Features

Integrated farming: why organic farmers should use transgenic crops

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The concept of organic farming is summarised and compared as an example to farming with biotechnology-derived crops. If done within an ecological concept, both methods can be seen as environmentally acceptable. Organic farming does not offer consistent arguments for the rejection of transgenic crops. Some arguments (from genomics to biodiversity) are discussed in order to demonstrate that the contrast between both farming systems is rated too high and that it is possible to overcome the divide. In this way the ground is prepared for a proposal on how to merge those otherwise incompatible agricultural management systems, a proposal that also will have to build on a new concept of sustainability. It will be dealt with in the second part of the article in the next issue of New Biotechnology.

Introductory remarks

It is important to distinguish properly between different kinds of organic farming. This text is not about small holders forced into 'organic farming' owing to lack of resources and in particular lack of synthetic fertiliser, or worse, encouraged through misguided foreign aid programmes that can only be maintained through external subsidies. Romantic views about traditional subsistence farming are not very convincing, since farmers also have a right to enjoy the virtues of a good life due to modern technology and proper mechanisation. Two accounts [1,2] provide ample insight into the negative factors of organic and integrated farming management systems *per se* and how by following strict rules, often not based on science, organic farming systems can lead to wrong decisions in management and production. Still, it cannot be denied that there are numerous scientific accounts that also demonstrate the positive sides of organic farming, as conceded even in otherwise critical reviews [3,4].

On the other side, biotech crops are often described in an unjustifiably negative way. I do not want to delve into the growing number of biased science texts with a clear negative agenda, often building on questionable experimental protocols [5], and for sure there is no room in this context for amateurish polemics collated by an ardent and long-time follower of the Maharishi cult [6]. Still, there has recently been an unfortunate tendency of producing high level UN related reports that, owing to an awkward production system, are seriously biased with a supposedly 'democratic' participation of hundreds of authors with no real independent peer review. This contrasts with the case of the UN global warming reports, which gives solid facts on global warming but remains highly controversial when proposing remedies [7–9].

This is why the IAASTD report 'International Assessment of Agricultural Knowledge, Science and Technology for Development' http://www.agassessment.org/ does not meet proper scientific standards and therefore comes to questionable negative conclusions about biotechnology in agriculture, [10–13]. Here just one of the IAASTD's unfounded conclusions, ignoring a plethora of science-based biosafety literature:

> ***Change is rapid, the domains involved are numerous, and there is a significant lack of transparent communication among actors. Hence assessment of modern biotechnology is lagging behind development; information can be anecdotal and contradictory, and uncertainty on benefits and harms is unavoidable.***

The approach I have employed here is strictly based on scientific views as published in peer reviewed journals and tries to give a balanced judgement, addressing the benefits of various agricultural management systems. It is also based on a more extensive contribution given in the 'IP Handbook of Intellectual Property Management in Health and Agricultural Innovation' by the author [14] and is based on extensive literature research. In order to make some viewpoints clear, a contrast is built between organic and biotech-supported farming, knowing very well that the intermediate

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zone would offer lots of positive thought and synergies. Indeed, the conclusion from this text could well be something like a new concept of integrated farming, taking into account the best from even the most diverse and seemingly incompatible farming systems. This synthesis will be the focus of the second part of this article in the following volume of *New Biotechnology*.

The concept of organic farming

Organic agriculture is developing rapidly, and statistical information is now available from 138 countries around the world. Its share of agricultural land and farms continues to grow in many countries. According to the latest survey on organic farming worldwide [15], almost 30.4 million hectares are managed organically by more than 700 000 farms (2006), which constitutes 0.65% of the agricultural land of the countries covered by the survey. It should not be overlooked that, with recently increasing food prices also in the developed world, organic farming could meet some economic limits [16,17].

Organic farming started as a heterogeneous agricultural management method owing to its multiple origins. Certification of organic farming practices with follow-up inspection has been introduced in various decades and many different places. Organic farming and a multitude of various similar labels are now growing rapidly out of the corner of backward thinking luddites (although admittedly they are still there), becoming a veritable industry. Regulation has been imposed more or less strictly on all organic farms of regions like California [18,19] and the European Union [20–22]. The International Federation of Organic Agriculture Movements (IFOAM) is now uniting the organic movements of the world with 750 members in 108 states, supported also by the United Nations FAO, www.ifoam.org. The website offers a lot of information, including some basic views on organic farming, such as the following four principles:

- *Principle of health*
  Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible.
- *Principle of ecology*
  Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.
- *Principle of fairness*
  Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities.
- *Principle of care*
  Organic Agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

The specific agricultural rules are still being debated, in order to find the desired mix between regulatory strictness; to allow for a maximum diversity of the rules according to region and crop. Some important documents, like the draft principles, intentionally exceed the basic principles of organic farming [23–26], in order to stimulate discussion and show targets and tendencies proposed. It can be said without hesitation that the above general rules can (or should) also be applied to most agricultural management systems of today.

