Organic agriculture requires process rather than product evaluation of novel breeding techniques

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Abstract

In organic agriculture the use of genetically modified organisms (GMOs) is banned. Recently, two novel breeding techniques have been developed, i.e., cisgenesis and reverse breeding, both of which are based on gene technology but should raise less moral concerns from the public. Whether the products of these breeding processes are classified as GMOs depends on the interpretation of the relevant EU regulations. In cisgenic plants, the genes introduced through genetic modification are from a crossable donor plant so that the source of the genes is considered to be of the same nature. In reverse breeding, the recombinant genes, essential to the breeding process, are no longer present in the product resulting from the entire breeding process, and thus the product as such is not transgenic. Should varieties obtained through cisgenesis or reverse breeding be allowed in organic agriculture? The answer to this question depends on whether the product or the process of breeding is taken into account. Assessment based on the product implies a choice of an ethical approach that only considers the extrinsic consequences of human action by making a risk-benefit analysis. It neglects so-called intrinsic, ethical arguments related to the applied technology (the process) itself. The organic movement uses the intrinsic argument of 'unnaturalness' against genetic engineering. We therefore conclude that products of cisgenesis and reverse breeding should be subject to the current GMO-regulations in organic agriculture and should thus be banned from organic agriculture.

Additional keywords: cisgenesis, ethical notions, extrinsic values, integrity, intragenesis, intrinsic values, naturalness, reverse breeding

Introduction

Genetic modification is widely used in plant breeding and the acreage of genetically modified crops increases rapidly, especially in North and South America, China and India (Anon., 2006a). The definition of a genetically modified organism (GMO) according to the European Directive 2001/18/EC is as follows: "Genetically modified organism means an organism, with the exception of human beings, in which the genetic material has been altered in a way that does not occur naturally by mating and/or natural recombination" (Anon., 2001a). In Europe the use of genetically modified crops in conventional farming is still a matter of public debate, as the technique gives rise to moral concerns (Anon., 2006b) and worries about ecological risks (Firbank *et al.*, 2003). However, in organic farming the debate has already been settled. A ban on GMOs has been incorporated in the Basic Standards for Organic Production and Processing of the (worldwide) International Federation of Organic Agriculture Movements (IFOAM) since 1993 (Anon., 2005). Since 1999, also the EU Regulation for organic agriculture 2092/91/EC prohibits the use of GMOs and the products obtained through the use of GMOs in organic produce (Anon., 1991).

However, molecular scientists have recently tailored gene technology by developing techniques that increase the efficiency of modern plant breeding and simultaneously diminish moral concerns from the public (Nielsen, 2003; Lusk & Rozan, 2006; Myskja, 2006). There are also claims that these techniques warrant less strict oversight than 'conventional' transgenics, because the ecological risks of the products are allegedly absent or very minor (Schouten *et al.*, 2006a, b). Two novel breeding techniques are of special interest in this context: *cisgenesis* (Rommens, 2004) and *reverse breeding* (Van Dun *et al.*, 2005). See Box 1.

Clarity on the status of these techniques is important for policies within and outside the organic movement, especially with respect to issues such as labelling and coexistence (De Cock Buning *et al.*, 2006). Cisgenesis is an interesting case as it is currently applied to obtain resistance in potato against late blight, a major disease, especially in organic farming systems. Reverse breeding provides breeders with a powerful tool for speeding up the development of F1 hybrids and could be excluded from the GMO-regulation, as the product does not contain recombinant DNA.

In terms of the *process* needed to create the desired *product*, both cisgenesis and reverse breeding are very similar to transgenesis: all three techniques require a step with gene technology. However, in terms of the *product* the three techniques are different. In the case of reverse breeding, the product does no longer contain the gene construct inserted during the breeding process. In the case of cisgenesis, there are new genes inserted, but they were already present in the gene pool of the species because they originate from a crossable parent or from the same species. In the case of transgenesis, a gene has been inserted that was not yet present in the gene pool of the species and neither could be obtained by mating or natural recombination.

