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Editorial

The ethical concerns about transgenic crops

Agnès E. Ricroch[1,2], Michèle Guillaume-Hofnung[1] and Marcel Kuntz[3]

[1]Collège d'Etudes Interdisciplinaires, Université Paris-Sud, 54 Boulevard Desgranges, F-92330 Sceaux, France; [2]AgroParisTech, Génétique évolutive et amélioration des plantes, 16 rue Claude-Bernard, F-75231 Paris cedex 05, France; [3]Université Grenoble Alpes, CEA, CNRS (UMR 5168), INRA (UMR 1417), Laboratoire de Physiologie Cellulaire & Végétale, 17 rue des Martyrs, F-38054 Grenoble cedex 9, France

Correspondence: Marcel Kuntz (marcel.kuntz@cea.fr)

It is generally accepted that transgenesis can improve our knowledge of natural processes, but also leads to agricultural, industrial or socio-economical changes which could affect human society at large and which may, consequently, require regulation. It is often stated that developing countries are most likely to benefit from plant biotechnology and are at the same time most likely to be affected by the deployment of such new technologies. Therefore, ethical questions related to such biotechnology probably also need to be addressed. We first illustrate how consequentialist and nonconsequentialist theories of ethics can be applied to the genetically modified organism debate, namely consequentialism, autonomy/consent ethics (i.e. self-determination of people regarding matters that may have an effect on these people) and virtue ethics (i.e. whether an action is in adequacy with ideal traits). We show that these approaches lead to highly conflicting views. We have then refocused on moral 'imperatives', such as freedom, justice and truth. Doing so does not resolve all conflicting views, but allows a gain in clarity in the sense that the ethical concerns are shifted from a technology (and its use) to the morality or amorality of various stakeholders of this debate.

Introduction

Do the technical and scientific characteristics of genetically modified (GM) crops justify that their surrounding ethical considerations be given a particular specificity? And if so, to what extent? The 'Devil is in the detail' is a common idiom, but in ethics he may well be in the thresholds. Many ethical issues are formulated in terms of threshold: from which threshold? Up to which? These questions lead us to the dilemma that is the essence of ethics. From which threshold will the GM technology be considered as beneficial? From which threshold will they no longer be considered as beneficial?

Lack of scientific certainty demands ethical questioning. However, when the scientific or technical certainties are unable to give certain answers, nothing justifies that ethical questions are formulated with a misleading technical or scientific sophistication. We then find ourselves in front of ethics in its fundamental unity.

In contrast, persisting in a sectored thought would nourish alleged ethical specificities, and in the end, would derogate from common ethics, which must be built. Ethical sophistication encourages violation of basic ethics, hidden by clouds of smoke. Basic ethics means the common core which is used as a basis for our behavior. Basic also means a simplicity of its formulation. In other words, ethics should be formulated almost in the same terms for a primary school pupil and for a researcher.

Below, we will first discuss the confrontation between ethics viewpoints regarding transgenic plants. This discussion will then gain in clarity by refocusing on issues such as freedom, justice and truth. Regarding truth, we could refer to Descartes who considered error as a sin when the error results from a refusal to seek the truth.

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Conflicting ethical views

Obviously, there are numerous ancient theories of ethics [1]. In the contemporary era, rather than a unified ethics, the philosophical debate has come up with different sorts of ethics, which can be presented as three general categories, namely consequentialism, autonomy/consent ethics and virtue ethics. These so-called paradigms have already been discussed with regard to the use of transgenesis for biotechnological improvement of crop. For example, Burkhardt ([2]; see also references at http://www.fred.ifas.ufl.edu/pdf/vita/burk.pdf) has shown that opposing basic ethical beliefs does not always result from irrationality or lack of information. Gregorowius et al. [3] presented the moral reasoning expressed in scientific publications regarding GM crops, with a focus on environmental issues. They showed how 'the perception of gene technology by academic experts, especially by natural scientists, differs from that of laypersons'. The ethical debate over GM technology has also been presented in detail by Peterson [4]. Our aim is not to resolve these conflicting views, but to show that this complex debate can gain in clarity when the ethical concerns are shifted from a technology to the stakeholders of this debate.