Since 2005 [27] there has been in existence an official definition document on organic agriculture (the process is still going on and is transparently elaborated at several positions of the IFOAM and other websites). The following is a recent text example included into the document, without approving it definitely:

> ***Organic agriculture, as defined by IFOAM, includes all agricultural systems that promote environmentally, socially and economically sound production of food and fibers. Recycling nutrients and strengthening natural processes helps to maintain soil fertility and ensure successful production. By respecting the natural capacity of plants, animals and the landscape, it aims to optimize quality in all aspects of agriculture and the environment. Organic Agriculture dramatically reduces external inputs by refraining from the use of synthetic fertilizers and pesticides, Genetically Modified Organisms and pharmaceuticals. Pests and diseases are controlled with naturally occurring means and substances according to both traditional as well as modern scientific knowledge, increasing both agricultural yields and disease resistance. Organic agriculture adheres to globally accepted principles, which are implemented within local socio-economic, climatic and cultural settings. As a logical consequence, IFOAM stresses and supports the development of self-supporting systems on local and regional levels.***

This is a remarkable statement stressing exclusively the rural situation—but what about the rapidly growing urban and semi-urban areas? Also the statement 'increasing both agricultural yields and resistance' seems, in the light of most of the scientific data, somehow too optimistic.

It is unacceptable to base on manipulated statistics some euphemistic statements [28] such as:

> ***organic methods could produce enough food on a global per capita basis to sustain the current human population, and potentially an even larger population, without increasing the agricultural land base.***

This paper has been convincingly contradicted [29], criticising its statistical basis.

Ecological aspects of organic farming

Altieri and Nicholls [30] see also the impressive volume of Scherr et. al. [31] summarise their views of agroecology (see also in http://www.cnr.berkeley.edu/~agroeco3/principles_and_strategies.html) as follows:

- Enhance recycling of biomass and optimising nutrient availability and balancing nutrient flow.
- Securing favorable soil conditions for plant growth, particularly by managing organic matter and enhancing soil biotic activity.
- Minimising losses due to flows of solar radiation, air and water by way of microclimate management, water harvesting and soil management through increased soil cover.
- Species and genetic diversification of the agroecosystem in time and space.
- Enhance beneficial biological interactions and synergisms among agro biodiversity components thus resulting in the promotion of key ecological processes and services.

Altieri and colleagues do not exclude explicitly transgenic plants but criticise heavily and unjustifiably multinational seed companies, this for the following two reasons:

- Surprisingly, in developing countries there are only minimal conflicts between multinational seed companies and subsistence farming, if one follows statistics published by Cohen [32] and the FAO [33]. The great majority of projects involving modern seed varieties in the developing world are controlled and developed by public research and local biotech companies.
- There is a growing tendency that modern seed varieties developed by multinational breeding companies are used in important projects for the introduction of transgenic varieties in developing countries, but it is already routine that, confirmed by contracts, the useful

germplasm is donated free of royalties: good examples are given by the biofortification programmes for the Golden Rice [34], the Harvest Plus programme [35] and the Super-Sorghum Africa Harvest programme http://www.ahbfi.org/.

Elaborate factorial networks have been established on the principles of organic farming related to soil, an instructive summary scheme of the complex interrelationships in an agrosystem being given by Watson [36] Fig. 1, and there is no reason why a system like this cannot be adopted by conventional farming including transgenic crops.

