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Editorial

I Have a Dream: Organic Movements Include Gene Manipulation to Improve Sustainable Farming

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Abstract: Several papers in a Special Issue of *Sustainability* have recently discussed various aspects to evaluate whether organic farming and gene manipulation are compatible. A special emphasis was given to new plant breeding techniques (NPBTs). These new approaches allow the most predictable genetic alterations of crop plants in ways that the genetically modified plant is identical to a plant generated by conventional breeding. The articles of the Special Issue present the arguments pro and contra the inclusion of the plants generated by NPBTs in organic farming. Organic movements have not yet made a final decision whether some of these techniques should be accepted or banned. In my view these novel genetically manipulated (GM) crops could be used in such a way as to respect the requirements for genetically manipulated organisms (GMOs) formulated by the International Federation of Organic Movements (IFOAM). Reviewing the potential benefits of disease-resistant potatoes and bananas, it seems possible that these crops support organic farming. To this end, I propose specific requirements that the organic movements should proactively formulate as their standards to accept specific GM crops.

Keywords: gene manipulation; organic farming; co-existence; NPBT (new plant breeding technique); IFOAM (International Federation of Organic Agriculture Movements); cisgenesis; genome editing; potatoes; bananas

1. Introduction

To address the problem of whether organic farming and gene manipulation may be compatible, I initiated a Special Issue in *Sustainability* by inviting experts of both fields to express their views on this topic [1–7]. I am most thankful to all contributors for joining this discussion, but also to the reviewers for evaluating these manuscripts. As an Academic Editor I tried my best to have the broadest spectrum of opinions, realizing that we will not reach a consensus. However, I strongly believe that it is most essential to have this discourse and based on the various opinions made, I try in this synopsis to distill a potential integration between these quite different worlds.

2. New Plant Breeding Techniques and Organic Farming

Lombardo and Zelasco [1] consider the new plant breeding techniques (NPBTs), also referred to as NBTs (new breeding techniques), to be most promising for organic farming. They acknowledge that the standards of organic farming exclude, in principle, gene manipulation, but argue that several new approaches could be considered as non-genetically manipulated (GM), as they can be obtained by conventional breeding. This interpretation is supported by the International Federation of Organic Agriculture Movements (IFOAM), the international umbrella organization of the organic world. In their norms for organic production and processing [8], IFOAM gives the following definition: "Genetic Engineering is a set of techniques from molecular biology (such as recombinant DNA) by which the genetic material of plants, animals, microorganisms, cells and other biological units are altered in ways or with results that could not be obtained by methods of natural mating and reproduction or natural recombination”. Therefore, approaches of NBPTs that manipulate the genome in such a way that they cannot be distinguished from natural processes would not be classified as genetic engineering and the corresponding plant would be a non-genetically modified organism (non-GMO). This IFOAM definition is confirmed in a draft position paper entitled “Position on Genetic Engineering and Genetically Modified Organisms” [9] and awaits its final version in 2017. Thus, the view of Lombardo and Zelasco is not in contradiction to the IFOAM criteria. Specifically, the authors consider the introduction of entire genes from sexually compatible species, referred to as cisgenesis, as a process comparable to natural events, especially when the cisgene without any other DNA sequences is inserted at a predetermined position of the genome by using site-directed genome editing. By this site-directed integration of the cisgene, the potential destruction of an endogenous gene can be avoided. Thus, in this scenario, genetic engineering is even more predictable as the conventional approach, as in conventional breeding the introgression of a specific trait involves two crossing-over events at unknown positions. Furthermore, conventional breeding is time-consuming, as the selection process involves several generations. More importantly, even after several rounds of backcrossing, it will always involve the transfer of closely linked genes (linkage drag) whose identity and characteristics are unknown. Using similar arguments, the authors favor genome editing techniques that result in position-specific defined genetic alterations that cannot be distinguished from conventional mutagenesis. Again, this site-specific mutagenesis by genome editing is predictable without disrupting the background genotype. Thus, it competes favorably with natural or induced mutagenesis that is random and requires time-consuming selection to isolate the desired trait. They further argue that spraying of antisense single-stranded DNA or double-stranded RNA is also compatible and strictly adherent with organic farming standards, as it inhibits messenger RNA translation and does not alter the genome itself. However, it is questionable whether spraying of nucleic acids can be handled as a cost-effective method in fields.