According to ***consequentalism***, the central question around GM crops is 'does transgenesis in agriculture produce good consequences?' If we consider that this is the case, then it may be argued that we have a moral obligation to use this technology, or at least allow its use, for example to feed a growing world population [5] or to reduce the environmental impact of agriculture [6,7]. If, on the other hand, we think that transgenesis will lead to harmful consequences (e.g. negative unintended effects worse than status quo products and practices; see http://natureinstitute.org/txt/ch/nontarget.php), banning the technology would be viewed as a moral obligation. However, in practice, things are not quite as amenable to an 'absolute' ethical judgment. Firstly, if we consider that the risks presented by GMO agriculture are 'unacceptable' on ethical grounds, how do we decide that non-GMO products and practices are 'acceptable' in comparison? This is not just a theoretical hypothesis: some transgenic crops have been scientifically shown to be more environmentally friendly and more sustainable than their non-GMO alternatives. If these GMO crops are nevertheless deemed 'unacceptable' on ethical grounds, for example, because of dissemination of their transgenic pollen, how do we *ethically* justify that dissemination of transgenes on one side weighs more than land preservation on the other, for example. In addition, all human technologies will produce good and bad consequences. It all depends on how a technology is used. This is where scientific risk assessment, rather than ethics, may help characterize these consequences and allow 'science-based' conclusions and decisions.

In the case of agriculture, for food security, in a climate smart-agriculture approach, and also in medicine, ideally good and bad consequences should be documented independently from political views. However, depending on how we view the world, we will inevitably give more weight to one or another consequence (even if characterized by sound science). For example, a 'bad consequence', such as low level of adventitious presence of an authorized genetically modified organisms (GMOs) in food, would be viewed as negligible (no harmful effects on farmers, consumers and on the environment) from a science-based point of view, but may well still appear unacceptable from a different point of view. Furthermore, whether alleged ethical claims are based on preservation of the real environment or rather on mythical views of the environment is also debatable [8]. Thus, scientific risk assessment will not prevent conflicting views of consequentialism.

Autonomy/consent ethics extol the self-determination of people regarding matters that may have an effect on those people. This ethical approach is not less conflicting. A farmer may decide that growing a particular GMO (an insect-resistant variety, for example) would reduce his/her exposure to chemical pesticides, while an organic consumer may decide he/she is entitled to zero fortuitous presence of GMOs in his/her diet.

Even when adopting a less extreme posture, conflicting positions may persist: thus, people may support a 'right-to-know' type of campaign on the basis that they have the *moral* right to choose what they consume or purchase, which may not necessarily be a *legal* right depending on the country (see https://food-ethics.com/2010/09/28/the-right-to-know-what-im-eating/ and [9]). However, one may suspect (and it has actually been shown, see https://geneticliteracyproject.org/2015/05/05/anti-gmo-right-to-know-movement-cashing-in-on-scaring-and-confusing-consumers/) that the ultimate goal of such campaigns for GMO labeling is to ban GMOs altogether, leading to no choice for consumers. It may also be argued that since most consumers know little of plant breeding, farm production techniques, food composition and safety, the 'right-to-know' may be considered to be rather the right to misinform for commercial or political reasons [10]. The sale of 'non-GMO project verified' salt in the U.S.A. illustrates this trend (http://www.science20.com/cool-links/nongmo_salt_i_cant_wait_to_see_this_in_whole_foods-111929).

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The concept that risk evaluation and its normative judgments should take the 'non-scientific' concerns into consideration [11] or even be somehow subjected to a democratic process has sometimes been proposed [12], as is the incorporation of interactions between science and 'society' into research programs [13]. However, caution is warranted since such strategies may drag scientists into the political field and allow politicians and political activists to interfere with the scientific methods applied in risk assessment [14].

According to ***virtue ethics***, whether an action is right or wrong depends on its adequacy, or not, with some values (or virtues). Virtues are ideal traits, often defined by tradition, such as caution, justice and moderation of passion or fortitude. Decisions to view life in accordance with God or with Nature can also be viewed as virtues. The Federal Constitution of the Swiss Confederation has brought such ethical views to a paroxysm by stating that '*The Confederation shall legislate on the use of reproductive and genetic material from animals, plants and other organisms. In doing so, it shall take account of the dignity of living beings …* ' Regarding plants, the concept of 'dignity' was not obvious and led to mocking comments against Switzerland [15] and has even been considered as 'a threat to plant biology' [16], but was justified by the Federal Ethics Commission for non-human biotechnology on the ground that '*any act of arbitrary nuisance to plants is morally reprehensible*'.

The Ancient Greek notion of 'hubris' (disregarding the divinely fixed limits on human action out of arrogance) is sometimes evoked against the use of GM technology in agriculture, but, is also criticized since it '*fails to have a proper understanding of agriculture as an inherently technological practice which is radically different from nature*' [17]. Inserting animal or human genes into plant genomes has also stirred ethical debates [18,19], as did the perceived differences between *trans*- and *cis*-genesis [20,21].

