Written comments to EGE Roundtable: "The Ethical aspects of Modern Developments in Agriculture Technologies"

June 18, 2008 by Jussi Tammisola, Assoc. Prof. in Plant Breeding (Univ. of Helsinki, Finland)

1. Why so much speech about plant breeding?

During the about 11 000 years of agriculture, productivity in plant yield (per unit area of field) suitable for human uses has risen up to 10–30 times. Half of this advance is contributed to plant breeding, the other half to improvements in all other agricultural technologies combined together. Global growing conditions are rapidly deteriorating, and the yields of present varieties in the world's primary agricultural areas shall diminish by tens of percents in forthcoming decades.

Furthermore, the metamorphosis to a biosociety based on renewable biological resources, proclaimed to be fundamental for our sustainable future, imposes great additional demands for increased efficiency in agricultural production. Hence, in the harsh environmental conditions of the forthcoming decades, the responsibility of plant breeding for human livelihoods shall be greater than in the old days.

Access to well-functioning plant varieties is the basis for any successful crop production. Two examples:

a) world wheat production shall collapse in the next decade due to a devastating new race of stem-rust disease, unless nearly all wheat varieties are being rapidly bred anew for rust resistance, warns Nobelist Norman Borlaug www.iht.com/articles/2008/04/27/opinion/edborlaug.php.

b) Drought may cause total crop loss for a resource-poor subsistence farmer without access to irrigation. The cultivation of a drought-resistant variety would bring her better food security.

Ethical contents: Ethics of providing for human needs and yet saving resources for other species.

a) Ethics of science requires that scientists act as experts only in their area of scientific qualification. In other fields they can only act as laymen (i.e. ordinary members of civil society). My own expertise is in ecology, genetics (including plant breeding) and plant sciences (with secondary competence in biochemistry and mathematics). Consequently, I mainly address science and its applications in these areas. Other specialists must take the responsibility of evaluating their respective fields of expertise.

> In IAASTD, conclusions regarding modern plant breeding were not composed by qualified (world-class) plant scientists but some "predestined" writers from other fields, among them high-profile opponents of modern plant biotechnology since many years.

b) Common erroneous belief: Non-professional NGOs are commonly being heard as if experts in science. That is ethically wrong. The expertise of e.g. Greenpeace is not in biological science but its destruction (and consequently most of its claims have traditionally been untenable in biological terms).

Half of the present-day breeding experiments of public universities are destroyed annually by such organizations in Europe. The sabotage falls without distinction also on humanitarian breeding efforts aimed at helping resource-poor farmers in developing countries.

Greenpeace and others have not bred a single plant variety for the need of humankind (whereas professional plant biologists have developed tens of thousands of plant varieties, and saved hundreds of thousands of old ones in public gene banks, during the century of scientific plant breeding).

2. Updating most of the existing plant varieties

...to cope with the changing requirements of tomorrow's world is a huge, not to say desperate, task for plant breeding (which in its classic form is a slow exercise taking decades). The most advanced biological science, especially the just emerged genetic knowledge and know-how, should be devoted to that aim.

In general, classic plant breeding cannot provide the required improvements, due to inevitable genetic reasons. Namely, the genetic resources of our most important crop species simply do not contain sufficiently of genetic variation for the necessary new traits (especially ecological tolerance), and consequently their breeding with classical crosses and selection cannot succeed. Meanwhile plenty of genes of importance for ecological competence can be found in the gene pool of e.g. 10 000 wild grass species. Such genes can be purified and introduced in cultivated crops with molecular-biological breeding methods (genetic modification).

Ethical contents: Ethics of food security.
Any deterioration in plant production shall first hit the food security of resource-poor people, as shown by the preliminary "food crisis" of today. Responsibility: essentially better plant varieties can only be bred by competent, and devoted, plant biologists. Their work should be promoted also in Europe (and not torpedoed).

3. Examples of modern plant breeding with ethical connections

3.1. Edible cottonseed

Cotton is a poisonous plant species. It contains, in all plant parts, an deadly alkaloid (gossypol) which is aimed at protecting the plant against pests, such as insects and human beings.

