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Popular misconceptions: agricultural biotechnology

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Agricultural biotechnology, especially genetic engineering or genetic modification (GM), is a topic of considerable controversy worldwide. The public debate is fraught with polarized views and opinions, some are held with religious zeal. Unfortunately, it is also marked with much ignorance and misinformation. Here we explore some popular misconceptions encountered in the public debate.

Introduction

Genetic modification (GM) technology is an esoteric field, requiring considerable training to be able to comprehend the capabilities – as well as the limitations – of GM applications in agriculture. Compounding this is the fear factor, a certain level of anxiety and awe of any powerful new technology. It is understandable, then, that the nontechnical public has legitimate concerns and questions: Is it safe? What are the benefits? What are the costs not only in economic terms but also to society and the environment?

Such questions as they relate to plants and crops have been discussed and debated since 1983, when the first plants were reported genetically modified using recombinant DNA technologies at the Miami Winter Symposium. Those and similar questions were also investigated in the professional scientific community, with a steady stream of biosafety investigations into the risks of GM technology conducted by, among others, the US National Academy of Sciences, The American Medical Association, The French Academy of Medicine and the UK Royal Society. Almost invariably, the general conclusion from studies conducted by professional medical and scientific societies was that GM was not entirely risk free, but carried the same kinds of risks as traditional means of genetic improvement. Although the initial questions and concerns over the risks associated with agricultural biotechnology have largely quieted in scientific circles, the emotional and polemic rhetoric continues in the public debate. Why, if the scientific community is now (mostly) comfortable with the relative safety of GM technology, is the public debate stuck on the same questions and fears raised a quarter century ago? As public scientists and educators, we are struck and deeply concerned by the poor state of scientific literacy among the wider community. Of course, molecular genetics is an arcane and complex field, requiring specialized training to comprehend fully. But the same rDNA technology when applied to medical advances or modern drugmaking engenders little to no public concern at all. If there were something inherently hazardous with the process of recombinant DNA technology, then those GM medical and pharmaceutical products would be just as suspect, perceived as just as hazardous. But they are not.

This dichotomy between medical and agricultural applications of the same technology likely contributed to a common belief in scientific circles that public skepticism of agricultural biotechnology (but not medical biotech) is largely driven by ignorance and that '*if only we can teach them the science, the public would accept agbiotech as readily as they do medical biotech*'. But this is facile, and often incorrect, thinking. As eloquently articulated by Mohr and Topping [1] in a recent review of consumer behavior, the scientific community should not assume consumer skepticism of agbiotech is owing to sheer and simple ignorance. Clearly, not all antibiotech sentiments are based on the ignorance of agriculture or of the rDNA technical mechanisms; the motivation in at least some cases seems based primarily on commercial and/or socioeconomic factors, not on health or environmental risk. Such players will cite, for example, concerns such as increased domination of the food supply by private corporations, or the likelihood of benefits of GE crops accruing disproportionately to large rich farmers at the expense of smaller, poorer farmers, or of disrupting the international trade dynamic. Although these issues may be legitimate points for discussion and debate, they are not borne of technical ignorance and they are not scientific risk based threats to health or environment.

Other skeptics are indeed simply ignorant, and the ignorance is not solely of molecular genetics or recombinant technologies. Instead, it is ignorance of basic biology and ordinary agriculture and food systems, reinforced by misinformation (so readily available on the internet, where many people now seek information) compounding the problem. The abundance of

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misinformation leads to a plethora of misunderstandings and misconceptions about agbiotech, which in turn lead to unnecessary anxiety and fear.

Some popular misconceptions

One of the most commonly stated concerns about GM is that it is unnatural, in that GM invariably transfers genes from one species to a different species, thus violating the natural 'species barrier', which, according to the belief system of some, does not occur in Nature or by conventional breeding methods.

Furthermore, GM is believed to be hazardous because it is 'fundamentally different' from traditional breeding, and traditional breeding to them is limited to cross-pollination, which only works between plants in the same species. In contrast, GM involves violent human mediated random insertion of DNA into the crop plant's genome, an unnatural disruption of the plant's DNA, in unpredictable, uncontrollable and with potentially hazardous unknown consequences.

In another misconception, organic farmers are told that if a pollen grain from a neighbor's GM crop floats into the organic crop, the farmer may lose organic status, followed quickly by the company owning the patent on the GM crop claiming legal ownership of the organic farmer's crop.