The position of the Pontifical Academy of Sciences on biotechnology [22] is an example of a position that can be viewed as based on both ethics of virtue (help the poor) and consequentialism (when agricultural technology can help improve the sustainability and productivity of agriculture, its implementation should not be prevented). Cardinal Peter Turkson, President of the Vatican's Pontifical Council for Justice and Peace, stressed on the dissemination of agricultural technology around the world to help improve the sustainability and productivity of agriculture (https://ofwlaw.files.wordpress.com/2013/10/cardinal-turkson-at-world-food-prize-in-des-moines-10-17-2013.pdf).

Biofortification can also be mentioned here. This aims to combat nutritional deficiencies (vitamins and minerals) through genetic modifications (not always GMOs) of staple crops to provide an increased supply of essential micro-nutrients (various biofortified crops have been developed for Africa and part of Asia, such as 'Golden Rice' enriched in pro-vitamin A by the 'Humanitarian Golden Rice' project [23]). Despite its humanitarian and noncommercial nature, Golden Rice is fiercely opposed by anti-GMO organizations because it may potentially lead to a better public acceptance of other GMOs.

We will show below that even universal values such as freedom, justice or truth have led to divergent views over GMOs.

Freedom

Patenting and restrictions for breeders and farmers

Objection of the principle on patenting of living objects — or parts of objects such as genes [24] — has fueled opposition to biotechnology. In a more concrete way, this ethical issue deals with the tools to protect plant varieties and biotechnological innovations as well as the consequences of intellectual property rights on access to plant genetic resources for breeding. In addition, the conditions under which a plant variety can be multiplied by a farmer for his/her own use (farm-saved seed, FSS) have also been debated (see below; see refs [25,26]).

However, it is important to keep in mind that intellectual property protection of plant innovation varies from country to country [27], depending on the cultural and political background. Plant varieties are not patentable in Europe, but inventions related to plants may be patented if their technical feasibility is not limited to a single variety. In contrast, it is possible to patent plant varieties in the U.S.A. (with a limited research exception and no possibility for FSS). In Europe, the only way to protect a plant variety is the Plant Breeders' Right as defined by the 'International Union for the Protection of New Varieties of Plants' (UPOV) convention. A list of crops for which FSS is allowed has been published. In addition, in certain European Union Member States, a system for collecting fees from farmers using FSS has been established (e.g. for wheat in U.K., France, Spain and Portugal) to support innovation in breeding.

The implications for developing countries of plant variety legislations have also been discussed (see http://www.iprsonline.org/ictsd/docs/ResourcesTRIPSharbir_singh.doc).

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Destruction of scientific research and harassment of researchers studying GMOs

About 80 acts of vandalism against academic or governmental research on GMOs in Europe have been compiled [28]. Many more attacks have targeted private research (more than 100 were perpetrated in Germany alone). Opponents quite often try to justify these destructions by claiming there is a 'state of necessity' to prevent dissemination of GMOs in the environment and that, consequently, they have the moral obligation to 'neutralize' these field trials.

However, no evidence of transgene dissemination from any field trial has ever been obtained in Europe. The case of the grapevine trial using Grapevine Fanleaf virus-resistant rootstocks at INRA — Colmar (France) is revealing in this respect: even some GMO opponents agreed that it was a 'confined outdoor' experiment since stacked prevention measures rendered transgene dissemination impossible (e.g. only stocks were transgenic and flowers were cut). It was nevertheless vandalized twice (in 2009 and 2010). Furthermore, although this trial has since been abandoned, an intrusion (a self-proclaimed 'citizens' inspection') of activists, with physical threats to researchers, occurred at the INRA research station at Colmar in August 2015.

Facts also show that destructions were not limited to field experiments since, in some instances, vandalism of confined experiments occurred [28]. In addition, the moral self-licensing by GMO destructors (allegedly based on environment protection) also lost credibility since, in a few cases, the destruction of an experiment was accompanied by additional damage to property and/or threats or violence against individuals. Furthermore, most of the destroyed academic or governmental experiments were actually designed to assess the safety of GMOs. It must be concluded that the opponents' primary goal is to stop all research on GMOs, not simply to protect the environment.

It can be argued that there are ethical justifications to publish the location of GMO field trials. Openness is one and 'access to justice' can be viewed as another (in the sense that if an accident occurs, the victims ought to be informed of where the problem originated). However, this openness (imposed by law in Europe) has not been matched by measures from the political authorities to prevent any vandalism facilitated by this openness. The concept of 'access to justice' has been hijacked by GMO opponents wanting to know GMO field locations simply to destroy them and not for transparency in a democratic process to inform all citizens.