Consequently, cotton seed cannot presently be eaten but 10 billion kg of high-quality seed protein is being wasted annually. Edible cottonseed could provide for the protein requirement of half billion malnourished people in the world.

Edible cottonseed *can never be bred* with classical breeding techniques – those are far too coarse for the task. Decades ago the formation of gossypol was stopped in experimental cotton lines by silencing the gene responsible for gossypol production in the plant with classical gene mutations. Formation of gossypol was ceased in all plant parts – with the result that insects gratefully ate all the cotton plants in the field. No human control sprayings whatsoever could save such plants which were lacking their indigenous, evolutionary pest protection.

Edible cottonseed have already been bred, using modern precision breeding based on genetic modification (genetic engineering). Namely, the production of the poison was only stopped in the plant part to be eaten by man, i.e. seeds. That was done by directing the gene-silencing to be functional only in the seeds and not in other plant parts. Hence, other plant parts retained their necessary insect resistance.
See http://agnewsarchive.tamu.edu/dailynews/stories/SOIL/Nov2006a.htm, and
Sunilkumar G, Campbell LA-M, Puckhaber L, Stipanovic RD, Rathore KS (2006). Engineering cottonseed for use in human nutrition by tissue-specific reduction of toxic gossypol. *PNAS* 103: 18054-18059. www.pnas.org/cgi/reprint/103/48/18054

Such detailed control of gene functioning can never be achieved with classical breeding methods, even in principle.

- Similar examples of more nutritious food plants bred with genetic engineering are protein rice and potato in India, protein sweet potato, A-vitamin rice in Switzerland, and oil plants containing the long-chained omega3-oils promoting nervous and cardiac health (soybean is awaited on market in 2011, see www.geenit.fi/EP101006.pdf).

<u>Ethical contents</u>:

1) <u>Ethics of food security</u> and quality. (Efficiency of food production, Nature conservation)

2) **<u>Effects of EU legislation</u>** on food security in the Third World. No developing country exporting cotton to EU can take that protein resource in use for feeding its own hungry people before the country has obtained permission for the product in EU according to our GM legislation (which shall take years and millions of EURs).

- If even a single edible seed of cotton would be found among the *cotton bales* arriving in EU, an import ban would be launched by us according to GMO directive 2001/18/EC. And the import of *cotton oil* would be prevented in any case, based on GM food and feed regulation (EC) No. 2003/29, unless the exporting country can prove having established (extra and expensive) systems of strict separation in its cotton production.

- That is the legal end result currently, though there would be *no ecological or health risk* whatsoever regarding edible cottonseed.

    a) Cotton is not growing wild in Europe but much care is required by a farmer to get it producing yield at all in Europe. Cotton demands a long and hot growing period, which can only be possible in the southernmost tips of Greece and Italy (and a pre-growth phase, under plastic cover, is still needed to prolong the growth period even there).

    b) Edible seeds is a trait with cannot in any circumstances have any adaptive benefit for the plant in nature. On the contrary, such cotton plants would have a definitive fitness disadvantage in nature (because its seeds would be consumed by interested animals unable to consume the poisonous traditional seeds). Hence, even if such plants would escape in the natural ecosystems, these would disappear from there even more rapidly than ordinary cotton varieties.

c) Gossypol-alkaloid is almost totally removed from cotton oil during processing. Though, better and more healthy oil would be obtained from edible cottonseed, because less processing is needed and even remains of gossypol can be avoided.

The core of the problem: GM legislation in EU is *not properly based on science* (biology). It is founded on breeding techniques though the scientific community in biosciences has already for two decades expressed its general consensus opinion that any risk considerations in plant breeding should concentrate not on technique but on the trait (characteristic) being bred in the plant (see e.g. 1989 Statement of EUCARPIA, presented as the last page of my 2006 biotechnology presentation in the European Parliament: http://www.geenit.fi/EP101006.pdf).

– Though, new breeding can in many instances prove essentially cleaner and better controlled than traditional breeding, as exemplified by the above breeding example. (For quantitative comparisons see the Appendix of the referred presentation: www.geenit.fi/EP101006App.pdf)

3.2. Moth-resistant Bt-cotton saved the cotton industry in India

The traditional cotton industry had drifted to great troubles in India, because native cotton production had during decades lost its once strong position and international competitiveness. Cotton yield levels had stagnated for a decade at a level (about 300 kg/hectare) much lower than its competing countries.