It is necessary to rethink whether and why the ban on GMOs in organic agriculture should also apply to the products from these two novel techniques or why not. For this rethinking process it is essential to clarify or reassess the position of organic agriculture on whether only the product of the breeding process or also the process of

Box 1. General description of cisgenesis and reverse breeding

Cisgenesis, also called intragenesis or ingenesis, involves – like in the case of transgenesis – gene transfer technology. *Cisgenic plants* are defined as plants that have been genetically modified with one or more genes (including introns and flanking regions such as native promoter and terminator regions in a sense orientation) isolated from a crossable donor plant, i.e., of the *same* or a *closely related* species or isolated from within the existing genome (Rommens, 2004; Schouten *et al.*, 2006a, b). This distinguishes them from *transgenic plants* that can be described as plants that contain *recombined* DNA from *unrelated* organisms. Technically, cisgenesis and transgenesis are two similar approaches to create genetic variability through gene technology; only the source of the genes is different. To obtain an 'all native' gene transfer system, companies have developed plant-derived selection markers and plant-derived T-DNA borders (Rommens, 2004). Genetically modified plants obtained in this way will not have any novel DNA sequences, although the introduced piece of DNA can always be traced because of its unique composition.

Reverse breeding (Van Dun *et al.*, 2005) is essentially a process in which the order of events leading to the production of a hybrid plant variety is reversed. It allows the breeder to reconstruct parents of a novel proprietary breeding line without having to go through the tedious back-crossing and selection process. This process is time and labour consuming because sexual reproduction is accompanied by recombination of chromosomes. Parents that would reconstitute the novel breeding line would have to be identified by screening large populations for the desired trait and genotype. Reverse breeding aims to rule out meiotic recombination and allows gametes to develop that contain *whole* chromosome sets of the parent. Because *in vitro* culture of pollen or egg cells allows the regeneration of plants, doubled haploid plants can be obtained. Any combination of parental chromosomes can thus be recovered in homozygous lines. Through DNA marker analysis these doubled haploids can be genotyped to select the homozygous lines that become the parents of the desired F1 hybrid. The essential step, suppression of recombination, is achieved by introducing in the novel breeding line an RNAi construct that suppresses the action of one of the known recombination genes. This transgenic line is used to generate dihaploid progeny. Because the parent is heterozygous for the RNAi construct half of the progeny will not contain this transgene. These are selected and used for further genotyping and F1 hybrid construction. The consequence is that the product no longer contains a transgene and thus does not have to be labelled as GMO.

breeding is essential. In other words, should novel breeding techniques be evaluated for organic agriculture on the basis of a product assessment or on the basis of the current process assessment in the regulatory guidelines on GMOs?

In this paper we shall first analyse the role of ethical values in organic agriculture and recapitulate and analyse the arguments why organic agriculture is opposing the use of GMOs. We shall then discuss in detail the process and product orientation in the regulation of GMOs and in the public debate on gene technology. Finally we shall apply the insight from these discussions to assess whether cisgenesis and reverse breeding are acceptable for organic agriculture or not.

Role of ethical values in organic agriculture

Alrøe & Kristensen (2004) listed several objectives of normative values or principles in organic agriculture:
- To resist unwanted developments;
- To support development and extension of organic agriculture into new areas;
- To plan pro-active research;
- To discuss organic rules.

This list shows that values not only have a restricting effect (to resist and exclude unwanted developments, such as genetic engineering) but also gives guidance to what 'organic' is. The latter can stimulate producers, researchers and other stakeholders to further develop organic agriculture (Padel, 2005). Values can help 'to resist unwanted developments'. This can be demonstrated by the case of genetic engineering. IFOAM (Anon., 2002) stated in a position paper that it is opposed to genetic engineering in agriculture, because of the unprecedented danger it presents for the entire biosphere and the particular economic and environmental risks it poses for organic producers. Most of the objections mentioned in this position paper were not formulated in terms of values that are threatened, but in terms of the consequences of the technology, with an emphasis on risks. There are exceptions: the position paper also referred to free choice and to the principles of sustainable organic agriculture. But what these principles are, was not made explicit (Verhoog, 2007a). It was not before 2005 that IFOAM explicitly accepted four ethical principles as being constitutive for the basis of values in organic agriculture: the Principles of Health, Ecology, Fairness and Care. Luttikholt (2007) elaborates these four ethical principles.

Why is organic agriculture opposing the use of GMOs?

The reasons why organic agriculture is against genetic engineering can be described in terms of the 'precautionary principle' as formulated in a publication by the Danish Research Centre for Organic Food and Farming (DARCOF; Anon., 2000), and in terms of the concept of naturalness as described by Verhoog *et al.* (2003) and Verhoog (2007a). The precautionary principle is put forward by DARCOF to explain the ban on pesticides and GMOs in organic farming:

> *"The rationale behind the precautionary principle is that in organic farming the interaction between Nature and Man is an important ingredient of the philosophy. [...] Organic farming builds on the concept that Nature is an integrated whole that people have a moral duty to respect, both for its intrinsic value and because, by using its regulatory mechanisms, one can establish a more self-sustaining agro-*

ecosystem. Nature is a very complex, coherent system, of which Man has often little understanding to appreciate the consequences of specific actions. Damage to Nature and the environment will ultimately damage Man." (p. 11).