In contrast, Wickson, Binimelis and Herrero are rather skeptical about gene manipulation [2]. They differentiate between the classical genetic modifications that led to the GM crops used today and the NPBTs that have emerged within the last few years. Referring to organic farming, they stress that this type of agriculture integrates many different aspects and does not just exclude synthetic chemicals. To answer the question of whether NPBTs can be part of organic farming, the authors use the requirements listed in a draft position paper from the International Federation of Organic Agriculture Movements (IFOAM) which was initially formulated in 2002 and is currently been revised [9]. Using these criteria, Wickson et al. conclude that the organic movement should maintain its opposition to GM despite the emergence of NPBTs. This conclusion may come as a surprise, since the IFOAM position paper does not exclude GM per se [9]. Specifically, I question this conclusion and challenge the claimed incompatibility of GM crops with the four requirements as follows: The authors argue that, so far, GM has not been developed and used in a responsible way (first requirement), since the existing GM crops have violated the principles of health and ecology (e.g., through negative impacts on biodiversity and soil fertility). This argument is well taken from the stand point of organic farming, but using NPBTs does not necessarily produce plants requiring herbicides or any other trait that threatens health or ecology. Furthermore, according to the definition of genetic engineering by IFOAM (see above), plants made by NPBTs may even be non-GMOs provided they can also be obtained by methods of natural mating and reproduction or natural recombination. Concerning the second requirement that plants made by NPBTs provide no evidence of benefits, I would argue that this constitutes a premature argument, as it really depends on the trait in the modified plant. Crops in the pipeline such as cisgenic late blight–resistant potatoes or biofortified bananas (see below) have high potential, yet due to their novelty, a limited success record. In my view, the lack of a beneficial track record cannot disqualify a priori a genetically engineered crop, since an identical situation exists with any novel variety generated by organic breeding. The third point of the IFOAM criteria that is said to be violated by plants derived by NPBTs concerns ensuring the common good and reforming public policy and laws. This includes the right of farmers to save and trade seeds and the rejection of the organic movements of any patents to life forms or their components. This is an important issue, but as it stands, at the moment, this is not a prerequisite for GM crops in general (see potatoes and bananas below). Interestingly, the authors argue that if organisms created by NPBTs are exempt from regulation on the basis that the changes could have occurred through natural breeding as well, any claim to patent the organism could be challenged, as the novelty could be called into question if natural breeding could deliver the same results. That is a remarkable notion and may constitute a compromise in making some plants created by NPBTs acceptable for organic farming. In essence, such an interpretation would mean a product-based approach where the evaluation of the specific agricultural trait is important and not the technical process used. Of course, a product-based regulation would eliminate the dilemma that plants created by NPBTs cannot be distinguished from conventionally bred plants. The idea that only gene manipulations that cannot be detected should be allowed, if these manipulations include a genetic marker for detection, is misleading, as the existence of this marker would be challenged as the modified plant's risk. Along this line, Ricroch and coauthors have proposed policy-makers should abandon the idea of deciding what a genetic modification is by law, since the concept is consistently evolving with new scientific discoveries [10]. For me, the proposal that the naturalness of plants generated by NPBTs precludes patents indicates that organic farming and gene manipulation may not be so far apart. Such an interpretation would allow farmers to save seeds for subsequent use as well as research on plants produced by NPBTs, a request made by the organic agricultural sector.

Wickson and coauthors further argue that the general process of technologically manipulating the genetic code of organisms is criticizable per se [2]. This position is very important for Nuijten, Messmer and Lammerts van Bueren [3]. They argue that genetic engineering does not respect the integrity of living entities. Their ethical argument is founded on the belief that techniques that go beyond the whole plant level are not suitable with the values of organic agriculture and thus not allowed for use in organic breeding programs. They consider that the plant cell is the lowest level of self-organizing life, as a plant can regenerate from a single cell and therefore its manipulation is not forbidden according to the organic regulation. In contrast, they argue, techniques directly engineering at the DNA level are violating the integrity of life and, more specifically, the genotypic integrity. According to this interpretation, the authors refuse any breeding techniques from genome editing to transgenesis. Their evaluation criteria are based on a position paper by the European Consortium for Organic Plant Breeding (ECO-PB), a member of the International Federation of Organic Agriculture Movements (IFOAM). Whether this view really reflects the official position of IFOAM is still open, as the draft report of IFOAM on the "Position on Genetic Engineering and Genetically Modified Organisms" awaits its approval [9]. Obviously, the organic movements have not settled this basic question.

