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The Life And Times Of Transgenics

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10 The life and times of transgenics

Hugh Lacey

The transgenics (TGs) – or genetically modified organisms (GMOs) – that have been planted and harvested in agricultural practices are offspring of the liaison of technoscience and multinational agribusiness. Ambiguities linked with this liaison – having to do with harms, risks, benefits and alternatives, and how to investigate them scientifically – underlie competing narratives of the life and times of these TGs and the turmoil that has marked it. A legitimating narrative emphasizes their technoscientific parentage and alleged scientific support for claims concerning the benefits and risks of their rapidly spreading use and the alleged absence of alternatives. A critical narrative contests that there is such scientific support, highlights agroecological alternatives, and emphasizes that the socioeconomic environment into which TGs were born, in which great stock is placed on technoscientific innovation that contributes to economic growth, has been a fertile one for their rapid spread into agricultural practices in many parts of the world. By clarifying what is at stake in these competing narratives, we are better able to understand the ontology and distinctiveness of TGs.

Figure 10.1 Golden Rice refers to varieties of TG rice that have been engineered to contain beta carotene, a source of vitamin A. Since 2000 it has been undergoing field trials and is not yet available for agricultural use. The legitimating narrative holds that, especially in impoverished regions of the world, it will be able to deaf effectively with problems, such as blindness, caused by deficiency of vitamin A. The critical narrative disputes this, and regards golden rice as a simplistic, techno-fix solution to such problems. Thanks to the International Rice Research Institute (IRRI) for giving permission to use this image.

Transgenics – technoscientific objects

TGs owe their existence to technoscientific research, development and innovation (R&D&I) – to technologically accelerated science (molecular biology and genetics) and scientifically informed technology (biotechnology). Their origins lie in the celebrated discoveries that genomes of organisms contain sequences of DNA and that separating and recombining them is the major mechanism underlying such biological processes as sexual reproduction, and in the development of engineering techniques that have enabled an expanded range of these sequences to be recombined. These techniques involve inserting into the genome of a seed or plant tissue-culture DNA sequences, typically taken from organisms of unrelated species, which bring it about that the mature or growing plants acquire designated properties. TGs are modifications, induced by these (and potentially other) techniques,[1] of plants that exist in agricultural fields or natural ecosystems. Yet, although they are biological organisms, they could not have arisen by means of the mechanisms of natural selection or traditional cross-breeding used by farmers and conventional plant breeders. TGs are technoscientific objects.

It is a matter for theoretically informed experimental investigation and further development of the techniques of genetic engineering to discover what properties plants could be engineered to have. They certainly include herbicide/pesticide resistance and toxicity to certain pests, and if ongoing R&D is successful, they will also come to include such properties as providing sources of nutrition, producing higher yields and ability to grow in salt depleted, mineral deficient, dry or waterlogged soils. This R&D is motivated by the convictions – none of which gain credibility simply from the fact that TGs are efficacious products of well conducted technoscientific research – that it is advantageous for crop plants to have properties like these regardless of the mechanisms of their origins, that these mechanisms are irrelevant for assessing the risks and benefits of growing them and consuming their products, and that TGs are needed (i.e., they can provide benefits that overall surpass those of other available agricultural options).

The space of agricultural options

Scientific research relevant to determining whether TGs are needed would first have to address questions about the space of agricultural options (see Lacey 2005, ch. 10, 2015a, 2016, forthcoming). If available agricultural approaches – 'conventional', organic, biodynamic, agroecological, indigenous and others – were appropriately combined, used with locally specific adaptations, accompanied by viable distribution methods and informed by appropriate scientific research, would they be sufficiently productive to meet the food and nutrition needs of the whole world's population in the foreseeable future, sustainably so and relatively free from serious risks?

If the evidence supports 'yes', then TGs are not needed for these agricultural ends, Even so, it would be pertinent to ask: What would be the advantages, if any, and for whom and under what conditions, of granting a place (and how significant a place?) to TG-oriented approaches among the approaches in use?

If 'no', then a third question becomes pertinent: What are the limitations of currently available approaches, and does scientific research support that introducing TG-oriented farming (utilizing TGs of what plants and with what properties?) could overcome them?

R&D&I of TGs was not a sequel to research that addressed questions like these. It went ahead without much input from farmers, their organizations, agricultural scientists and others working to address the food and nutritional needs of poor people. Research dealing with the space of agricultural options was not conducted or even contemplated. Thus, TGs were not introduced in response to scientific evidence supporting, e.g., that they have a role to play in overcoming limitations of prevailing farming practices. Nevertheless, if TGs were to be engineered successfully to have such properties as containing sources of nutrition, ability to produce higher yields or to grow in salt depleted or mineral deficient soils, then it might be plausible to consider it a matter of priority to investigate their effectiveness (and the side effects of their use) in comparison with those of plants that can be produced by, for example, agro-ecological methods. The TGs actually being used in agriculture today, however, do not have these properties.