Much has been written on the *biodiversity aspects* of organic farming. First we should ask about *what* biodiversity we want to enhance and maintain in our agricultural systems. It is a romantic misunderstanding that within the crop fields we should tolerate weeds and even call them euphemistically 'Beikräuter' and not 'Unkräuter' as Germans sometimes define them. Weeds mixed within yield often spoil the harvest considerably [37]. Misconceptions like these are often suggested by ecologists who have only little knowledge about agriculture and who have always worked in natural or nature-like ecosystems [38]. Rather we should seek the benefits of a more balanced agroenvironment with a higher biodiversity *outside* the production fields [23,39–44]. The misunderstandings about ecological agriculture go even deeper than just mentioned above for other reasons. It is a widespread misconception that ancestral farmers worked with crop fields with a high biodiversity, tolerating *nolens volens* a lot of weeds. As Wood and Lenne [45] have shown in 'Nature's Fields', our main crops like rice, wheat, barley, sorghum, among others thrived in natural monocultures and this was the reason for choosing them. The same misconception is perpetuated in the British Farmscale Experiments, which aim at a high biodiversity *per se* by a comparison of transgenic with non-transgenic crops, revealing that transgenic maize and beet show better biodiversity data, not so oilseed rape [46–48].

We should aim at a more realistic idea of biodiversity in agriculture, which works with a landscape concept; in addition we should not generalise prematurely, but will have to seriously differentiate according to crop and region [49].

A meta study [50] comes to the same conclusions, also verifying that the introduction of holistic-organic agricultural activities into landscapes with predominantly intensive and industrial agriculture has a much higher positive effect than in small-scale landscapes comprising many other biotopes as well as agricultural fields.

According to another extensive review [51] three broad management practices are highlighted that are largely intrinsic (but not exclusive) to organic farming and that are particularly beneficial for farmland wildlife:

- prohibition/reduced use of chemical pesticides and inorganic fertilisers
- sympathetic management of non-cropped habitats and
- preservation of mixed farming

However, the review also draws attention to the following issues:

- It remains unclear whether a 'holistic' whole-farm approach (i.e. organic) provides greater benefits to biodiversity than carefully targeted prescriptions applied to relatively small areas of cropped and/or non-cropped habitats within conventional agriculture (i.e. agri-environment schemes) such as proposed by Dollacker [43,52]
- Many comparative studies encounter methodological problems, limiting their ability to draw quantitative conclusions; therefore our knowledge on the impacts of organic farming is limited and there is a pressing need for longitudinal, system-level studies.

In a 21 year experiment monitoring organic farming methods in Switzerland, the results demonstrated clearly positive effects on biodiversity and soil fertility [53,54], but also revealed clearly lower yields for the organic methods [55,56].

A critique of arguments why organic farming rejects transgenesis and closely related breeding methods

While the concept of organic farming contains good elements, it is often also distorted by ideological bias, foremost the one against certain modern breeding methods. Biodynamic agriculture, based on the ideas of Steiner [57], is a mix of interesting spiritual thought and traditional down to earth knowledge, again needing to be carefully scrutinised to sort the wheat from the chaff. Here I concentrate on some of the mainstream arguments—why, for example, organic farmers nearly all reject modern plant breeding with transgenesis and many rules also reject mutational breeding and even distant hybridisation.

Van Bueren *et al.* [58] try to explain at the molecular level, why organic farming cannot accept genetic engineering, with a number of arguments. Following Verhoog *et al.* [59], they state that the *concept of naturalness* of organic agriculture not only leads to the avoidance of inorganic, chemical inputs and to the application of other agroecological principles, but also implies integrity of the crops as a whole. This concept also embraces their definition of the *intrinsic integrity* of plant genomes, taking into account a *biocentric perspective* (both of which terms lack a precise definition; for more comments see [14]).

From the definition provided above of the nature of plants and their qualities, a number of criteria, characteristics, and principles for organic plant breeding and propagation techniques are listed by the authors for exclusion: in addition to transgenesis, all breeding methods resulting in mutants through chemicals like colchicine or gamma radiation, all methods not allowing a full life cycle of the plant, and all methods manipulating the genome of the organisms, among others should be excluded.

Unfortunately, the authors completely miss the point that the structure and assembly of DNA has been changed heavily over the decades and centuries of traditional breeding. Modern wheat in all its variants and traits used today – also by organic farmers – is a product of processes, wherein the 'intrinsic value of the genomic naturalness' has been completely ignored and any imaginable change has been successfully integrated. In an extensive study, 58 major types of chromosomal rearrangements have been found [60] in wheat alone. As a matter of fact, most major crops have been subject to a multitude of genomic changes and chromosomal inversions, translocations, among others. The reality, whether we accept it for any kind of definition or not, is that most of the principles advocated on the molecular level [58,59,61–63] are clearly violated by almost all existing modern crop traits and cannot be redone, unless one could theoretically return to the mostly vanished ancestral traits with all their dramatic disadvantages. Genetic information is frequently disturbed by introduction of modified or mismatched bases into duplex DNA, and hence all organisms contain DNA repair systems to restore normal genetic information by removing such damaged bases or nucleotides and replacing them by correct ones [64,65].