As Nuijten et al. [3] reject gene manipulation due to the destruction of DNA integrity, they prefer the development of alternative breeding concepts for the organic sector. They describe approaches for crop improvement in organic agriculture that may even include molecular genetics as an analytical tool, such as marker-assisted breeding. Similar to Wickson et al. [2], they strongly argue that the IFOAM criteria on the principle of health, ecology, fairness and care should be the guide for organic breeding. While I can fully accept this position, I cannot appreciate the full rejection of any interference with genetic engineering. It seems to me that the view that conventional breeding is something completely different ignores that in conventional breeding, genes are also changed and selected for by human interference, yet in a much more black box scenario.

In my view, both teams [2,3] ignore the high potential benefits of the NPBTs to improve sustainable organic farming. This is convincingly shown by the cisgenic potatoes and bananas described below.

3. Coexistence of GM Crops and Organic Farming

The fourth IFOAM requirement for GMOs that would, according to Wickson et al. [2], preclude genetic engineering in organic farming stresses the inability of coexistence between GM and non-GM crops. However, this concern is not valid for GM plants that contain genes present in natural variants or wild-types [1]. An admixture of a genetically engineered plant gene that is identical to a gene in sexually compatible wild plants is not detectable and thus cannot constitute a contamination. Of course, the coexistence of GM crops with conventional farming is a serious problem, as in many cases transgene flow has not been rigorously excluded. In fact, over the past years, unintentional transgene escape has been reported in oilseed rape, maize, cotton and creeping bentgrass [11]. For organic farming this is not only an environmental concern, but also a financial problem, as the presence of GMOs in organic products jeopardizes organic certification, resulting in loss of the premium price of organic products. A few illustrative examples of decertified organic products due to GMO contamination are listed in the paper of this Special Issue by Reeves and Phillipson [4]. The potential contamination of organic crops with GMOs constitutes, for Wickson et al. [2], an example of how GM crops infringe on the principles of fairness. However, the spread of GMO contamination into organic fields is not necessarily valid for plants generated by NPBTs. These new approaches allow, for instance, reverting domesticated crops in such a way that they regain traits that were lost during human domestication [12–14]. This so called rewilding of crops changes the gene to its original version found in the wild population or may even bring back a gene that was lost during domestication. Transfer of this genome-edited or regained gene into an organic plant is identical to gene transfer from the wild population and does not constitute a contamination that triggers decertification of the organic label, nor does its presence in an organic product lead to a financial drawback.

The contribution of Reeves and Phillipson [4] addresses the impact of mass releases of genetically modified insects on organic farmers. Mass releases of irradiated insects have been used to reduce the size of the pest population for more than 50 years. In many cases this sterile insect technique (SIT) has been very successful to suppress pests mediated by insects without necessarily dispersing chemical insecticides into the environment. This biological pest control is therefore also welcome by organic farmers. With techniques of genetic engineering, SIT programs could be modified by replacing radiation-sterilized insects with genetically modified insects carrying genes, lowering the production of viable offspring in a population (GM-SIT). The authors are most cautious to recommend GM-SIT, since area-wide application of genetically modified insects that is essential for successful population decline is rather impossible without affecting organic farmers. They present the hypothetical impact for an organic farm located near an approved experimental release of GM diamond moths to combat this most important pest of cruciferous crops. The scenario presented is quite realistic, as such a project was approved by USDA-APHIS (United States Department of Agriculture, Animal and Plant Health Inspection Service), but has not been executed so far. They postulate that the organic spinach produced by an organic farmer and exported worldwide as a 100% organic product is contaminated with a GM diamond moth. They show that even the presence of one GM diamondback moth in 10 kg of spinach may be sufficient for the organic farm to lose its certification and thus the price premium attached to the organic product. This outcome is highly likely, as no GMOs are allowed in organic products (zero tolerance), and in comparable cases decertification has occurred. More importantly, based on current law, the organic farmer has no chance to get a refund for his economic loss. The authors stress that it is eminent to plan any future uses of GM-SIT in such a way as to eliminate or at least ameliorate these potentially significant consequences for organic farmers as well as for organic export markets. According to the authors, there are only a few proposals where GM-SIT would work and conventional SIT would not. Therefore, one should prefer conventional SIT if both approaches are feasible to avoid the problem of contamination.