The interests of multinational agribusiness

Commercial interests have dominated the R&D that produced the TGs currently being planted and harvested for major crops. Early on, for technical, economic and strategic reasons, attention was given to developing and marketing TGs with the properties of toxicity to certain classes of insects or resistance to herbicides whose active ingredient is glyphosate. (Except in passing, I will explicitly discuss only herbicide resistant TGs.) Technically, it is simpler (and less costly) to engineer TGs of these kinds, and they can be developed more quickly than those (e.g., higher yielding plants) that, if they can actually be produced, will require more complex engineering techniques. Economically, they could be put to use quickly to recoup the costs of the R&D&I and begin to produce profits. Strategically, agribusiness corporations, as a consequence of gaining intellectual property rights (IPR) to genetic engineering techniques and newly developed transgenic varieties, have been able to use those protections to control most of the research that is conducted on TGs.

TGs (including varieties of corn, soy, canola, rice and cotton) of these two kinds and their products have been successfully marketed in many countries, especially to large-scale producers, manufacturers of processed food and companies that market food for growing livestock. In addition, raw and processed products of TGs have been successfully marketed to consumers in supermarkets throughout the world, but in the United States, for example, they are not labeled as TG products and marketed as such. Successful marketing to farmers is connected with the claims that glyphosate may be used efficaciously for weed control without harming the growing TGs; that using it with TG crops requires less use and fewer applications of pesticides – factors said to be conducive to higher yields or reduced crop losses, higher profits and a more congenial work environment. It is also said to be less toxic to human beings than most other available herbicides and more friendly to the environment since it dissipates rapidly in soils. Many farmers (not all), especially large-scale producers, based on their experience of using TGs, testify to benefits like these and continue to engage in TG-oriented farming. Others engage in it because (linked with the merging of seed companies with those that produce TGs) they find it difficult to access non-transgenic seeds and because the conditions needed for engaging in other forms of farming have been weakened.

TGs with herbicide resistance and toxicity properties exist, and are now widely used, because using them is deemed advantageous by agribusiness and its clients. Technoscientific R&D&I brought them into existence, and it provides evidence for the efficacy of their use under specified conditions. Nevertheless, this does not suffice to provide scientific backing for the social value or legitimacy of these uses of TGs, for the questions about the space of agricultural options, which involve ecological and social factors, fall outside of its compass. This kind of R&D&I lacks the methodological resources, for example, to appraise the potential impact of forms of farming like agroecology.

Agroecology admits no place for using TGs; it is aimed at satisfying simultaneously, and in a balance determined by farmers and their communities, a variety of objectives, including productivity, sustainability of agroecosystems and protection of biodiversity, health of members of the farming communities and their surroundings, and strengthening of their culture and agency (Altieri 1995). In many ways, it is a development of traditional agricultural approaches that is informed by scientific knowledge and the living record of its practitioners.[2] It exemplifies practices in the space of agricultural options with proven success and whose potential needs to be more fully investigated empirically, and it provides a point of contrast that enables us to discern more clearly what TGs are.

Commodities or renewable, regenerative resources[3]

Traditionally, crop seeds have been (for the most part) renewable regenerative resources, sources and parts of farmers' harvested crops, reproduced in and selected from crops using methods that have been adapted and improved by numerous farmers, informed by local, traditional knowledge that has been accumulating over the centuries. Crop plants, grown from seeds selected in traditional ways (and contemporary agroecological extensions of them), tend to be integral parts of sustainable ecosystems that generate products that meet local needs, and cultivating them is compatible with local cultural values and social organization. Crop seeds, which embody traditional knowledge (that can be consolidated, corrected and expanded in the light of practical experience and scientific knowledge), have been considered to belong to the common patrimony of humankind, available to be shared as resources for replenishing and improving the seeds of fellow farmers.