The perpetrators of violence against scientific experiments, GMO research and also harassment against researchers are encouraged by organizations that often benefit, directly or indirectly, from public funding, either from the European Commission, national governments or local authorities. It is difficult not to consider as a serious breach of ethics the fact that these political authorities stay blind over the fact that public money may actually be financing violence in democracies.

Harassment of farmers growing GMOs

The case of France is revealing [29]. Insect-resistant *Bt*-maize cultivation increased in the country from 2005 to 2007, which led anti-GMO activists to not only vandalize some fields but also to intimidate farmers. For example, these activists conducted, on November 4, 2006, a so-called GMO traceability operation at a farmer's property near Bordeaux. Actually, they poured a toxic dye in an elevator containing 2000 tons of maize, which led to a physical confrontation between the farmer and the activists. The worst incident occurred on August 5, 2007, in south-west France: faced with a confrontation with activists planning to destroy his field, a farmer committed suicide. In 2008, a French law proclaimed 'the right to cultivate with or without GMOs', whereas in the same year the French government initiated a ban on cultivation of *Bt* maize (the only one previously authorized).

Justice

The concept of global justice applied to GMOs has already been discussed elsewhere [30]. We will focus here on seed ownership.

Seed companies prohibiting seed saving and suing farmers

In North America, the seed company Monsanto imposes contracts to farmers who want to purchase its GM seeds, in which these farmers commit themselves to not saving and replanting seeds produced from the purchased seeds. Farmers are free not to buy GM seeds, but these contracts have largely contributed to the detestable image of the company. It is often viewed as nonethical since it prevents a practice that has been part of

agriculture for centuries. It has led to a worldwide 'David against Goliath' narrative after Monsanto sued the Canadian farmer Percy Schmeiser for patent infringement. Although Schmeiser lost at all three Federal Court levels available to him (the Courts concluded that the farmer deliberately used Monsanto's seeds; see http://www.ielrc.org/content/a0503.pdf), the public opinion was left to believe that farmers could face penalties for patent infringement when seeds grew spontaneously in their fields (as a consequence of undesired gene flow, for example). Monsanto's explanations (https://monsanto.com/company/media/statements/saving-seeds/) failed to counteract this farmer bullying narrative.

On the other hand, a context where Monsanto is obviously not imposing its view exists in other countries. Again, the case of France is revealing [29]. Monsanto was not even invited to participate, and to defend itself, during a national debate on the 'environment' during the fall of 2007, which led to the ban of cultivation of its MON810 insect-resistance (Bt) trait for maize.

The fertility of the seed sterility rumor

Although no company has ever commercialized a biotech trait that resulted in sterile seeds, such 'potential' sterility has raised concerns for small landholder farmers who cannot afford to purchase seeds every year. It is unclear whether or not such Genetic Use Restriction Technologies (GURT; dubbed 'terminator' by the anti-GMO organization RAFI) are actually functional. Patents only describe concepts for transgenic techniques which come up with plants which produce a normal harvest, but whose grains will not germinate [31]. Nevertheless, campaigns against 'terminator' genes are constantly launched and many people erroneously believe that all GMOs produce sterile seeds.

On the other hand, it would be desirable to prevent foreign genes from spreading to conventional crops, especially in the case of transgenic plants engineered to produce pharmaceuticals or other bioproducts, and which are grown outdoors, not in greenhouses or as cell cultures [32].

Truth

The rise of a parallel 'science'

The way the tobacco industry created a 'junk science' to deny the health effects of smoking is well known [33]. Political ecologists and advocacy groups have been faced with a large scientific consensus on GMO food safety, which they try to deny on the basis that there is no unanimity among scientists. To artificially increase this nonunanimity, they created what is best described as a parallel 'science' (http://www.geneticliteracyproject.org/2014/07/15/parallel-science-of-ngo-advocacy-groups-how-post-modernism-encourages-pseudo-science/).

Parallel 'science' differs from most political lies (during election campaigns for example) in that it attempts to reconstruct a scientific field (toxicology for example) in contradiction with the truth-seeking approach which is the essence of science. However, for lay people or most journalists, parallel 'science' seemingly resembles science, despite the fact that it differs from 'normal' science since its conclusions precede experimentation and are chosen to fit their ideology. For example, parallel 'science' shows that rats with tumors allegedly caused by a GMO or a pesticide, without presenting the control rats that also had similar tumors … Even when its allegations have been scientifically demonstrated to be erroneous, parallel 'science' keeps them alive *as if they were true.*

Politically motivated distortion of scientific facts by governments

Many governments, in various regions of the world, moved from being publicly supportive of green biotech to a precautionary doctrine just for political reasons. It was unexpected that several European countries, including France and Germany [29,34], would even go further: by-pass their national risk assessment agencies and develop their own parallel 'science' to justify, with false scientific arguments, their politically motivated bans of GMO cultivation [35,36].