Cotton varieties genetically modified for resistance against the most important cotton pest, cotton moth, were accepted for cultivation in India in 2001. These have now almost doubled the yield levels of Indian cotton fields in six years. Thus, India has regained its position in world cotton markets (see www.geenit.fi/IntPuuv.pdf, http://www.cotcorp.gov.in/statistics.asp)

– Consequently, Pakistan has now started its own program of genetically modifying cotton in order to reproduce the scientific success of its competing neighbour country.

Ethical contents: Ethics of livelihoods, competition, development and national economy.

a) Sowing seed of Bt-cotton is not “expensive as gold” (as curiously stated by Ms. Raina). Seed of moth-resistant cotton costs 2 to 3 times that of old cotton varieties (except in some Indian states where governments have ordered lower GM seed prices to provide all subsistence farmers better access to the more reliable commercial seed instead of them obtaining lower-quality and less productive "brown-bag" seed from farmer-to-farmer markets). In large areas of India where cotton moth causes considerable yield losses the higher seed price is however amply *compensated* by better yields and considerable savings in insect control costs.

b) Lately, also homozygous (pure line) Bt-cotton seed have been bred, which can be easily reproduced by the farmers themselves (by taking sowing seeds from their own fields).

c) Resistant seed naturally provide *more secure production* (once also the illiterate subsistence farmers have been taught to know the new practices of integrated pest control which shall be followed when regular insecticide sprayings are being reduced).
- See e.g. www.geenit.fi/AgBioView271106.pdf .

3.3. Sugarcane with doubled content of sugar

For decades plant breeders have been trying to increase the sugar content of sugarcane with classical breeding techniques, without gaining much success. Using genetic modification, however, the sugar content of sugarcane was doubled in a single round of breeding.
Wu L, Birch RG (2007). Doubled sugar content in sugarcane plants modified to produce a sucrose isomer. Plant Biotechol. J. 5: 109-117. doi: 10.1111/j.1467-7652.2006.00224.x www.blackwell-synergy.com/doi/abs/10.1111/j.1467-7652.2006.00224.x?journalCode=pbi . The new varieties have already grown in field trials for a few years in Australia.

According to International Energy Agency, the by far most sustainable raw material currently available for bioethanol production is sugar obtained from tropically grown sugarcane plants: www.iea.org/journalists/arch_pop.asp?MED_ARCH_ID=417. About 7 to 8 times more energy is reached in the form of bioethanol, when compared with the amount of fossil energy needed in its production. The (eco)-efficiency of that production can still be greatly enhanced by growing GM sugarcane varieties with much higher sugar content.

Ethical contents: Ethics of eco-efficiency, Nature conservation, and production of bioenergy without endangering food security.

3.4. Sugarcane for production of cellulose ethanol

A RD coalition has been founded in Australia for genetically modifying sugarcane to be suited for the production of ethanol from the cellulose residues which remain after sugar has been pressed out of sugarcane tissues. Sugarcane produces more than 200 tonnes of biomass per hectare, and its pressing residues are by far the greatest source of biomass available for energy uses in Australia.

Harrison M (2008). New Ways with Plants. Cellulosic ethanol, huge potential but challenging. Centre for Tropical Crops and Biocommodities. Queensland Univ. of Technol. www.nt.gov.au/business/documents/general/Bio_Industry_Forum_Dr_Mark_Harrison.pdf. See also www.syngenta.com/en/media/pdf/mediareleases/en/Syngenta_starts_research_partnership_in_Australia_.pdf.

In general, cellulose ethanol is not yet a realistic option for bioenergy. Cellulose-splitting enzymes (cellulases) are still far too expensive in practice, and strong and expensive pre-treatments of wood are required to provide the enzymes access to cellulose molecules in plant cell walls. Consequently, current cellulose ethanol systems are still far from being economically sustainable.