In recent times, ever intensifying efforts have been made to replace crop seeds that are predominantly renewable regenerative resources by seeds that, like currently used TGs, are for the most part commodities. As commodities, they have features and uses that are integrally connected with the availability of other commodities (e.g., chemical inputs and machinery for cultivation and harvesting); increasingly they are grown for uses other than human food production (e.g., biofuels), often implicated in regimes of intellectual property rights (IPR), developed by professional breeders and scientists and produced largely by capital-intensive corporations. They are not reproduced in and selected from farmer-harvested crops; they are not components of stable ecosystems, and they are not available to be shared freely with fellow farmers. The commoditization of the seed is an integral part of the transformation of the social relations of farming in the direction of the dominance of agribusiness and large-scale farming. It depends on breaking the traditional unity whereby seeds (renewable regenerative resources) are simultaneously sources and parts of crops and harvested grain is both source of food and seed for new plantings. This transformation predates the discoveries that enabled the development of TGs. It was initiated with the introduction of 'high-intensity' models into agriculture, models based on growing monocultures with consequent weakening of ecological sustainability and biodiversity, mechanization, the extensive use of chemical inputs and agrotoxics, and further developed by planting hybrids that do not reproduce reliably, so that new seeds must be bought regularly from seed companies. The introduction of TGs, and their being protected by IPR, have reinforced and intensified pressures for the breakdown of the traditional unity.[4] Furthermore, the IPR protections underlie a socioeconomic mechanism that, if needed, would function to block decisively even the remote possibility that TGs might themselves become new renewable regenerative resources; their manufacturers make use of the IPR to prohibit farmers selecting seeds from their crops and saving them for subsequent plantings.

Transgenic plants share many biological features with all plants, and unlike hybrids, some of them may reproduce reliably for some generations. However, there are biological mechanisms that virtually ensure that TGs cannot themselves become new renewable regenerative resources. First, it is unlikely that TGs would reproduce reliably beyond a few crop generations, for they are complex biological, ecological and social objects in a complex environment, open to multi-causal analysis implicated in various levels of organization, higher level properties, and feedback loops between higher and lower levels of organization. This kind of complexity involves deep uncertainty, for example, about possible switching of the location (or breaking up) of the inserted genetic materials across generations and about its consequences (Mitchell 2009, ch. 5). Second, any variety of TGs is likely to be usable for only relatively few generations. Consider, for example, crops that are resistant to glyphosate. Research supports that using glyphosate for spraying these crops is efficacious (it kills targeted weeds leaving the crop unharmed) for some generations. When glyphosate-resistant TGs were introduced, however, it was anticipated that in accordance with well known evolutionary mechanisms, after an unpredictable number of generations (that could be extended by using glyphosate in accordance with appropriate regulations and guidelines), weeds would appear ('superweeds') that themselves would be resistant to it.[5] Then, using these TGs increasingly becomes obsolescent. Consequently, if herbicide-resistant TGs are to be used efficaciously over the long haul, new varieties must be introduced regularly that are resistant to herbicides (successors to glyphosate, e.g., one known as '2,4-D') (Pollack 2014) required to deal with new generations of superweeds. In other words, a regular sequence of new {TG variety, herbicide} pairs is required, more generally of {TG variety, herbicide, fertiliser, . . .} 'n-tuple packages'.

TGs are typically components of n-tuple packages. What the components of the packages are, and the mechanisms leading to obsolescence of earlier varieties, varies with the kind of TGs involved. TG-oriented farming depends on regular innovations of new varieties of TGs and generally of n-tuple packages that contain externally provided inputs required for using them efficaciously. This exacerbates the breakdown of the traditional unity (that nurtures seeds as renewable regenerative resources), and furthers the dependence of agriculture on agribusiness, with questionable ecological and social consequences.

Risk assessments and the legitimacy of using transgenics

I indicated previously why priority was given to R&D&I of varieties of TGs that have herbicide resistant and toxicity properties. Once developed and their use confirmed to be efficacious, and – as normally expected of any biotechnological innovation – they had passed standard risk assessments [SRAs], they were rapidly introduced into agricultural practices. SRAs are empirical (laboratory or small-scale field) studies concerning the effects – described as potentially harmful for human health or the environment and occasioned by physical, chemical, or biological mechanisms – of implementing innovations in socioeconomic practices and of their seriousness, probability of occurrence and capacity for being effectively regulated and thereby contained (Lacey 2005, ch. 9, 2015b).

Agribusiness and public regulatory bodies usually agree that, when the use of a variety of TGs has been confirmed to be efficacious, the legitimacy of using it and introducing it widely into agricultural practices depends, in addition, only on it passing an adequate array of SRAs and then being used according to regulations informed by the SRAs. Moreover, they generally maintain that the TGs actually in use have met this condition. In accordance with this, they do not engage in or take into account outcomes of research pertaining to the space of agricultural options. It is as if the quick, thinly mediated movement from efficacy to legitimacy gains its rationale from a covert, unarticulated, unchallenged ethical principle – the Principle of the Presumed Legitimacy of Technoscientific Innovations [PLT] (Lacey 2016) – that applies generally to technoscientific innovations:

> Ceteris paribus, it is legitimate to implement efficacious technoscientific innovations in social practices without delay, and even to tolerate a measure of social and environmental disruption in doing so, provided that, after adequate and sufficient research has been conducted, compelling evidence has not been obtained to demonstrate that the implementation would occasion serious harm or risk of it – and normally this condition is satisfied if the array of SRAs performed is judged to be satisfactory by technical experts in risk assessment.