'Words of mass destruction'

The way news media (mis)represent GMOs and journalists interpret their own representations and amplify the social perception of risk has been analyzed in several countries. The fact that only a minority of news reports provide accurate information on GMOs (http://www.scidev.net/sub-saharan-africa/gm/scidev-net-at-large/conference-unravels-poor-media-coverage-of-gmo-debates.html) questions the concept of deontology when applied to journalism. However, the abundant literature [37–41] on this topic will not be further analyzed here.

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The social media obviously also played a major role in shaping the public's perception of GMOs. Often, scientific facts are deliberately misrepresented in the social media by activists. Whether this can be prevented in the future by providing clear education regarding genetic engineering is unclear. It has been argued that '*it is only when the public fully understand what a GMO is that it can start to effectively debate the ethical nature of GMOs*' (http://www.newsactivist.com/en/articles/media-ethics-section-07/food-thought-misrepresentation-gmos-social-media).

Confirmation bias and the ethical demands of argumentation

Confirmation bias is a cognitive error which occurs when we seek evidence to support what we already believe. Confirmation bias has been discussed, for example, in legal deontology and has been shown to 'undermine effective lawyering' (https://www.2civility.org/legal-ethics-and-confirmation-bias/) or to be responsible for forensics errors (http://www.sjsu.edu/people/mary.juno/courses/admj63/s1/Confirmation_Bias.pdf). While the GMO debate is overwhelmed by confirmation biases, to the best of our knowledge this trend has never been discussed in terms of ethical reasoning and argumentation (which could explain the lack of significant progress in this debate).

Public access to balanced and objective information

It is a general fact that the public does not have full access to the scientific information and does not always have an adequate understanding of agriculture and its technological practices. This becomes an ethical problem when amplified, as it is in the GMO case, by the above-mentioned distortion of facts. It is legitimate that lay people have ethical views on 'nature' and 'biodiversity' which may be different from those of scientists. However, it is regrettable that this leads to rejection of GMOs on the basis of misrepresentations. According to scientists in plant science and researchers in philosophy and moral sciences, '*people tend to rely on intuitive reasoning to make a judgment on GMOs. This intuitive reasoning includes folk biology, teleological and intentional intuitions and disgust. Anti-GMO activists have exploited intuitions successfully to promote their cause. Intuitive judgments steer people away from sustainable solutions.*' [42]. Communication on the potential of green biotechnology (e.g. for environmental or health benefits) is desirable. It is, however, unclear whether this will change the perception of GMOs.

'Democracy' in science as a new moral imperative

Recently, the National Academies of Sciences of the U.S.A. published a report on 'gene drive' [43] whose sub-title is '*Aligning Research with Public Values*'. Such an 'alignment' ignores that science seeks to establish universal laws, while public values are highly variable depending on the civilization and the historical time considered. This part of this report and its ambiguous endorsement of 'public engagement' in research (a concept fluctuating in the report from scientists being open to dialog, a value of Enlightenment, to more relativist views) have been criticized as an ideological shift toward postmodernism [44].

It has also been argued that postmodernist concepts such as 'Democratization of Science' or 'Responsible Research and Innovation' are not merely a moral choice for researchers, but have actually become social coercive tools [45].

Conclusions

Various ethical considerations have been expressed in academic publications concerning the use of GM crops (for further reading, see refs [46–51]). Used in an appropriate manner, GM varieties and gene-edited varieties [52] can be relevant for sustainable agricultural practices. For example, pest-resistant crops can promote biodiversity when they do not harm nontarget organisms (NTOs), while pesticides can harm both NTOs and farmers when used without precaution. High tech seeds may be required for food security in the context of a diminishing supply of productive arable land or scarce water resources. Biotechnology, in combination with other approaches, can contribute to the solving of problems that are specific to developing countries and resource-poor farming. Consequently, one can argue that there is a moral imperative to make the benefits of agricultural biotechnology available on a larger scale to all, and especially to poor and vulnerable populations [53].

A major problem is that, in some jurisdictions, the cultivation of GM plants is blocked, allegedly because of risks to the environment. It has been proposed [54] that this dispute is primarily over normative values and

that '*debates about values will clarify decision-making criteria*'. The question of values is illustrated, for example, by the concept of moral responsibility linking ownership and hazards [55].

However, the ethical debate about GMOs is obviously sectored by different ethics viewpoints. By refocusing on universal values such as freedom, justice or truth, it appears that the ethical concerns are shifted from a technology (and its use) to the morality (or rather the amorality) of various stakeholders of this debate.