This explanation mentions the holistic philosophy of nature that underlies the risk-perception in organic agriculture. The intrinsic value of nature is respected and reference is made to the self-regulation of the agro-ecosystem. Man is seen as part of nature or as a participant in nature.

The concept of naturalness of Verhoog *et al.* (2003; 2007a) is based on a similar way of thinking. These authors distinguish three approaches in organic agriculture based on different aspects of the concept of naturalness:

- The no-chemicals approach. Agriculture based on the principles of living (organic) nature, e.g. refraining from chemical-synthetic inputs and replacing them by natural substances; dealing with the notion of nature that grows by itself, of the autonomy of life, and of a principle of health.
- The agro-ecological approach. Man is part of nature and in agriculture man must take into account the self-organizing capacity of nature in a holistic way (ecosystem approach, thinking in cycles, harmony, balance, resilience). Learning from the wisdom of nature.
- The integrity approach. All other living entities are seen as partners in the whole, which we choose to respect morally (intrinsic value, inherent worth). They have a characteristic 'nature' of their own. Respect for the integrity of natural entities is related to their wholeness and a relative autonomy (Verhoog, 2005). Four levels of integrity can be distinguished: integrity of life, planttypic integrity, genotypic integrity and phenotypic integrity (Lammerts Van Bueren *et al.*, 2003; Lammerts Van Bueren & Struik, 2005).

On the basis of respect for the value of naturalness genetic engineering will be rejected as being 'unnatural' because it disturbs the harmony or balance of the whole, but also because the recombinant DNA constructs used are not 'natural substances' but synthetic constructs (relating to the no-chemicals approach). Furthermore, genetic engineering does not stimulate self-regulatory processes (relating to the agro-ecological approach). By crossing species barriers (relating to the integrity approach), genetic engineering does not respect the characteristic way of being ('nature') of living organisms.

Genetic engineering is based on a mechanistic and not on a holistic way of thinking about life. So the objections against engineering of organic agriculture go well beyond the risks of the gene technology. They also relate to the technology itself, and the human attitude towards nature it reflects.

Process and product orientation in regulation and public debates on gene technology

Some people have intrinsic concerns about the process of gene technology, related to the human attitude towards nature. In this context terms like 'playing God', 'human hubris' (arrogance in believing that man can intervene in whole organisms without risks), 'unnaturalness', and 'violation of the integrity of the plant or animal (species)' are used. In organic agriculture, intrinsic arguments are essential as they relate to the no-chemical, ecological, ethical and socio-economic values of organic agriculture (Lammerts Van Bueren *et al.*, 2003; Lammerts Van Bueren & Struik, 2005; Verhoog, 2007a).

Most of the official GMO-regulations, however, are based on the product. The approach is very much consequential-utilitarian, i.e., focused on the usefulness and on the potential risk of the product, but does not take the inherent worth into account (Verhoog *et al.*, 2003; 2007a). The approach corresponds with the dominance of reductionistic and mechanistic thinking in applied biotechnology. Also the debates on the risks and benefits of gene technology usually deal with the product only, and extrinsic product-oriented arguments are dominant. Participants focus on the consequences of applying genetic engineering, such as the risks of the technology for humans (safety) and for the ecosystem (gene transfer to wild plants or animals). The whole process that leads to these products is usually left out of the ethical reflection. An example of a case where the intrinsic issues were ruled out from the very beginning is the public debate 'Food and Genes' that took place in the Netherlands in 2001. The debate focused on specific case studies, such as late-blight resistant potato, pesticide-resistant maize, salmon with resistance to cold water, vitamin A rice, and BSE resistant cows. The information given to the public was mainly about weighing the costs (risks) and the benefits. At the end of the debate the organizing committee concluded that 'ethical issues' (defined as intrinsic concerns) played a minor role in the debate (Terlouw, 2002). But this minor role may have been due to the focus on risks and benefits. Opportunities to discuss intrinsic issues were very scarce (Anon., 2001). This is a general trend. Sooner or later, intrinsic arguments tend to be ruled out in public debates and in official policies (Verhoog, 2003). The question is why this happens.

The report 'Genetically modified crops' by the Nuffield Council on Bioethics (Anon., 1999) provides a clue. The explicit choice for scientific values and utilitarianism leads to the dismissal of intrinsic concerns, *in casu* moral concerns, in the debate about gene technology and food. Arguably the choice of scientific values and the choice of a utilitarian approach to ethics are mutually dependent and tend to reinforce each other. They form an implicit or explicit alliance between science and utilitarianism in debates on the socio-ethical aspects of genetic engineering, in particular in the argumentation of those who are in favour of genetic modification techniques.