The tumultuous times of transgenics

The 'common sense' of our times tends to take for granted that technoscientific innovations are indispensable for solving the big problems facing the world today, that valuable practical uses will soon be found for virtually any technoscientific innovation and that questions of the legitimacy of using innovations rest only upon their efficacy and the quality and sufficiency of the SRAs conducted on them – and so lie within the authority of technical experts in risk assessments. Concerning TGs, most of the experts, who consult with agribusiness and regulatory bodies, endorse the legitimacy and social value of using them. From this perspective, then, the R&D&I of TGs should have been uncontroversial.

Nevertheless, it has occasioned a lot of turmoil. TGs have experienced tumultuous times. The necessity, social value and legitimacy of using them has been questioned by an assortment of groups for a variety of reasons, and the resulting controversies tend to be marked by confrontational tactics and discourse often marked by rhetorical excesses (Lacey 2005, ch. 6). This should not obscure, and the critical and legitimating narratives that I will sketch should also not obscure, that the turmoil is principally about the social value of R&D&I of TGs – about the legitimacy of their immediate implementation, intensive utilization and widespread diffusion throughout the world in the agricultural practices that produce major crops, and about the place that should be accorded them (in relation to other forms of agriculture) in national and international agricultural policies (Lacey 2005, ch. 6).

The critical narrative

In the critical narrative that has emerged, the social value of using TGs is challenged, as also is the claim that there is sound scientific backing for the legitimacy of using them (Lacey 2005, forthcoming). The most fundamental proposal of this narrative, as I interpret it, is that better ways to farm (using agroecological methods), which could reap more significant benefits with less risk for most people, can be identified in the space of agricultural options (Lacey 2005, 2015a). It also cites empirical evidence that supports that using TGs (1) is irrelevant for meeting the needs of vast numbers of smallholder farmers especially in poor regions and for contributing to worldwide food security, and (2) is actually causing serious harm for agroecosystems and many poor rural communities. It occasions risks (i.e., potentially harmful consequences [Lacey 2015b]), concerning human health, the environment, social arrangements and worldwide food security, that lie outside of the purview of SRAs. Hence, these two conclusions are taken to indicate that SRAs are insufficient for adequate risk assessment and for informing regulations;[6] and, in view of the role played by PLT, that judgments made by regulatory bodies about risks (that only consider the results of SRAs) are not 'ethically neutral' technical judgments. Furthermore, the critical narrative maintains the central role accorded to TGs in many national and international policies does not take into account empirical investigation concerning risks (that cannot be dealt with in SRAs) and agroecological alternatives, or the interests of those who may be affected negatively by the policies – largely because political and economic power is exercised on behalf of interests of capital and the market in ways that (among other things) make it difficult to conduct independent research on TGs, and keep results of research that might run counter to the interests of the producers of TGs out of policy and regulatory deliberations.

According to the critical narrative, the deep roots of the turmoil lie in the fact that the introduction of TGs has not been informed by research dealing with the space of agricultural options, and that due attention has not been paid to the kinds of scientific methodologies needed to conduct such research and adequate risk assessments. This will be elaborated in my critical comments on the legitimating narrative in the section, 'The two narratives in critical interaction'.

The legitimating narrative

For the most part, agribusiness and regulatory/policy bodies simply dismiss the claims made in the critical narrative; they tend to take PLT for granted, and so they boil issues of legitimacy down to matters of efficacy and the technical adequacy of the SRSs. They appeal to specialized science to provide a cover of legitimacy for the offspring of the liaison of technoscience and agribusiness. Moreover, they do not concede the ethical high ground to the critics. Deeply rooted in the 'common sense' of our times, in which PLT is secreted, they consider it virtually an ethical imperative to prioritize technoscientific 'solutions' for the big problems of the world (e.g., hunger in poor countries), as well as for any harmful effects that may be caused by technoscientific innovations themselves (e.g., environmental damage), and an ethical failing to cast doubt on the potential or the legitimacy of R&D&I that may lead to such 'solutions' (Lacey 2016).