'A peace plan for resolving GMO conflict' has recently been proposed (https://allianceforscience.cornell.edu/blog/peace-plan-resolving-gmo-conflict). Rather than wishful thinking about activists voluntarily stopping fear campaigns or violence, exposing their amorality with respect to such universal values could, at least to some extent, convince them to refocus the debate on their real (political) motivation. Exposing amorality of an industrial project (for example, the above-mentioned 'terminator' project) has led to its abandonment. There is no reason why this should not equally apply to opponents of a technology.

Abbreviations

FSS, farm-saved seed; GMO, genetically modified organism; NTOs, nontarget organisms.

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Competing Interests

The Authors declare that there are no competing interests associated with the manuscript.

References

1 Graham, G. (2004) *Eight Theories of Ethics*. Routledge
2 Burkhardt, J. (2001) The GMO Debates: Taking Ethics Seriously. [updated 2018] Available from: https://www.researchgate.net/publication/268415257_The_GMO_Debates_Taking_Ethics_Seriously
3 Gregorowius, D., Lindemann-Matthies, P. and Huppenbauer, M. (2012) Ethical discourse on the use of genetically modified crops: a review of academic publications in the fields of ecology and environmental ethics. *J. Agric. Environ. Ethics* **25**, 265–293 https://doi.org/10.1007/s10806-011-9330-6
4 Peterson, M.J. (2008) *Ethical Evaluation of New Technologies: Genetically Modified Organisms and Plants*. International Dimensions of Ethics Education in Science and Engineering. Available from: http://scholarworks.umass.edu/cgi/viewcontent.cgi?article=1033&context=edethicsinscience
5 Rotman, D. (2013) MIT Technology Review. [updated 2014 January–February; cited 2017 November 13] Available from: https://www.technologyreview.com/s/522596/why-we-will-need-genetically-modified-foods/
6 Bennett, A.B., Chi-Ham, C., Barrows, G., Sexton, S. and Zilberman, D. (2013) Agricultural biotechnology: economics, environment, ethics, and the future. *Ann. Rev. Environ. Resour.* **38**, 249–279 https://doi.org/10.1146/annurev-environ-050912-124612
7 Barfoot, P. and Brookes, G. (2014) Key global environmental impacts of genetically modified (GM) crop use 1996–2012. *GM Crops Food* **5**, 149–160 https://doi.org/10.4161/gmcr.28449
8 Scott, I.M. (2000) Green symbolism in the genetic modification debate. *J. Agric. Environ. Ethics* **13**, 293–311 https://doi.org/10.1023/A:1009511616869
9 Uusitallo, S. (2008) *Affective Implications of GM Food on Social and Individual Integrity: An Ethical Approach in Women in Biotechnology*. pp. 257–262, Springer, Netherlands
10 Twardowski, T. and Małyska, A. (2015) Uninformed and disinformed society and the GMO market. *Trends Biotechnol.* **33**, 1–3 https://doi.org/10.1016/j.tibtech.2014.11.006
11 Devos, Y., Maeseele, P., Reheul, D., Van Speybroeck, L. and De Waele, D. (2008) Ethics in the societal debate on genetically modified organisms: a (re) quest for sense and sensibility. *J. Agric. Environ. Ethics* **21**, 29–61 https://doi.org/10.1007/s10806-007-9057-6
12 Meghani, Z. (2014) Risk assessment of genetically modified food and neoliberalism: an argument for democratizing the regulatory review protocol of the food and drug administration. *J. Agric. Environ. Ethics* **27**, 967–989 https://doi.org/10.1007/s10806-014-9511-1
13 MacDiarmid, R. (2007) Genetically modified crop plants: science versus society? A perspective. *Australas. Plant Pathol.* **36**, 516–519 https://doi.org/10.1071/AP07064
14 Kuntz, M. (2013) Why the postmodern attitude towards science should be denounced. *EMBO Rep.* **14**, 114–116 https://doi.org/10.1038/embor.2012.214
15 Zubler, V. (2008) *Le monde se moque de la dignité suisse des plantes*, Tribune de Genève
16 Abbott, A. (2008) Swiss 'dignity' law is threat to plant biology. *Nature* **452**, 919 https://doi.org/10.1038/452919a
17 Moula, P. (2015) GM crops, the hubris argument and the nature of agriculture. *J. Agric. Environ. Ethics* **28**, 161–177 https://doi.org/10.1007/s10806-014-9526-7
18 Knight, A.J. (2009) Perceptions, knowledge and ethical concerns with GM foods and the GM process. *Public Underst. Sci.* **18**, 177–188 https://doi.org/10.1177/0963662507079375
19 Amin, L., Azlan, N.A.A. and Ahmad, J. (2011) Ethical perception of human gene in transgenic banana. *Afr. J. Biotechnol.* **10**, 12486–12496 https://doi.org/10.5897/AJB11.1062
20 Myskja, B.K. (2006) The moral difference between intragenic and transgenic modification of plants. *J. Agric. Environ. Ethics* **19**, 225–238 https://doi.org/10.1007/s10806-005-6164-0