4. The Challenge by GM Potatoes

Two papers specifically address the problem of whether late blight–resistant potatoes made by cisgenesis are compatible with organic farming. Gheysen and Custers [5], as well as Pacifico and Paris [6], discuss the potential benefits of potatoes generated by NPBTs. Both groups review the problem of late blight disease caused by the oomycete *Phytophthora infestans* that infects potatoes and necessitates the application of copper fungicides even in organic farming systems, although copper is a toxic heavy metal whose accumulation in the soils reached dangerous levels in several places. Since traits conferring resistance to *P. infestans* infection are present in the potato gene pool, in principle resistance can be introduced by conventional plant breeding techniques. However, it took almost half a century to establish the resistant varieties Bionica and Toluca containing a single resistance gene [15]. Gheysen and Custers stress [5] that these breeding strategies involved the use of the chemical colchicine to double the number of chromosomes. The use of this drug violates the nonchemical principle of organic farming and according to some proponents of organic farming, its application should be forbidden [16].

Both teams review the alternative approaches that have evolved from the transgenesis via cisgenesis/intragenesis to genome editing. Using NPBTs it is possible to create cisgenic potatoes resistant to *P. infestans* which contain genes exclusively present in the potato genome. Using NPBTs it is essential to introduce several different resistance genes, as *P. infestans* has a highly flexible genome, causing rapid adaption to host resistance. The authors refer to the publically funded research project DuRPh (Durable Resistance in potato against Phytophthora), showing that stacking of multiple cisgenic resistance genes can reduce fungicide use by 80%. Notably, in the application of these cisgenic potatoes, spatial and temporal management where different cisgenic lines are used in a cultivation rotation scheme are recommended. This illustrates that one is aware that a well-designed cultivation of cisgenic *P. infestans* resistance potatoes is essential to maximize resistance durability. Thus, the producers of these late blight–resistant potatoes are fully aware that a holistic approach is essential, a setting typical for organic farming. More importantly, the DuRPh researchers at the University of Wageningen (Netherlands) that patented the isolated genes foresee exploitation through non-exclusive licenses to avoid a monopoly that would jeopardize a wider use by small and medium enterprises [17]. Gheysen and Custers [5] mention that the Bionica potato made by conventional breeding for organic production has less desirable characteristics such as lower palatability and inferior processing qualities. This reflects the inclusion of undesired traits by linkage drag in conventional crossings. In contrast, cisgenesis can be performed on a cultivar with desirable agronomic, eating and processing characteristics and will only add disease resistance [5].

In conclusion, it appears to me that the DuRPh project fulfills the requirements of the IFOAM standards presented by Wickson et al. [2] that are essential to consider a GM crop to be compatible with organic farming. It is not really important whether these cisgenic potatoes are called GM or non-GM crops. Gheysen and Custers [5] propose that the regulatory requirements for cisgenic late blight–resistant potatoes, if any, should be very limited. They go on to argue that a high regulatory burden will generate high costs and thus impede their commercialization. This is especially problematic, as an optimal application of cisgenic potatoes requires resistance management using several different varieties with various combinations of resistance genes. To achieve this goal, which mirrors an integrated approach most welcome in organic farming, under the current situation each individual transformation event has to go through the most costly regulatory process. This impedes any small- or mid-sized company from embarking on this application. The authors question why a cisgenic potato resistant to late blight should be treated differently compared to Bionica, a variety generated by conventional breeding for organic farming and containing the same resistance gene as the cisgenic cousin.