This 'common sense' provides the background and key categories for the unfolding of the narrative in which the social value of TGs (GMOs)[7] is articulated (in the press, at public hearings, on websites of agribusiness corporations, etc.). In addition to claims about the benefits of using TGs (see the "The interests of multinational agribusiness" section), the legitimating narrative incorporates claims like the following:[8]

1 GMOs are the latest development in a long line of genetically modified organisms going back to the beginnings of agriculture. They are biological organisms just like – 'substantially equivalent to' – their predecessors, and they need no more scrutiny and regulation than new varieties introduced by older methods of selection and cross-breeding.
2 GMOs are novel technoscientific inventions – produced in the first instance, not by biological mechanisms, but by techniques of genetic engineering informed by knowledge and skills gained in molecular biology and biotechnology – and so, unlike their predecessors, they and the techniques that produce them can be incorporated into regimes of intellectual rights (IPR).
3 R&D is well advanced on GMOs with a range of 'highly desirable' properties (e.g., providing sources of nutrition and ability to grow in mineral depleted soils), so that potentially using GMOs could provide benefits for all farmers, as well as solutions to hitherto intractable problems of hunger and malnutrition and of dealing with certain kinds of pests. Herbicide resistance and insect toxicity are prioritized in the 'first generation' of GMOs; these have provided a kind of testing-ground for the kinds of GMOs that will follow, which require more complex engineering techniques, and so take more time and investment of resources to develop.
4 Agribusiness corporations are contributing to deal with problems of hunger and malnutrition, by licensing (frequently free of charge) the use of patented materials for developing crops with some of the properties (mentioned in item 3) to research institutions like CGIAR that aim "to reduce poverty and hunger, improve human health and nutrition, and enhance ecosystem resilience through high-quality international agricultural research, partnership and leadership."[9] The GMOs that these institutions develop have nothing to do with profits for agribusiness; they may be given as 'gifts' to the farmers; and (in some cases) farmers may be permitted to save seeds from the harvest for planting for future harvests.
5 GMOs occasion no serious risks to health or environment that cannot be managed under scientifically informed regulations, and empirical studies confirm that those already released for commercial use, having passed an appropriate array of SRAs cause no significant harm (cf. the 'Risk assessments and the legitimacy of using transgenics' section).
6 Unless GMO-oriented farming becomes widespread, there is no way to provide for the food and nutrition needs of the world's population over coming decades – there is no alternative to continued and prioritized R&D&I of GMOs that does not occasion the risk of massive hunger throughout the world.[10]
7 Items (1), (3), (5) and (6) have the backing of science.

The two narratives in critical interaction

In this section, principally by exploring some of the implications of the legitimating narrative, I will identify key points at which the legitimating and critical narratives come into sharp conflict.

Dualist ontology

TGs are, among other things, biological organisms that under appropriate conditions will grow into mature plants from which, for example, grain will be harvested, and products of genetic engineering, not of mechanisms of natural or farmer-aided selection. The legitimating narrative maintains that, as biological organisms, TGs are just like any other crop plants (item 1); but, as technoscientific objects, they are unlike them (item 2). It incorporates a kind of dualist ontology: in the context of risk assessment, TGs are said to be just like any other crop plants; in commercial contexts they are hailed as novel technoscientific inventions, for which (unlike for other types of crop plants) intellectual property rights (IPR) may be claimed. What they are in the commercial context (products of genetic engineering) is considered irrelevant to what they are in the context of risk assessment, as if their different kinds of origins must make no difference to their functioning as plants, and to their (possible) effects on human beings and the social and ecological environment. Hence, according to the narrative, risk assessment (item 5) does not involve investigating the effects (on people, social arrangements and ecologies) that using TGs might occasion in virtue of mechanisms that derive from their being commercial objects and property. Just as Descartes's dualist account of human beings required keeping the mind out of accounts of the causal order of the material world, so does the narrative's dualist ontology of TGs serve to keep their commercial and property aspects out of causal analyses pertinent to harms, risks and alternatives. It also contributes to isolate the alleged role of TGs in solving problems connected with hunger and malnutrition (item 6) from investigations of the social causes of the problems and their persistence, and thus to undercut investigations concerning whether or not using them may strengthen corporations that are themselves integral components of the very socioeconomic system that maintains and deepens these problems (Lacey 2005, ch. 8).

Are transgenic seeds just like seeds used in agroecology?

TGs are typically components of n-tuple packages (see the "Commodities or renewable regenerative resources" section). The efficacy of using them depends on planting them, not in potentially sustainable ecosystems, but in ecosystems that receive and continue to receive the required industrially produced inputs. This cannot be ignored when they are used by farmers, and it is important for commercial considerations. Based on appeal to item 1, however, it too is ignored in risk assessments, as is the fact that the spread of TG-oriented farming must undermine the conditions needed for preserving the traditional unity of seeds as both sources and parts of crops. Contrary to item 1, TGs are not just like seeds and plants used in farming practices (like agroecology) that aim to preserve seeds as renewable regenerative resources. The two kinds of farming are incompatible. With the deployment of TGs on an ever larger scale over an extended period of time, the conditions for practicing, for example, agroecology would be further eroded. Then, not only would it remain the case that the productivity (as well as sustainability, capacity to provide food security for everyone, etc.) of TGs has not been empirically compared with that of farming practices like agroecology, but also it would become less and less possible to engage in empirical research that could make such comparisons.