Another popular misconception, regarding herbicide tolerant (HT) GM crops, holds that GM crop farmers are able to 'douse' the HT crops to kill all weeds, leaving the GM crop to thrive [2]. Implicit in this belief is that HT crops are immune to any dose of any herbicide, and that HT crops can only be created by GM technology. Popular media embellish and perpetuate this fear, for example citing GM.

> ***'. . .superweeds, resistant to herbicides, are spreading almost everywhere modified crops are grown, often because they have acquired genes though cross-pollination'. [3].***

In addition to these globally distributed misconceptions, some are more localized to particular regions.

- In 2004 in America, voters in Mendocino County, California, banned the cultivation of GMOs in the county and at the same time legally redefined DNA as a protein.
- A Judge in the Philippines asks just how strolling through a GM cornfield can cause a man to become gay.
- Farmers in India are told that GE seeds carry a 'Terminator gene' that renders the seeds sterile and will infect other crops, causing them to be sterile too.
- The president of Zambia rejected food aid for his country (in the midst of a terrible famine) as he was counseled that the GM corn food aid was poisonous.

None of these misconceptions are true, in spite of some people's sincerely held belief that they are true.

Explanations and refutations

Fortunately, most of the misconceptions are easily refuted, if only to those willing to challenge their cherished beliefs.

Many of those who cite the 'species barrier' as a basis for rejecting GM technology will persist in their beliefs even after being shown how genes do indeed cross this 'barrier', both by Mother Nature and by the hand of humans conducting traditional plant breeding. An obvious example is bread wheat (*Triticum aestivum* L.), an ancient (and natural) hybridization of three different species. More recently, human hands, using conventional breeding techniques, created Triticale, a stable hybrid crop (used mostly for feed) composed of the genomes of rye (*Secale cereal*) and wheat (*T. aestivum*), which are not only different species, but different genera and even have differing chromosome numbers. The genomes of many crop species, when analyzed, show remnants of DNA originating in other species, so the concept of an inviolable 'natural species barrier' is demonstrably, flatly, unequivocally, wrong. Of course, conventional breeding cannot effect pollen-mediated hybridization between, say, a tomato plant and a fish. But that is not because the DNA of each is somehow unique or incompatible. This is why it is misleading to talk about a 'tomato gene' or a 'fish gene', as it perpetuates the misconception that there is something proprietary about fish or tomatoes having distinctive DNA and imparting 'ownership' over their respective genes. We know from genetic homology that most genes are shared anyway, with, for example, the human insulin gene being over 90% identical to the insulin gene of a rat [4]. While such homology may not convince skeptics, it will sway many, especially those diabetics who previously controlled their disease by injecting bovine insulin (before the availability of human insulin produced, incidentally, from GM bacteria genetically engineered with inserted *human* DNA!). But even the skeptics may be surprised to learn that plants can also carry a gene highly homologous to insulin [5], even though plants have no need to control blood sugar.

Furthermore, GM gene transfer is not invariably interspecific, in that it is possible to transfer genes from one plant to another plant of the same species (called 'cisgenics'). Why would anyone use controversial and highly regulated rDNA methods when noncontroversial and unregulated traditional crossing could transfer the useful traits? Sometimes desirable genes are located in proximity to undesirable genes that get carried along like unwanted baggage in conventional crossing, and GM allows the breeder to circumvent such 'linkage' problems by transferring only the useful gene. However, the use of GM for intraspecific gene transfers has not appeared to placate many skeptics or regulatory agencies.

The concern over GM's random insertions of DNA into the genome is borne of ignorance of ordinary biology. The plant's genome is not naturally stable and immutable, but constantly undergoing changes on a far greater scale than a simple insertion of a relatively small piece of DNA. Nature provides genomic disruptions via unpredictable, uncontrollable and with potentially hazardous unknown consequences from such natural events as spontaneous mutations, transposable elements and chiasmata (meiotic crossing over), all at apparently random loci and often with much greater disturbance to the plant's genome.

Traditional breeding can entail far more than simple cross-pollination, as assumed by so many. Plant breeders over the many years have acquired a substantial tool box of various means to alter the genetic makeup of a plant, of which cross-pollination is just one. Others include, but are not limited, to selection out of a population, somaclonal variation, and even mutation breeding using ionizing radiation to disrupt the DNA in myriad ways, all unpredictable, all uncontrollable and all with potentially hazardous unknown consequences. And none of the resulting new crop varieties are regulated for safety. Even the organic industry allows organic farmers to grow crop varieties developed using ionizing radiation to mutate the DNA of the (previously) 'natural' crop. But the mutant organic crops are not even labeled to allow consumers skeptical of ionizing radiation as a breeding method to avoid them.

