiking) genes from wild potato

Popular old varieties can be rescued and improved

- Russet Burbank is a favourite American potato variety since 100 years
- It is still grown on almost half of the total potato area in USA
- Popular clonally (vegetatively) propagated plant varieties can be kept competitive for the future
  - by revising their obsolete (bottleneck) characteristics or enriching their vital traits with the help of gene technology
- Burbank potato can be turned blight resistant (’BR Burbank’)
  - ...and the European favourites alike

Blight resistance benefits environment and food quality

- Productivity and tuber quality are greatly deteriorated by blight infection
- In temperate climates, controlling blight often requires 10 fungicide sprayings

– ...but in hot areas, suh as Mexico or Asia, up to 25 sprayings may be needed per season

– ...which badly hinders moving from rice to water-saving potato cultivation in the tropics

- BR potatoes would save EU each year from
  - 860 million kg of potatoes being wasted
  - 7.5 million kg of fungicides* to be used
    (*measured in active ingredient)

☞ Phipps & Park (2002). *J Animal Feed Sci.*11**:** 1–18

☞ Gianessi et al (2003). Potential impact for improving pest management in European agriculture. Potato case study. NCFAP

Insulin from plants resolves world insulin crisis

- Human insulin precursor is produced in high amounts in GM safflower (*Carthamus tinctorius*) seed oil
  - ...from which it can be readily extracted in a pure form and processed into active insulin
- High yield & dramatically lower production costs → affordable insulin for all diabetics in the Third World
- Three commercial farms is enough
- Drug approval (FDA) is awaited in 2010

☞ http://www.sembiosys.com/Products/Diabetes.aspx

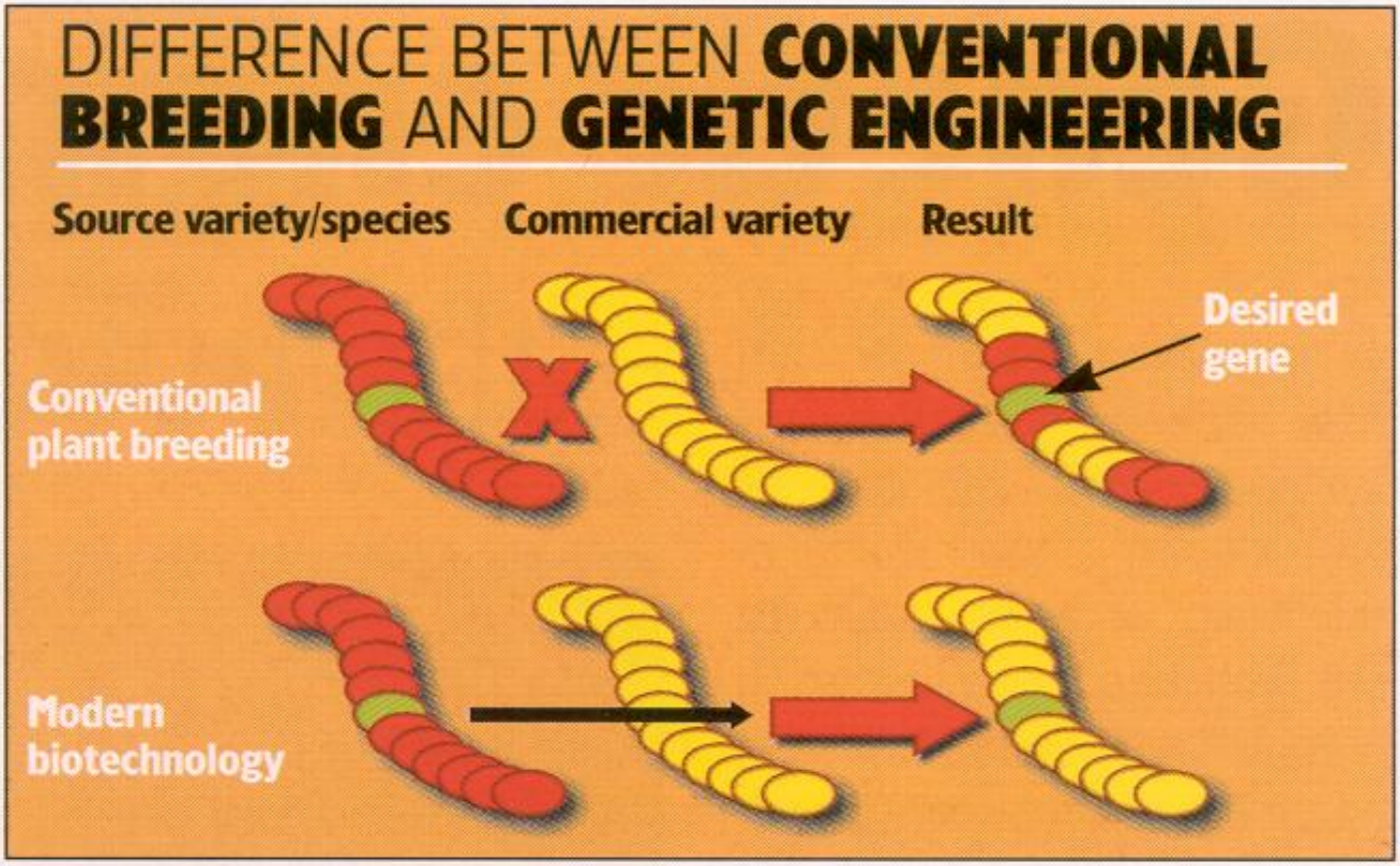
☞ http://www.sembiosys.com/Products/Technology.aspx