However, sugarcane has recently been modified genetically to produce the required cellulases by itself, i.e. free of charge. The production of cellulases is being launched in sugarcane cells 2–3 days before harvest, based on a tightly regulated triggering element (inducible promoter). Enzymes produced inside the cell are able of accessing and splitting cell wall cellulose much more efficiently than enzymes applied from outside to the tissues. Thus, after pressing the sugar out of the canes, the residual biomass consisting mostly of cellulose can be split down to sugars which are then fermented into cellulose ethanol.

Such a system of production from the cellulose fraction of GM sugarcane may well prove the first sustainable system of "second-generation" bioethanol production.

Ethical contents: Ethics of eco-efficiency, Nature conservation, and production of bioenergy in a large scale without harming food security.

3.5. Third-generation biofuels: producing hydrogen by splitting water with GM microalgae

In a recent science congress on cyanobacteria, several ways of producing biofuels with the help of microalgae were considered.
ESF-EMBO Symposium: Molecular Bioenergetics of Cyanobacteria: Towards Systems Biology Level of Understanding. Sant Feliu de Guixols, Spain, 29.3 - 3.4 2008. www.esf.org/activities/esf-conferences/details/confdetail253.html .

The captured solar energy could be utilized vastly more efficiently by generating hydrogen gas than by wasting the bulk of the energy as recurrent losses in the numerous steps of building complicated organic molecules. That is, only the first stage of photosynthetic reactions (i.e. splitting of water with solar energy) is necessary, and advisable, for biofuel production in the long term.

Microalgae can already produce hydrogen to a certain amount, but their metabolism can be optimized with genetic modification towards our needs of energy production. Thus, hydrogen produced by microalgae may constitute a practical and ample source of renewable energy already within a couple of forthcoming decades.

Ethical contents: Ethics of livelihoods, sustainable use of natural resources, and Nature conservation.

3.6. Frost tolerance into crop plants from Antarctic grass species

Frost takes 15 percent of world plant production. A gene for frost tolerance was found and purified from a very frost-tolerant Antarctic grass species (*Deschampsia antarctica*). The protein coded by the gene prevents the formation of ice crystals in plant cells. Hence, the cells containing that protective protein are not damaged but retain their viability also if exposed to below-zero weather conditions.

Even if wheat is a hybrid between altogether three different grass species it could not get the efficient gene form needed for frost-tolerance from its ancestors. The tolerance gene has recently been transferred to wheat from the above mentioned grass species, and the genetically modified wheat plants have proven highly frost-resistant in field trials.
http://cropwatch.unl.edu/archives/2006/crop8/cropantifreeze.htm

– Other examples of plant breeding (genetic modification) for *enhanced ecological tolerance*: salt-tolerant rice, soybean and tomato in China (gene purified from a seaside salt herb, *Suaeda salsa*), salt-tolerant rice in India (gene purified from a delta brackish-water mangrove tree), and drought-tolerant wheat in Egypt (gene was purified from barley). Much research is going on to develop other crop plants with tolerance to drought, flooding, heat, cold, salt and acidity, as well as resistance to insect pests, nematodes etc, and devastating plant diseases caused by viruses, fungi and bacteria, and more efficient utilization of plant nutrients in the soil (see e.g. www.geenit.fi/EP101006.pdf).

– One special example of the salvation of popular plant varieties in a changing environment could be the potential restoration of commercial banana varieties by transferring a couple of disease-resistance genes to them from wild banana species. Forty years of unsuccessful efforts in classical banana breeding show that such salvation could only be achieved with genetic modification. A popular banana variety (Gros Michel) was destroyed 50 years ago by the previous races of banana diseases, and their novel races are now threatening Cavendish bananas with a similar fate.

– One should also notice that many contemporary GM plant varieties are especially suited for cultivation without tilling. Consequently, GM soybean and corn varieties have increased the area of no-till cultivation manifold during a decade in America (especially USA and Argentina) www.geenit.fi/GmSoijaArg.pdf . That prevents environmental problems, because it is known that no-till production diminishes erosion on average 488-fold. Montgomery DR (2007). Soil erosion and agricultural sustainability. *PNAS* 104: 13268-13272. www.pnas.org/cgi/reprint/104/33/13268.

Ethical contents: Ethics of food and energy security, and Nature conservation.