Biochemical Journal (2018) **475** 803–811
https://doi.org/10.1042/BCJ20170794

21 Jochemsen, H. (2008) An ethical assessment of cisgenesis in breeding late blight resistant potato. *Potato Res.* **51**, 59–73 https://doi.org/10.1007/s11540-008-9090-5

22 Pontifical Academy of Sciences. Transgenic plants for food security in the context of development. Proceedings of a study week of the pontifical academy of sciences, Vatican City, Rome, Italy, 15–19 May 2009 (Potrykus, I. and Ammann, K. eds). *New Biotechnol.* **27**, 445–717 http://www.casinapioiv.va/content/dam/accademia/pdf/newbiotechnology.pdf

23 Zeigler, R.S. (2014) Biofortification: vitamin A deficiency and the case for golden rice in plant biotechnology. In *Experience and Future Prospects* (Ricroch, A., Chopra, S. and Fleischer, F., eds), pp. 245–262, Springer

24 Konstantinov, K., Mladenovic-Drinic, S., Andelkovic, V. and Babic, M. (2010) Ethics in scientific results application: gene and life forms patenting. *Genetika* **42**, 195–208 https://doi.org/10.2298/GENSR1001193K

25 Cornejo Plaza, M.I. and Rodríguez Yunta, E. (2015) Implicancias éticas y jurídicas en el desarrollo de la biotecnología transgénica: reflexiones en torno a la tramitación de la ley de obtentores vegetales en Chile biotechnology: reflections on the transaction of the law of vegetable breeders in Chile transgênica: reflexões ao redor a tramitação da lei de obtentores vegetais no Chile. *Rev. Lat. Bioética* **15**, 132–143 https://doi.org/10.18359/rlbi.541

26 Negrín Ruiz, A. and Pino Rivero, L. *Biotechnology in plants genomics: a legal and bioethics overview. Paper presented at: International Conference on Multidisciplinary Sciences 2017. Proceedings of the MOL2NET 2017*, 3rd edition, 2017 15 Feb–20 Dec; Sciforum Electronic Conference Series, Vol. 3

27 Le Buanec, B. and Ricroch, A. (2014) Intellectual property protection of plant innovation in plant biotechnology. In *Experience and Future Prospects* (Ricroch, A., Chopra, S. and Fleischer, F. eds), pp. 59–73, Springer

28 Kuntz, M. (2012) Destruction of public and governmental experiments of GMO in Europe. *GM Crops Food* **3**, 258–264 https://doi.org/10.4161/gmcr.21231

29 Kuntz, M. (2014) The GMO case in France: politics, lawlessness and postmodernism. *GM Crops Food* **5**, 163–169 https://doi.org/10.4161/21645698.2014.945882

30 Toft, K.H. (2012) GMOs and global justice: applying global justice theory to the case of genetically modified crops and food. *J. Agric. Environ. Ethics* **25**, 223–237 https://doi.org/10.1007/s10806-010-9295-x

31 Lombardo, L. *Genetic Use Restriction Technologies: Good for Seed Companies and Bad for Farmers?* ISB news report [cited 2014 November]. Available from: http://www.isb.vt.edu/news/2014/Nov/Lombardo.pdfn

32 Sang, Y., Millwood, R.J. and Neal Stewart, Jr, C. (2013) Gene use restriction technologies for transgenic plant bioconfinement. *Plant Biotechnol. J.* **11**, 649–658 https://doi.org/10.1111/pbi.12084

33 Samet, J.M. and Burke, T.A. (2001) Turning science into junk: the tobacco industry and passive smoking. *Am. J. Public Health* **91**, 1742–1744 https://doi.org/10.2105/AJPH.91.11.1742

34 Morris, S.H. and Spillane, C. (2010) EU GM crop regulation: a road to resolution or a regulatory roundabout? *Eur. J. Risk Regul.* **1**, 359–369 https://doi.org/10.1017/S1867299X00000805

35 Ricroch, A., Bergé, J.B. and Kuntz, M. (2010) Is the German suspension of MON810 maize cultivation scientifically justified? *Transgenic Res.* **19**, 1–12 https://doi.org/10.1007/s11248-009-9297-5