Arguments to support this idea of an alliance are:

1. *The history of the recombinant DNA debate, which started with concerns about the risks to humans of genetically engineering bacteria.*

The focus was on risks. Technical safety committees, mainly consisting of natural scientists, were installed to discuss and advise governments about the risks. The scientific and ethical aspects were sharply distinguished and discussed in separate committees. Most of the time, when the scientists advised that the risks were minimal or negligible, the research could go on. If there was a risk of some kind, containment measures had to be taken to minimize the effects. The result has been that the (natural) scientists became the main actors in the field. Science also became the basis for regulation and policy (Davies *et al.*, 2002). No weighing of risks and benefits took place, not even in the field of plant biotechnology.

2. *The tendency both in natural science and in utilitarianism to make a separation between*

the realm of the subject and that of the object (objective nature) (Verhoog, 2003). The belief in the value-freedom of science leads to the view that values only come in afterwards, when the knowledge is applied. Looking at the consequences from only a utilitarian point of view makes one abstracted from the human-nature relationship. This almost automatically creates a niche for science as the means to study the consequences.

3. *The separation, often made in secularized (multi-cultural) societies, between the 'public sphere' and the 'private sphere' of moral judgements.*

Utilitarian deliberations about extrinsic concerns are seen as public whereas intrinsic concerns, which are usually related to specific world views, are seen as private. Private beliefs are personal, subjective and should thus be ruled out in public decision-making. Scientists even tend to call such beliefs irrational or emotional. Science is seen as 'neutral', standing above all world views.

This alliance between science and utilitarianism can exist as long as it is taken for granted that the scientific (reductionistic) view on nature is the only true one, and not a world view in itself. Once this 'truth' is questioned, debates on food and biotechnology can be broadened beyond the utilitarian framework that now dominates the discussions, both in practice and in ethical theory development. To question that truth, one only needs to move one's attention away from experimental reductionistic science, and focus on approaches that are closer to the world of our immediate experience. In our direct contact with plants and animals, the organisms are usually experienced as living wholes. From this (more holistic) perspective it is possible to experience gene technology as a violation of the integrity of the organism (Verhoog, 2005; 2007b). Integrity has to do with wholeness, with a harmonious balance between all the parts of an organism, the genes included. For a 'holistic thinker' genes are not just exchangeable elements or building materials. Such holistic viewpoints are not just gut feelings of laymen, but substantial elements in the philosophy of organic farming (Lund, 2002). The choice of a kind of agriculture without GMOs is, as will be shown, an informed and 'reasonable' choice within the rational framework of organic farming.

From a non-holistic, reductionistic point of view, experimental natural sciences (including sciences relating to biotechnology) are based on a certain philosophy of nature, which leads to a product-orientation and to corresponding utilitarian ethics. In organic agriculture, the more holistic philosophy of nature leads to a process orientation with a corresponding ethical approach in which there is room for intrinsic arguments.

Assessment of cisgenesis and reverse breeding

Process- and product-oriented reasons for not using cisgenesis

The fact that cisgenesis is a genetic modification technique is not disputed. From the process point of view, this breeding technique does not comply with the EU regulations for organic agriculture. Plant breeding at DNA-level, instead of at whole-plant level, violates the integrity of life as described in the concept of naturalness (Lammerts Van Bueren *et al.*, 2003). Cisgenesis, like transgenesis, implies at random insertion of the 'cis' gene(s), which always makes the effect of the insertion on the genome and the concomitant risks unpredictable. Still, some authors (Schouten *et al.*, 2006a, b) argue that products of cisgenesis are comparable to products of traditional breeding. Schouten *et al.* (2006a, b) question whether the product (i.e., the variety) of cisgenesis needs the full risk assessment procedure for admittance. They even suggest that the variety can be excluded from the European Directive 2001/18/EC as the process only integrates heritable material from related species and thus no 'new' genes have been inserted into the new variety. What they mean is that the products of cisgenesis contain DNA sequences that could have been combined in a new variety by traditional breeding. However, they ignore that in traditional breeding the 'desired' gene is imbedded in its chromosomal context. For instance, a resistance gene introduced by gene transfer technology will rarely integrate close to its original position (as usually occurs in traditional breeding) and its expression will therefore be influenced by the genomic context (Mes *et al.*, 2000). Although no natural barriers are crossed when inserting a gene from crossable species, isolating a gene from its natural genomic context and its random insertion can still be considered as a violation of the genotypic integrity. So organic farming should not use cisgenic products, because both the process and the product are unnatural.