GM insulin saved diabetics and whales

- Insulin was at first obtained from swine
- ...but from whale spleen after WW II
  - Special whaling fleets were founded by pharmaceutical companies, e.g. Nordisk
- Animal insulin carries the risks of zoonoses and insulin allergy
- Human insulin from GM yeast was developed by Hoechst in Germany
- Hoechst insulin factory should have started production in 1984
- ...but anti-science movements in Germany succeeded in retarding its permission for 14 years
  - ...by all kinds of administrative trickery
- ...rendering it ”The most expensive biotechnology museum in the world”
- Meanwhile world insulin markets were safely lost to American and Danish drug companies

☞ http://www.nature.com/nbt/wilma/v16n5.894052109.html

Gene is transferred in a purified form in modern breeding



Precautionary Principle is misused in EU

- ”Where there are threats of serious or irreversible damages,
  lack of full scientific certainty shall
  not be used as a reason for postponing
  cost-effective measures
  to prevent environmental degradation”
  (1992 Rio Declaration on Environment and Development)
- The Principle aims at facilitating the *early use* of necessary new means under development for environmental protection
- Though in EU, it is inconceivably being applied to *preventing* the mobilization of more efficient and safe methods based on modern sciences
- ...which would be invaluable for finding solutions to the ”infernal” problems we shall meet with conserving key natural resources, taking account of the pace of major changes going on in the world

Nature herself tests silencing native genes

- Silencing any native gene in a crop species has been tested in millions of times during millennia by the Nature
  - without ecological problems
- Disarming a plant does not give selection advantage to it in Nature
  - but the weakling and its progeny disappear more rapidly from natural ecosystems
- ➔ Accordingly, the silenced gene
- neither conquers ecosystems
- nor causes permanent changes, but
  - at most transient impacts comparable to, or smaller than, the changes resulting from everyday choices of a crop to be cultivated or methods of its cultivation

Genetically modified weaklings?

- Long-term eclogical studies in UK showed that all GM plants under study (oilseed rape, potato, corn, sugar beet)
  - proved weaker in Nature, and
  - disappeared more rapidly than their conventionally bred counterparts

☞ Crawley et al. (2001). *Nature* 409: 682–683

Many breeding traits are ecologically benign

- Quality traits improving the usability of plant products for human needs
  - are generally not prone to help the plant invade or survive better in natural ecosystems...
  - ...the more than similar traits bred before by old means
  - but are as a rule discarded from ecosystems due to natural selection
- Whereas adaptive breeding traits deserve more careful scrutiny for environmental effects (Tammisola 2009)
  - because such traits might become more common (though not necessarily dominating) in natural plant populations

["The Classic"]
1989 Statement of Eucarpia* on Risk Assessment Regarding the Release of Transgenic Plants

1. It is the prime competence and responsibility of every research worker to evaluate potential risks of his research and to find ways to control these.
2. The plant is a relatively easy organism to control. Many crop plants are fully dependent on man for their existence.
3. In assessing risks the potential gene flow is crucial. This is determined in amount by the mating type and by the degree of taxonomic relationship. Much knowledge on these phenomena is already available in the literature.
4. Secondly, the effect of the gene is relevant and not the way it was introduced into the genome.
5. It should be kept in mind that well-defined genes, such as those transferred to plants by molecular techniques, can precisely be identified and controlled at the molecular level. However, their phenotypic expression must always be monitored most carefully.
6. There are genes which a priori are known to be harmful. These are not to be transferred into crop plants.
7. Presently, case studies with the release of transgenic plants are underway in several countries. All results should be fully published.
8. Eucarpia has established a working group of competent scientists on the subject of risk assessment for the release of transgenic plants.

*European Association for Plant Breeding Research

Is anything going on for the food security of the Third World?

- Yes... with private funding (...!)
- Gates and Rockefeller Foundations are financing large programs for food, agriculture, health and livelihoods in the developing countries
- See e.g. **Biocassava Plus** program, which aims at improving the safety, nutritional content, plant health and storage properties of cassava
  - An important but much neglected crop suited for being cultivated in poor soils everywhere in the tropics
  - ...though thus far poor in nutritional value and at times deadly poisonous due to cyanides occurring erratically
- http://biocassavaplus.org/