The safety of transgenics – scientifically based or convenience for agribusiness?

TGs are outcomes of genetic engineering (item 2), not of natural or farmer-aided selection. Appeal to item 1 serves to ground ignoring the different mechanisms of the origins of TGs and the seeds used, for example, in agroecology when discussing items 5 and 6, although research that could test the 'substantial equivalence' of their respective products (item 1) would have to take into account the considerations about complexity mentioned previously (see the "Commodities or renewable regenerative resources" section). Because of the biological complexity of TGs and their being components of n-tuple packages, SRAs need to be conducted one-by-one for each {TG-variety, environment} of use, and to be accompanied by ongoing monitoring of their actual uses, partly to pick up potential oversights of the SRAs that have been conducted and new risks that might arise, and partly because environments change in response to agricultural use. Although these features of well-conducted SRAs are generally acknowledged by regulatory bodies, they are downplayed in practice – and also in the legitimating narrative, which claims that using TGs is safe (item 5) and will remain so for the new varieties that will be regularly introduced in the future. Since the efficacy of using particular varieties of TGs is likely to be short lived ("Commodities or renewable regenerative resources" section), claiming (without significant qualifications) that TGs do not occasion serious unmanageable risks serves to deflect concerns about the safety of future varieties. This claim is also part of the argument that developments of TGs with herbicide and toxicity properties are just initial steps (item 3) that demonstrate that using TGs can be efficacious and free from serious risks, and that provide the technical context for testing and perfecting more complex engineering techniques that are fundamental for realizing the promised potential of R&D&I of TGs (item 6). SRAs need to be conducted one by one for each {TG variety, environment} of use; however, those conducted on currently used TGs[11] cannot provide evidence that the TGs of the future will be safe. Asserting item 5 reflects commercial, economic and political policies; it is not backed by the results of well-conducted scientific research (contra item 7).

Objects that embody the values of capital and the market

The TGs actually in use are commodities and/or objects for which IPR may be held (item 2). IPR serve as instruments for ensuring profits. . . . The legitimating narrative maintains emphatically that holding IPR to TGs is indispensable for their development; without them, agribusiness corporations would not provide funds for R&D&I of TGs, for they would not readily be able to protect their investments and rapidly recoup the costs of the R&D&I.

While not highlighted in the narrative, IPR are also deployed to gain competitive advantage, to gain control both of R&D&I of TGs and of as many aspects of the agricultural economy as possible, and to prevent unauthorized (i.e., independent) research on the risks of using TGs. These deployments are crucial for understanding the social environment that has nourished the development of TGs. Agribusiness corporations – by developing the 'first generation' of TGs rapidly (item 3) and (in the process) gaining IPR protections to numerous varieties and genetic engineering techniques – have been able to shape and largely control the research agenda of TGs. Furthermore, in the name of item 6, they have used their power to push for control of the whole agricultural research agenda, so that TG-oriented farming is prioritized and pressures are exerted (not without resistance) to sideline other forms of farming. It is of the nature of these TGs to spread widely throughout the world by way of mechanisms of the market and intellectual property.

Item 4 maintains that TGs may be used in service to a variety of values, not only increasing profits for agribusiness and its clients, but also values like those pursued by CGIAR (item 4). To date, few of the kinds of TGs promised for dealing directly with the needs and problems of impoverished areas have actually been introduced commercially. Leaving that aside, however, the more fundamental point is that the range of values that TGs currently in use, and those anticipated, may come to serve is inherently limited because these TGs embody values of capital and the market. This is reinforced by the fact that TGs cannot be used without inputs that usually are only available commercially, and that introducing the TG-oriented farming in poor countries requires also some degree of penetration of the institutions of capital and market – furthering the breakdown of the traditional unity (that nurtures seeds as renewable regenerative resources), and undermining the social relations that go hand in hand with practices that incorporate it. TGs, developed to serve values of poverty reduction and the like, are not exceptions, for the research that produces them cannot proceed without licensing agreements (which are vulnerable since they may be revoked) with the corporations.