So, in reality, the principle of the 'intrinsic values of the plant genome' is a fiction and not based on the science. Also the working papers of FIBL, authored by Karutz, do not really help here, since they avoid going into modern molecular biology [66,67]. The whole concept of violation of the intrinsic naturalness of the genome by inserting alien genes from other species across the natural species barrier is also falsified by the occurrence of a naturally transgenic grass discussed in [68].

It is questionable to criticise the overcoming of natural hybridisation barriers by genetic engineering, since this has been done by traditional breeding methods in former decades. There is the example of 'somatic hybridisation' (i.e. non-sexual fusion of two somatic cells). The advantage of this method is that, by the fusion of cells with different numbers of chromosomes (for instance different species of Solanum), fertile products of the crossing can be obtained at once because diploid cells are being somatically fused. Polyploid plants are obtained containing all the chromosomes of both parents, instead of the usual half set of chromosomes from each after meiosis. For this, cells are required whose cell walls have been enzymatically removed and are only enclosed by a membrane (protoplasts). With the loss of their cell walls, protoplasts have also lose their typical shape and are spherical like egg cells. This mixture of cells to be fused is then exposed to electric pulses. In order to obtain from the cell mixture the 'right' product of the fusion (since fusion of two cells from similar plants can also occur), one different selectable character in each of the original plants is necessary, parallel to the methods used in transgenesis. Only cells that survive this double selection are genuine products of fusion. Protoplast fusion has been investigated and applied to potatoes and citrus fruits [69–71]. In the EU, regulations cover the deliberate release of genetically modified organisms into the environment, but somatic hybrids are not considered as GMOs and do not require authorisation. The most recent draft of the EU organic regulations in which the introduction of GMOs into organic cultivation is forbidden, follows the above definition.

Moreover, the concept of violated intrinsic naturalness of the genomes by transgenity is falsified by the publications of Arber, (Nobel Laureate 1978), where he compared designed genetic alterations (including genetic engineering) with the spontaneous genetic variation known to form the substrate for biological evolution [72]:

Interestingly, naturally occurring molecular evolution, i.e. the spontaneous generation of genetic variants has been seen to follow exactly the same three strategies as those used in genetic engineering. These three strategies are:

(a) small local changes in the nucleotide sequences,
(b) internal reshuffling of genomic DNA segments, and
(c) acquisition of usually rather small segments of DNA from another type of organism by horizontal gene transfer.

See also Arber [73–75,76] in writings that confirm this important comparison on the genomic level of evolutionary and modern plant breeding processes. But there are of course, despite all the similarities, some major differences: natural mutation acts in a natural time scale, that is under most circumstances the mutants will need hundreds if not hundred of thousands of years to overcome selective processes until they really succeed and take over against their natural competitors. This is different with the transgenic crop products: they run through an R&D phase, the transgenesis is done in a targeted way, and the regulatory process takes about 10 to 20 years until the crops are deregulated. But somewhere along this process they will be propagated to the millions in the field, covering in a evolutionary extremely short time span millions of hectares.

This basic insight of a molecular biologist (more details in [14]) has been confirmed by analysis of modern breeding processes and their real products in crops, as an example here a comparison on the genomic level between transgenic and non-transgenic wheat traits [77]: conventional plant breeding involves the selection of novel combinations of many thousands of genes, transgenesis allows the production of lines that differ from the parental lines in the expression of only single or small numbers of genes. Consequently it should in principle be easier to predict the effects of transgenes than to unravel the multiple differences that exist between new, conventionally produced cultivars and their parents.

The above statements are confirmed by other genomic studies [78,79]—they could be extended to other methods of transformation, such as direct insertion of DNA fragments [80] and, with some questions about long-term stability, also to the agrobacterium mediated transformations [81]. But what is really interesting in the present context is that it has been demonstrated [82] that, overall, genome disturbances in traditional breeding in comparable cases are measured and found to be greater than in transformation. It is suggested that the presence of the transgenes does not significantly alter gene expression and that, at this level of investigation, transgenic plants could be considered substantially equivalent to the untransformed parental lines on the genomic level.

In a most recent publication about the same issue, [83] the similar conclusion is drawn:

We found that the improvement of a plant variety through the acquisition of a new desired trait, using either mutagenesis or transgenesis, may cause stress and thus lead to an altered expression of untargeted genes. In all of the cases studied, the observed alteration was more extensive in mutagenized than in transgenic plants. We propose that the safety assessment of improved plant varieties should be carried out on a case-by-case basis and not simply restricted to foods obtained through genetic engineering.