4. Genetic modification is quick and cheap as such

Contrary to common claims, producing improvements in plants with genetic modification is less costly than ordinary plant breeding.

a) The price of molecular biological methods has greatly decreased during the last decade, when these methods have become in a large-scale routine use ubiquitously in biological research and commercial applications.

b) The *time* required for breeding a new trait in a crop plant is much shorter (often halved) when using genetic modification. Consequently, expert and process time is saved, with concomitant savings in general operation costs of breeding. (And, of course, the hopes of breeding our necessary new varieties can be fulfilled more securely and in due time, remembering the “anciently” slow developmental rates inherent in classical plant breeding: breeding an essentially better new variety may often take decades – e.g. the development of protein corn required 35 years of uncertain classical breeding work).

c) Breeding a new potato, fruit tree or strawberry variety demands crosses and selection of up to hundreds of thousands of progeny individuals over many plant generations. Whereas *only 50 to 200 plant lines* shall be generated and compared if a ready top variety is being improved further by adding a beneficial extra trait to it by using genetic modification. That means about *thousand times better efficiency* (and respectively lower workload, field space requirement and costs in their testing and selection) than in the classical breeding (based primarily on trial and error).

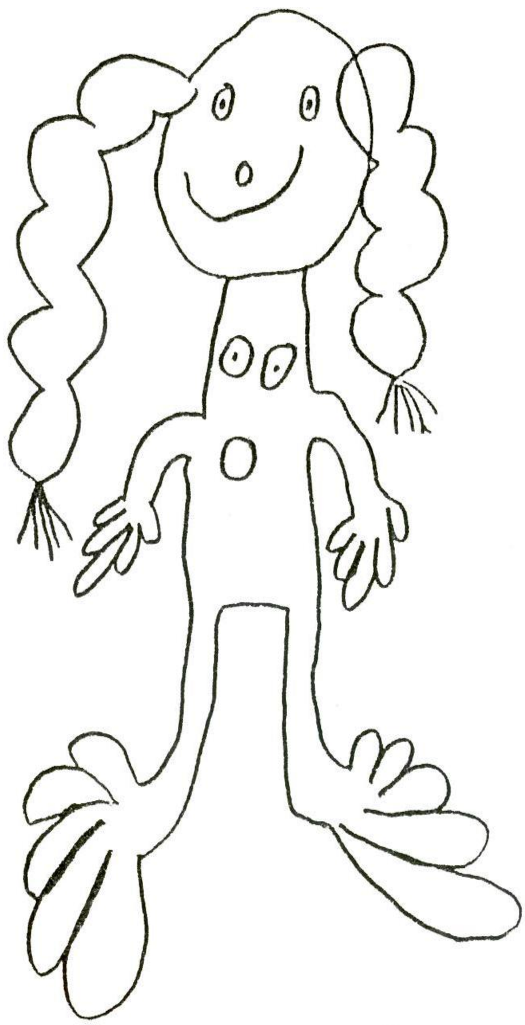
– Furthermore, in classical crosses the original unique (beneficial) genotype of the variety is being lost (due to crossing), and it cannot ever be restored with any amount of breeding work (even in theory). That is large-scale and recurrent wastage (á la king Sisyphos) of work done by previous human generations. Whereas genetic modification keeps the former achievements intact and only adds new improvements on these.

In summary: The biology of modern biotechnology is not any more expensive but essentially *cheaper* than classical plant breeding. Whereas genetic modification has been *made artificially expensive* by non-science-based legislation, which imposes heavy extra requirements for any applications bred by using the technology, irrespective of the breeding traits and their often unusually low levels of biological risks. (For analysis see www.geenit.fi/EP101006App.pdf pages 1–6, and for legal conclusions and modest proposals for regulatory changes see pages 6–7, respectively.)

- As a consequence, vastly more risky genetic operations with obsolete, non-controllable and dirty old techniques can be done and marketed freely, without any risk studies whatsoever, and thereby greatly favoured legally over more precise and clean modern know-how. (That is ethically wrong?)

Ethical contents: Ethics of food safety, food security, and access to technical development.

Postscript



Human being stands on the globe, but
her hands are free for all deeds.
(Outi Tammisola, 5 years)