Organizations like CGIAR often criticize agribusiness for excessive concern with profits and for not giving enough attention to the needs of the poor, and they do not prioritize research on TGs to such an extent that all alternatives in the space of agricultural options are completely sidelined. Nevertheless, like those engaged in directly commercially motivated research, they tend to presuppose a negative answer to the first of the questions about the space of agricultural options (the "The space of agricultural options" section), and to presuppose that TGs are not only indispensable for the agriculture of the future (item 6), but also that many immediate problems and needs cannot be addressed without developing and using appropriate TGs. These presuppositions lead to prioritizing research related to TGs and leave few resources for investigating other alternatives in the space of agricultural options. Consequently, risks that cannot be assessed in SRAs –that using TGs threatens to undermine the conditions (e.g., the traditional unity) for engaging in forms of farming, such as agroecology, especially suited for smallholder farmers in poor countries – will not be adequately investigated. Then, relevant kinds of evidence will not be brought to bear on item 5, so that it will remain inadequately tested empirically. And item 6 is simply presupposed (perhaps because it seems to fit so well with the 'common sense of our times'). Certainly, like item 5, it is not supported by scientific evidence; and it could not be, unless R&D&I of TGs were to become embedded in research that addresses the space of agricultural options. The seeds developed in organizations like CGIAR may be used outside of the dominant market mechanisms, but their existence and the forms they have depend on the commercially instigated research that has been conducted, and on how they fit into national and international policies tied to economic growth – and they remain subject (to greater or lesser degrees) to claims of IPR. They embody the same kind of knowledge as commercially exploited TGs, and like them embody (albeit to a lesser degree) values of capital and the market (Lacey 2015a).

Must TGs embody values of capital and the market? If research on the space of agricultural options had shown that some varieties of TGs were needed in some environments, and if the resulting R&D were not dominated by institutions linked to policies that seek innovations that contribute toward economic growth, the life and times of TGs might have been different. Even so, it would remain that TGs are components of n-tuple packages and that agricultural approaches like agroecology have enormous unfulfilled promise. Nevertheless, it cannot be precluded a priori that some types of TGs (perhaps not yet anticipated) might have a substantial place in the agriculture of the future.

Does the use of TGs have the backing of science?

The legitimating narrative puts the authority of science behind the R&D&I of TGs, appealing not only to the technoscientific parentage of TGs, but also to science for giving a semblance of legitimacy to the offspring of its liaison with agribusiness. Item 7, therefore, has an important place in it. I have maintained, however, that item 5 and 6 are not well supported by scientific evidence. The conviction that they are well supported reflects that the narrative draws upon an impoverished conception of science, albeit one widely held in mainstream scientific institutions.[12] According to this, scientific research is conducted under 'decontextualizing strategies' (DSs) (Lacey 2012, 2016): theories and hypotheses are constrained so that they are able to represent things and phenomena as being generated from their underlying structures, their processes and interactions and those of their components, and the laws governing them; and empirical data that are sought for and recorded are largely quantitative, obtained by means of interventions with measuring instruments, and often of phenomena in experimental spaces. DSs dissociate the phenomena investigated from their human, ecological and social contexts, from any links they have with ethical and social value. If 'science' is limited to the use of DSs, then – provided that a sufficient array of SRAs (which deploy DSs) are passed – there is no 'scientific' evidence that serious risks (that cannot be contained by enforced 'scientifically' based regulations) are occasioned by using TGs (item 5). Moreover, 'science' cannot assess any alternatives to TGs other than those that rely on the input of research conducted under DSs; and of these alternatives (that include agrotoxics-intensive conventional agriculture) TGs may indeed be superior. That is what the 'scientific' backing for using TGs amounts to (see Lacey 2005, 230–235).

DSs are inadequate for investigating the consequences of using TGs, qua commercial objects and property, however, and so for investigating risks (potentially harmful consequences) for human beings, social arrangements and ecological systems that may be occasioned by socioeconomic mechanisms. Thus, the absence of 'scientific' evidence obtained under DSs for the existence of risks is never sufficient reason for denying that there are risks incurred by using TGs (Lacey 2005, ch. 9, forthcoming). Similarly, DSs are inadequate for investigating the possibilities of agroecosystems that are cultivated in accordance with the objectives of agroecology.[13] But, without investigating them, the questions raised about the space of agricultural options cannot be answered on the basis of empirical evidence, and item 6 could not become well established. The outcomes of research conducted more or less exclusively under DSs cannot be decisive in the context of actual agricultural practice – where risks are occasioned in virtue of all the kinds of things that seeds and plants are, and where there is plenty of empirical support for the benefits of practices like agroecology that are integrally connected with the contexts of their use.

To investigate risks and alternatives adequately, context-sensitive strategies (CSs) need to be adopted (complementing, not doing away with, DSs), where knowledge and understanding gained under them is held to the same standards of testing as those utilized under DSs. The strategies of research in agroecology provide exemplary instances (Lacey 2015a, 2016). Research conducted under CSs confirms that there are risks of using TGs, including that of undermining forms of agriculture that offer better promise of being responsive to food security issues throughout the world, and it underlies the claim that alternative approaches such as agroecology should not only not be discarded but given priority support (Lacey 2015a). The legitimating narrative is permeated through and through with the conception of science as using only DSs; and also with the widely shared presupposition that is linked more generally with technoscientific developments (Lacey 2012) that science (so conceived) not only is shaping the future, but is the key to a better future. However, this presupposition could not be supported without investigation that uses some CSs. Challenging item 7 of the legitimate narrative in this way shows that some of the items and presuppositions of the legitimating narrative can only be held dogmatically, and that the narrative lacks the categories needed to grasp fully and clearly what TGs are.