On another line of argument, there are papers published claiming that transgenesis or the insertion of promoters in transgenic plants could be the reason for DNA scrambling mutational disturbances [84], but the publications lack a fundamental demand for such conclusions, namely a comparison with non-transgenic crops. The same syndrome of deficient comparison applies to another study [85], claiming that the 35S promoter frequently used to enhance transgene expression demonstrates some activity in cultures of human cells. The authors just 'forget' to tell the readers that the very same promoter is part of daily diets including vegetables from *Brassicaceae* worldwide (whether transgenic or non-transgenic).

The consequences of the above are that organic farming, using the argument of artificial DNA breeding disturbance, should opt for the transgenic crops in specific cases. Another consequence is that transgenic crops of the first generation should never have been subjected to regulation purely based on the process of transgenesis; rather it would have been wiser to have a close look at the products in each case, as John Maddox already proposed in 1992 in an editorial in Nature [86]. This is also roughly the view of Canadian regulators [87,88]. In the case of the Golden Rice this has serious ethical consequences, because each year lost to unreasonable and unscientific regulation causes hundreds of thousands of deaths due to severe vitamin A deficiency, especially among the children of developing countries of S.E. Asia. In Europe this kind of unscientific regulatory basis hinders the development of transgenic crop breeding for the benefit of a more ecological production. In particular, it hampers public research considerably (see www.pubresreg.org). And on top of this the organic farming industry does not shy away from false and often hypocritical propaganda against genetically engineered crops for the sake of marketing their own products.

The concept of the green and evergreen revolution in agriculture as opposed to organic farming

Two names are linked to the Green Revolution with all its incomparable success: Norman Borlaug (Peace Nobel Prize 1970) [89–91] and Monkombu Sambasivan Swaminathan, World Food Price Laureate 1987 [92,93].

Assessments [94,95] of the Green Revolution came up with the following summary: Over the period 1960–2000, international agricultural research centres, in collaboration with national research programmes, contributed to the development of 'modern varieties' for many crops. These varieties have contributed to large increases in crop production. Productivity gains, however, have been uneven across crops and regions. Consumers generally benefited from declines in food prices. Farmers benefited only where cost reductions exceeded price reductions.

Very early, Swaminathan [96] warned of unwelcome developments related to the Green Revolution:

> ***The initiation of exploitive agriculture without a proper understanding of the various consequences of every one of the changes introduced into traditional agriculture, and without first building up a proper scientific and training base to sustain it, may only lead us, in the long run, into an era of agricultural disaster rather than one of agricultural prosperity.***

After the unique success of the Green Revolution, detrimental effects (upsurge of pest insects, growing insect resistance against widely used pesticides and negative effects on the soil fertility and a rising number of herbicide resistant weeds), Swaminathan called for an *Evergreen Revolution* as early as 1968 and in 1990 see in [93,97]: higher productivity in perpetuity needs a new emphasis on better infrastructure, crop rotation, sustainable management of natural resources and progressive enhancement of soil fertility and overall biodiversity.

Biotechnology has proven to be a helpful contribution to the evergreen revolution, since it helps to enhance some ecological factors and some review papers provide lots of facts about this statement [98–103]. Biotechnology has reduced pesticide use, having a positive influence on non-target insect populations. Three important meta-analyses are solid proof that non-target insects benefit from Bt crops [104–106]. GM crops also helped to introduce no-tillage management beneficial to soil fertility: numerous scientific studies give proof of those benefits for soil fertility [107–111].

An emerging variant of industrial farming is developing rapidly in the United States: called Precision Farming, it is a management system based mainly on satellite monitoring. It helps saving energy and time and can lead to a more ecological farming with higher yields [112–117]. Methods of precision farming, applied in an acceptable manner, do not directly contradict the main rules of organic and integrated farming and should seriously be considered as helpful auxiliary methods.

Overall, modern breeding, together with the strategies of the Evergreen Crop Revolution, has proved to be beneficial for the environment and there is a clear future convergence ahead of us with organic and integrated farming.

1. Closing remark

In Chapter 4 (Conclusions), in the next issue of *New Biotechnology*, a draft outline for a new, sustainable agriculture, incorporating the beneficial practices of organic, integrated and biotech farming, will be presented. It will be open for debate in a separate blog.

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