36 Kuntz, M., Davison, J. and Ricroch, A.E. (2013) What the French ban of Bt MON810 maize means for science-based risk assessment. *Nat. Biotechnol.* **31**, 498–500 https://doi.org/10.1038/nbt.2613

37 Frewer, L.J., Miles, S. and Marsh, R. (2002) The media and genetically modified foods: evidence in support of social amplification of risks. *Risk Anal.* **22**, 701–711 https://doi.org/10.1111/0272-4332.00062

38 Coo, G., Robbins, P.T. and Pieri, E. (2006) 'Words of mass destruction': British newspaper coverage of the genetically modified food debate, expert and non-expert reactions. *Public Underst. Sci.* **15**, 5–29 https://doi.org/10.1177/0963662506058756

39 Zajc, J. and Erjavec, K. (2014) 'Othering' agricultural biotechnology: Slovenian media representation of agricultural biotechnology. *Public Underst. Sci.* **23**, 678–687 https://doi.org/10.1177/0963662512467412

40 Augoustinos, M., Crabb, S. and Shepherd, R. (2010) Genetically modified food in the news: media representations of the GM debate in the UK. *Public Underst. Sci.* **19**, 98–114 https://doi.org/10.1177/0963662508088669

41 Maeseele, P.A. and Schuurman, D. (2008) Biotechnology and the popular press in northern Belgium. A case study of hegemonic media discourses and the interpretive struggle. *Sci. Comm.* **29**, 435–471 https://doi.org/10.1177/1075547008316221

42 Blancke, S., Van Breusegem, F., De Jaeger, G., Braeckman, J. and Van Montagu, M. (2015) Fatal attraction: the intuitive appeal of GMO opposition. *Trends Plant Sci.* **20**, 414–418 https://doi.org/10.1016/j.tplants.2015.03.011

43 National Academies of Sciences, Engineering and Medicine. *Gene Drives on the Horizon: Advancing Science, Navigating Uncertainty, and Aligning Research with Public Values, 2016*. The National Academies Press

44 Kuntz, M. (2016) Scientists should oppose the drive of postmodern ideology. *Trends Biotechnol.* **34**, 943–945 https://doi.org/10.1016/j.tibtech.2016.08.008

45 Kuntz, M. (2017) Science and postmodernism: from right-thinking to soft-despotism. *Trends Biotechnol.* **35**, 283–285 https://doi.org/10.1016/j.tibtech.2017.02.006

46 Reiss, M.J. (2001) Ethical considerations at the various stages in the development, production, and consumption of GM crops. *J. Agric. Environ. Ethics* **14**, 179–190 https://doi.org/10.1023/A:1011384323885

47 Lacey, H. (2002) Assessing the value of transgenic crops. *Sci. Eng. Ethics* **8**, 497–511 https://doi.org/10.1007/s11948-002-0003-8

48 Lassen, J., Madsen, K.H. and Sandøe, P. (2002) Ethics and genetic engineering — lessons to be learned from GM foods. *Bioprocess Biosyst. Eng.* **24**, 263–271 https://doi.org/10.1007/s004490100262

49 Lönnroth, M. (2003) The use of GM crops in comparison with previously ethically loaded issues in the relationship between man and nature. *Acta Agric. Scand. Sect. B* **53**, 68–72 https://doi.org/10.1080/16519140310015067

50 Karlsson, M. (2003) Ethics of sustainable development — a study of Swedish regulations for genetically modified organisms. *J. Agric. Environ. Ethics* **16**, 51–62 https://doi.org/10.1023/A:1021735201970

51 Glass, S. and Fanzo, J. (2017) Genetic modification technology for nutrition and improving diets: an ethical perspective. *Curr. Opin. Biotechnol.* **44**, 46–51 https://doi.org/10.1016/j.copbio.2016.11.005

52 Ricroch, A., Clairand, P. and Harwood, W. (2017) Use of CRISPR systems in plant genome editing: towards new opportunities in agriculture. *Emerg. Top. Life Sci.* **1**, 169–182 https://doi.org/10.1042/ETLS20170085

53 Weale, A. (2010) Ethical arguments relevant to the use of GM crops. *New Biotechnol.* **27**, 582–587 https://doi.org/10.1016/j.nbt.2010.08.013
54 Devos, Y., Sanvido, O., Tait, J. and Raybould, A. (2014) Towards a more open debate about values in decision-making on agricultural biotechnology. *Transgenic Res.* **23**, 933–943 https://doi.org/10.1007/s11248-013-9754-z
55 Robaey, Z. (2015) Looking for moral responsibility in ownership: a way to deal with hazards of GMOs. *J. Agric. Environ. Ethics* **28**, 43–56 https://doi.org/10.1007/s10806-014-9517-8