As reviewed by Pacifico and Paris [6], genome editing is also feasible to alter specific genes of the potato in such a way that the final product is identical to a natural mutant. Such genome-edited potatoes have properties such as lower levels of toxic acrylamide after frying. The authors stress that with the NPBTs, most precise modifications can be performed at a well-predefined genomic region. They argue that the use of these new techniques is the most reasonable solution for organic production, since changes have been made in the potato genome by classical mutagenesis since 1930, and they are compatible with the principles of organic farming. They also refer to the argument of Nobel Prize winner Werner Arber that transgenesis and molecular evolution follow exactly the same strategies, and therefore the conjectural risks of genetic engineering are similar to those of natural evolution and of classical breeding. Arber's view may be challenged, as gene exchange between species that are sexually not compatible (horizontal gene transfer) is a rare event in plants [18]. Furthermore, the integration of a bacterial gene such as the gene encoding the Bt-toxin to confer pest resistance is always done by embedding the bacterial gene into regulatory elements of eukaryotes to get expression of the transgene [19]. Such expression-targeted gene integration is most unlikely to occur by horizontal gene transfer. In contrast, using cisgenesis and genome editing in potatoes does not cross species barriers, as no foreign gene is introduced into the potato genome. The authors also stress that with the NPBTs, many other interesting traits present in the potato genome, but lost during domestication, could be re-introduced into cultivated species. Thus, in fact, the NPBTs have the potential to combat the loss of genetic diversity that is often deplored. This cannot only be achieved by the rewilding of elite crops, but also by using many different cultivated varieties, since the techniques are already well established and cost-effective. Pacifico and Paris [6] as well as Gheysen and Custers [5] discuss the problem of GMO regulation that is especially tight in Europe and the reluctance of the public to accept GM food. They argue that it is essential to educate consumers on the use of biotechnology to produce healthy food. Addressing the question of co-existence of organic, conventional and GM crops, Pacifico and Paris [6] point out that the vegetative mode of potato propagation essentially eliminates the problem of outcrossing and they conclude that no significant changes of practices are needed when GM potatoes are grown. For cisgenic or genome-edited potatoes, co-existence is no problem at all, as these genetically modified plants lack any foreign gene. The authors' argument [6] that social, ethical and political aspects should be left aside is, in my view, too extreme. Indeed, it may be wise to include such properties as required by IFOAM. Evaluating cisgenic late blight potatoes I cannot see any clear incompatibility with the IFOAM standards. As pointed out by Gheysen and Custers [5], Ulrich Niggli, the director of the Swiss-based research institute of organic agriculture FiBL (Forschungsinstitut für biologischen Landbau), has recently proposed deciding upon the specific application of GM crops from case to case instead of maintaining a complete ban. He argues that it would be annoying if conventional farmers cultivate cisgenic potatoes without any pesticide, whereas the organic farmer has to rely on copper spraying [20].

5. The Banana Case

Dale, Paul, Dugdale and Harding [7] review the potential of genetically modified bananas for organic farming. Bananas grown almost exclusively in the wet tropics and the sub-tropics are consumed worldwide as an in-country popular staple food or as a favorite fruit exported into most countries. They stress that bananas are difficult to genetically improve, as nearly all banana cultivars and landraces are triploids and thus have a high level of male and female infertility. This property is negligible for cultivation, as bananas are propagated vegetatively by suckers, but is a major obstacle to introgress new properties by breeding. This drawback can be overcome by genetic engineering. The author argues that improvement of the current banana cultivars is most important, since many diseases challenge successful banana cultivation. The most important threat is Fusarium wilt, also referred to as Panama disease, which essentially eliminated the cultivar Gros Michel in the last century. The new strain of Fusarium, TR4, now threatens other cultivars grown as important staple foods in many countries, but also Cavendish, the most popular export dessert banana. As the fungus Fusarium is soil-borne and can survive for decades, chemical control is most unrealistic. Therefore, the authors argue that genetic resistance to Fusarium wilt is the most appropriate control strategy and that genetic manipulation seems to be the only realistic solution, as conventional breeding is hardly possible. According to Dale et al. [7], the major drawback of conventional breeding is that due to the low fertility, it is essentially impossible to repeatedly backcross the initial hybrids to the original cultivars and that fertile cultivars may lack desirable traits. In addition, many of the major cultivars contain integrated copies of the banana streak virus (BSV) which upon hybridization can form infectious BSV and symptoms of that infection. Based on these handicaps, the authors favor genetic engineering to introduce resistance genes against fungal or viral diseases challenging banana cultivation. The authors go on to argue that nutritional improvement of bananas is another application of gene manipulation to advance the potential of bananas as a valuable staple food. The traits that are introduced include an enhanced level of pro-vitamin A or of iron. To be compatible with organic farming, it seems to me essential that any transgene flow is excluded by restricting these manipulations to cisgenesis or genome editing approaches that do not introduce any foreign DNA, unless banana cultivars are used that are proven to be completely infertile. The authors' lab has shown, in a recent proof of concept [21] using the Cavendish cultivar, that a substantial increase in pro-vitamin A can be obtained by the integration of banana gene sequences exclusively. The data show that the use of a banana promoter as well as the banana phytoene synthase 2a gene results in bananas expressing a 10-fold higher level of pro-vitamin A which is reflected in the golden flesh, hence the name golden banana. As these golden bananas contain the fusion of two independent segments of the banana genome, it is most unlikely that such a variant can be obtained by conventional breeding. To distinguish such insertions from a single fragment insertion (a cisgene), it is referred to as an intragenic modification. It seems open for discussion whether such an intragenic banana can still be accepted by organic farmers. If the leading principle relies on coexistence and any contamination of other banana cultivars can be excluded, intragenic bananas may be acceptable provided they are sterile. However, one could argue that this interpretation is on a slippery road, as similar arguments could be made for transgenic sterile bananas.