Many organic farmers fear the mere presence of any GM material in their organic crops jeopardizes the organic status. But the rules, at least in the USA, are clear.

Organic status is based on a method of farming, so as long as the organic farmer follows the organic procedures, the organic status is not threatened, even if some prohibited material finds its way into the otherwise organic crop [6]. It is curious the organic industry has generous allowances for the presence of all manner of otherwise prohibited materials, usually on the order of 5%, but there is zero tolerance for intentional presence of GM material. Curiously, this 'zero tolerance' for GM was established within the organic industry itself, not by any open or democratic process. Yet now the organic industry wants democratic civil societies to enforce the fiat of a group of unelected partisans on everyone. But even this problem is readily solved. All of the friction between organic and conventional or GM farmers would dissipate if the organic industry would adopt a reasonable tolerance for GM materials, as they have for other undesired products.

The fear about a company claiming ownership of a farmer's crop based on the inadvertent presence of GM pollen grain or seed is also widespread and equally unfounded. The usual cited source for such fears is the 2001 Monsanto versus Schmeiser litigation, in which the company sued Mr Percy Schmeiser, a Canadian farmer, for growing their Roundup Ready canola without an appropriate license. As his defense, Mr Schmeiser claims Monsanto's Roundup Ready canola turned up on his farm due to either cross-pollination from '. . .*wind or insects, seed blown from passing trucks, or dropping from farm equipment, or swaths blown from neighbours' fields*' [7]. In any case, Mr Schmeiser claims he was entirely innocent of the charges and in fact Monsanto's seeds have 'trespassed' and contaminated his own canola. When the trial judge ultimately ruled in favor of Monsanto, word spread that Mr Schmeiser lost the case even though he was the innocent and wronged party. The court record shows, however, that it was not just a few seeds from a passing truck, but that Mr Schmeiser was growing a crop of 95–98% pure Roundup Ready plants, a commercial level of purity far higher than one would expect from inadvertent or accidental presence. The judge could not account for how a few wayward seeds or pollen grains could come to dominate hundreds of acres without Mr Schmeiser's active participation, saying '. . .*none of the suggested sources could reasonably explain the concentration or extent of Roundup Ready canola of a commercial quality evident from the results of tests on Schmeiser's crop*'. [7].

HT crops are certainly among the most successful GM crops commercialized and among those attracting the most attention from skeptical public. But those who believe GM farmers relish being able to douse their fields with any herbicide to kill all weeds while the crops flourish are mistaken on several points. First, few farmers are profligate with pesticides, including herbicides. They are expensive, among the highest input costs for most farmers, so farmers use them as sparingly as possible. Also, most farmers recognize that all chemicals can be hazardous if abused and so need to be treated with respect. Second, HT crops are made resistant only to a specific herbicide, and gain only a limited immunity (usually double the normal lethal dose). That is, a plant made tolerant to, say glyphosate (the active ingredient in Roundup^{TM}) is still fully susceptible to glufosinate, or 2,4-D, or bromoxynil, or any other herbicide that would control the non-GM parent variety. And a sufficient dosage of the relevant herbicide will still kill even the HT plants. Finally, not all HT plants are exclusive to GM technology. All plants are naturally tolerant to at least some herbicides (otherwise there would be no selective herbicides), and some 'modern' HT crops were developed using traditional breeding methods. Triazine tolerant canola, popular in Australia, arose from a non-GM mutant line, for example, and Clearfield HT soybean and canola varieties are non-GM mutations. Such HT crops have been grown by farmers for years, without any popular outcry, although if there is any risk with GM HT crops, the same risk is carried by non-GM HT crops.

All over the biosphere of Planet Earth, DNA is a nucleic acid. Everywhere except Mendocino County, California, where the power of democracy has legally redefined DNA as a protein. The legal definition in force in Mendocino, under Ordinance Title 10A is clear: *'(B) "DNA" or "deoxyribonucleic acid" means a complex protein that is present in every cell of an organism and is the "blueprint" for the organism's development.'* [8].

During a conference on Science and Law conducted by the Supreme Court of the Philippines, a national judge, obviously an educated and (otherwise) intelligent man, asked how a GM cornfield would cause a man to become gay. During a divorce trial, he heard an argument that the husband's (apparently *de novo*) homosexuality was caused by his strolling through a GM cornfield, and granted the divorce on that basis. His question at the conference was not whether it was true, but instead to satisfy his curiosity on the technical mechanism by which GM cornfields caused the now-ex-husband's homosexuality [9].