Concluding remarks

What are TGs? They are technoscientific objects that embody scientific knowledge gained under DSs. They are biological organisms, realizations of possibilities discovered in research conducted under DSs (in molecular biology, genetics and biotechnology) brought to realization by means of technical, experimental and instrumental interventions. As such, they are components of social and ecological systems that embody values of technological progress (Lacey 2005, 17–28, 2012). They are also normally components of 'n-tuple packages', whose other components are essential in the immediate agroecosystems in which they are grown, as well as parts of an agroecosystem (the market) with worldwide dimensions, in which they are commercial objects whose uses are constrained by claims of IPR. As such, they embody values of capital and the market.

TGs have effects on human beings, social arrangements and ecological systems in virtue of all of the kinds of things that they are. Using them consolidates breaking the traditional unity (seeds both sources and parts of crops; harvested grain both source of food and seed for new plantings), and destroys the network of social relations linked with maintaining it. What TGs are cannot be grasped on the basis of the scientific inquiry using only DSs and knowledge that underlies their coming into being and that explains the efficacy of their use. Furthermore, that there are fundamentally different alternatives to using them gets no recognition or empirically based rebuttal in the legitimating narrative, and so those immersed in it also cannot grasp the intelligibility and scientific foundation of the alternative possibilities (especially agroecology) from which the most significant criticism comes. The proponents of the widespread use of TGs cannot understand the turmoil that marks the life and times of TGs.

Notes

1 Techniques not based on DNA recombination are now being developed – for example, one that leads to suppressing the expression of genes that enable the reproduction of certain viruses involves inserting double stranded (ds) RNA into a plant's genome.
2 Altieri (1995) and Vandermeer (2011) are key sources on agroecology, evidence for its productive successes and further potential, and its special suitability for farming in impoverished regions. See Lacey (2005, ch. 10) for more details and references.
3 The analysis of the next two paragraphs derives largely from Kloppenburg (1987) and from Shiva (1991). See Lacey (2005, ch. 7).
4 The breakdown of the traditional unity is not complete, and efforts to strengthen it are growing throughout the world – especially fostered by movements who aspire to 'food sovereignty', for whom agroecology is the preferred approach to farming (Lacey 2015a).
5 These TGs were introduced in the mid 1990s, and by 2010 superweeds had begun to cause problems. See Benbrook (2012).
6 The critical narrative also includes allegations that the SRAs dealing with TGs that have actually informed the decisions of regulatory bodies have been marked by numerous scientific shortcomings, including that they do not take into account that TGs are parts of n-tuple packages (Lacey 2016, forthcoming).
7 The term 'transgenics' is intended in the critical narrative to connote that the kind of 'genetic modifications' involved in the production of these organisms could not occur in accordance with the mechanisms of natural or farmer-aided selection. Because the legitimating narrative highlights that they are, like those produced by farmer-assisted selection procedures and indeed any organism at all, modifications of already existing organisms, it refers to them as 'genetically modified organisms' (GMOs). As used in this article, 'TGs' and 'GMOs' are coextensive. I will use 'GMOs' only in this section.

8 The following claims are referred to in the text as 'item 1' to 'item 7'.
9 CGIAR, Consortium of International Agricultural Research Centers, http://en.wikipedia.org/wiki/CGIAR (accessed July 17, 2016). 'Golden rice' is the most celebrated instance of TGs being developed by CGIAR.
10 This claim is celebrated in high profile events – for example, in 2013, three scientists (connected with agribusiness) were awarded the World Food Prize for their significant contributions to the development of GMOs. See http://www.worldfoodprize.org/en/laureates/2010__2015_laureates/2013__van_montagu_chilton_fraley/ (accessed July 17, 2016). In contrast, in the same year the competing Food Sovereignty Prize, http://foodsovereigntyprize.org/the-honorees/ (accessed July 17, 2016), was awarded to three groups: Basque Country Farmer's Union, National Coordination of Peasant Organizations (Mali), and Tamil Nadu Women's Collective (India), that represent forms of farming present in the space of agricultural options that provide evidence for the productivity and sustainability of appropriately managed and developed traditional forms of farming, and that play key roles in addressing food security issues in impoverished communities.
11 This leaves aside questions about the alleged shortcomings of TGs; see also note 6.
12 This conviction is endorsed by many distinguished scientists (Lacey 2016, forthcoming).
13 See note 2.

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