Concerning gene-manipulated bananas expressing an enhanced level of pro-vitamin A, it is noteworthy that major concerns raised against Golden Rice [22], the transgenic rice expressing enhanced pro-vitamin A [23,24], do not apply to golden bananas. First, as the phytoene synthase 2a gene is from the edible banana cultivar Asupina, any health reservation is not justified. Second, using infertile bananas excludes problems of transgene escape, in contrast to rice where outcrossing is a major problem [25].

Dale and coauthors [7] strongly believe that the line between conventionally bred and genetically modified bananas is becoming increasingly blurred. They predict that it is highly likely that by genome editing of regulatory elements of genes involved in pro-vitamin A production, biofortified bananas with higher pro-vitamin A can be generated. To this end, the genetic make-up of the Asupina cultivar expressing a high pro-vitamin A level may be the guiding principle. The authors further believe that smaller labs in the wet tropics and subtropics will develop the capacity to genetically but not conventionally modify bananas by improving their local favorites, if allowed to develop unimpeded. This scenario is quite likely as the techniques of genetic engineering are so advanced and well established that they do not need a large infrastructure. They argue that the ideals of organic farming movements can be followed using gene technologies by the conservation of traditional and heirloom cultivars and landraces, as well as by elimination of pesticide use and reduction of micronutrient deficiencies. In this context, it is most promising that suckers of the cisgenic cooking bananas rich in provitamin A, which have been developed in Uganda in cooperation with Dale's group, will be given free to "early adopter" farmers on the condition that they later provide double that amount to other farmers who in turn have to distribute double the amount they received, and so on [14]. This pyramid scheme conforms to the standard of free access expected by the organic movements.

6. The Dream

Several years ago, I proposed to develop a new category of GM plants, i.e., orgenic plants, genetically modified plants, that are compatible with the standards of organic farming [26]. Reviewing all the arguments made pro and contra gene manipulation as a technique compatible with organic farming in the Special Issue of *Sustainability*, I strongly believe that a integration is possible by respecting the various positions. It seems clear to me that it is essential to evaluate the properties of a genetically engineered crop and not the process used. The organic farming community should formulate, in a proactive manner, the requirements of genetically engineered crops to make them attractive for supporting sustainable agriculture. The IFOAM draft [9] may be considered as a starting point. However, in my view it is not advisable to call genetically engineered crops which could also be obtained by natural breeding as non-GMO. By the process used, they are GM crops. The organic movements should base their decisions on the product and specifically list GM crops that are acceptable according to norms of organic production. Based on the discussion raised in this Special Issue, I think that cisgenic potatoes resistant to late blight, bananas resistant to wilt disease, as well as golden bananas, are excellent candidates to be acceptable for organic farming. Of course, there are many other examples that should be evaluated.

Based on the IFOAM criteria, I propose the following requirements to be essential to make a GM crop acceptable for organic farming:

(1) The GM crop should not contain any DNA that is not present in sexually compatible species. Thus, only cisgenic or genome-edited plants are acceptable and the absence of any foreign DNA should be verified by genome sequencing.
(2) Any GM crop that contains DNA from a species that is not sexually compatible should be absolutely sterile to avoid transgene escape. The same rule applies to intragenic plants, as they contain gene arrangements that are most unlikely to occur naturally.
(3) The GM crop should allow cultivation under organic farming standards. Specifically, it should not require any synthetic chemicals such as herbicides or fertilizers.
(4) The GM crop should be freely available and any farmer should be allowed to propagate and further improve the GM plants.

In my view, with these four basic rules, organic farming can absorb gene manipulation to support the principles of organic farming including health, ecology, fairness and care. The organic movement should also support a loose regulatory regime, if any, for such genetically modified crops to allow broad development by small entities as well as to apply these new breeding techniques to a broad spectrum of valuable cultivars to maintain seed diversity.

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