Would cisgenesis be useful for organic agriculture? Despite the agro-ecological approach in organic agriculture, some diseases cause severe losses, such as late blight (caused by *Phytophthora infestans*) in potato (Speiser *et al.*, 2005). To date, very few varieties are available on the market that are completely resistant to late blight, and no effective control treatments are available for organic farmers, apart from copper, which is not allowed in the Netherlands (Speiser *et al.*, 2005). In most years almost every organic potato crop is infected by late blight and yields are on average 30–50% lower than in conventional agriculture (Tamm *et al.*, 2004). So also organic growers would benefit from new varieties resistant to late blight (Speiser *et al.*, 2005), but not at all costs. The genes that will be used in the proposed cisgenic approaches are so-called R-genes, which confer absolute resistance. This kind of resistance is easily broken, especially with both mating types of the oomycete being present in the Netherlands. Therefore, this approach would require constant addition of new R-genes by cisgenesis, as the pathogen population develops. Organic potato growing prefers to work with the results of traditional breeding yielding a rather constant flow of varieties with some level of resistance.

Process- and product-oriented reasons for not using reverse breeding

In Article 5.3h of the EU Directive for organic agriculture it is laid down that organic products should be produced without genetically modified organisms or derived products. This means that in the production process of organic products no GMOs or GMO-derived products are allowed, even when the product itself cannot be identified as being GM. For example, oil derived from GM soya beans does not contain enough protein or DNA to allow the identification of its GM origin (Partridge & Murphy, 2004). Still, because the origin of the raw material can be traced to a GM source, this product is not permitted in organic foods. Following this line, neither a hybrid originating from reverse breeding complies with the production process according to the values that underlie the standards of organic agriculture.

Would reverse breeding be useful for organic agriculture? The main advantage of reverse breeding is that breeders can produce seeds of a new F1 hybrid in a much shorter time than with conventional techniques, as reverse breeding circumvents inbreeding (dihaploids) and selection of appropriate recombinants in large populations. This means breeding with a narrowed focus based on the knowledge one has already gained and on available DNA markers, thus disqualifying new, unexpected combinations that may appear with traditional crossings and segregation of the populations by allowing genotype × environment interaction (Haring, 2005).

Consequences

For the next decades the organic sector will still largely depend on the results of conventional breeding as there are only a few organic breeding programmes running (Legdzina & Skrabule, 2005). This implies that it is desirable to label varieties that result from breeding techniques that are not permitted in organic agriculture. However, if seeds from reverse breeding will end up unlabelled, as is the case with seeds from mutagenesis and protoplast fusion experiments (see Annex 1b of the GMO Directive 2001/18/EC), then a 'black' list may be made up with varieties not to be used (Raaijmakers, 2004). Alternatively, an organic certification system should be developed for organic breeding programmes in which only breeding techniques are applied that comply with the standards of IFOAM, resulting in a 'green' list of varieties that are allowed in organic agriculture. When designing a certification system, a relevant question is how many crossings one should go back to assess whether undesired techniques were applied.

Conclusions

Genetic engineering is the result of a mechanistic way of thinking that necessarily leads to a kind of risk analysis focused on the product, because the technology itself is believed to be value-free. Intrinsic process-related arguments against genetic engineering are excluded and only utilitarian ethical arguments are accepted.

Intrinsic arguments against genetic engineering are related to a holistic view of nature in which the integrity of plants, animals and ecosystems prevails. This also is the case with traditional breeding based on whole organisms in their specific agro-ecosystem. With the shift to breeding at cellular and DNA level the intrinsic ethical arguments disappear, together with the role of the farmer in the breeding process. Removing the contextual elements (the whole plant in relation to its farming system) stresses the utilitarian and economical drive behind the breeder's decisions. This reductionistic approach ignores the richness and complexity of biological processes and leaves no space for ethical considerations of any kind. The emphasis shifts from the process and intrinsic values to a risk / benefit analysis of the product. Ethical questions are reduced to personal world views and therefore not relevant for assessment of the final product.

This product-thinking provides the arguments for scientists who wish to promote cisgenesis and reverse breeding as novel breeding techniques that do not bear the burden of genetic modification. For convenience, the whole process is ignored, whereas this is a relevant aspect for those who use intrinsic arguments: organic farmers and their customers. Organic agriculture is based on respect for the naturalness and integrity of all organisms in the agro-ecosystem and this respect is the main basis of the ban on gene technology. These intrinsic ethical arguments against GMOs also apply to cisgenesis and reverse breeding.

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