The president of Zambia rejected food aid from the US for his country (in the midst of a terrible famine) as he was counseled that the GM maize food aid was poisonous. 'Simply because my people are hungry, that is no justification to give them poison, to give them food that is intrinsically dangerous to their health' said Zambian President Mwanawasa [10]. It is most unfortunate that this leader believed the misinformation. He seemed unaware that this 'poisonous' food was the same stuff 300 million Americans had been eating for years, with still not a single documented case of harm attributable to the GM material. As well, the European Commission sponsored 81 research projects over 15 years covering all areas of concern and determined [agricultural biotechnology] '. . .has not shown any new risks to human health or the environment, beyond the usual uncertainties of conventional plant breeding. Indeed the use of more precise technology and the greater regulatory scrutiny probably make then even safer than conventional plants and food' [11].

In an open letter to Jairam Ramesh, India's Minister for Environment and Forests and at the time deliberating giving final approval for commercial release of the GM Bt Brinjal in India, Bharat Mansata [12] pleads with the Minister to reject the GM eggplant, asserting in his argument that '. . .*once the terminator seeds are released into a region, the trait of seed sterility can pass to other non-genetically-engineered crops and plants, making most or all of the seeds in the region sterile!*'. This invasive sterility feature of GM crops appears to be a fairly common misconception worldwide, at least among people who do not question how the sterility can spread if the seed cannot even sprout. And it is not known whether Minister Ramesh holds this belief, but it is known that he rejected the approval for the Bt Brinjal in spite of the overwhelming support for approval from both the Indian and international scientific communities based on safety data.

Conclusions

In the examples, a combination of technical ignorance and misinformation gives rise to the

problems precluding a truly informed and vital public debate. Some problems are due to sheer ignorance of simple facts, such as the biological ubiquity of genes and DNA. When Europeans [13] and Americans [14] were asked (in separate surveys) if they agree with the statement: *Ordinary tomatoes do not contain genes, while genetically modified tomatoes do,* only 35–40% of respondents knew enough to disagree. Such basic ignorance among even the planet's most wealthy and well-educated people does not engender optimism for a vital and informed debate [15].

If they cannot get even simple basic facts right, it is not surprising they cannot comprehend more complex conceptual abstractions. Distinguishing the concept of product versus process is lost on many concerned but misinformed consumers ignorant of the salient facts, as they believe the process of GM itself may be hazardous, while the scientific and regulatory communities recognize that hazards, when they arise, are invariably associated with specific products. Skeptical but misinformed consumers may also fail to reconcile absolute and relative risks, believing that encountering *any* detectable amount of a toxin is hazardous, and furthermore that all chemicals are equally hazardous (believing, for example, that a kilo of glyphosate herbicide is just as damaging as a kilo of paraquat herbicide) when experts recognize relative toxicity and dosage as paramount. Finally, anti-GM sources are notorious for emphasizing concerns about potential problems with GM products but neglect to mention that conventional versions of the same products carry the same (of greater) problems [11,16]. For example, some skeptical consumers worry that scientists do not guarantee that GM crops and foods are absolutely safe, failing to realize that scientists cannot make such guarantee for *any* crops or foods.

Popular misconceptions might be considered amusing if they are held only by a small 'fringe' group. But sometimes the misinformation and fear can become infectious and pathogenic, instigating bad public policy, with substantial negative consequences to everyone. In 2009 alone, several shipments of grain from USA and Canada to Europe were refused unloading at European ports because authorities detected trace amounts of GM material. Several soybean shipments from America were turned back because GM corn dust residue – from a previous cargo – was detected in the ship's hold. The European Union enforces a 'zero tolerance' of any detection of any amount of GM material they themselves have not approved for the EU, even if the offending GM material had been approved elsewhere. The European Commission June 2007 report on 'Economic Impact of Unapproved GMOs on EU Feed Imports and Livestock Production' states: '*EU legislation does not provide for any tolerance threshold for the accidental presence of unapproved GMOs that have received approval in other countries*' [17]. All of the cargoes turned back, including soy, rice and flaxseed shipments, carried barely detectable trace amounts of GM material, on the order of less than ten GM seeds (or equivalent in dust) per 10,000 regular seeds in the cargo. The EU itself knows the lack of a reasonable tolerance for low level presence of GM material is an intractable problem, as a recent report from the EU's own Joint Research Centre predicts an increase in such trade problems as more and more GM crops are cultivated in more and more countries worldwide [18]. In addition, as the sensitivity of detection assays increases, from the current level of one GM seed in 10,000 to, say, one GM seed in 20,000 non-GM seeds, the problem will become even more acute, as that level of seed purity is virtually impossible to guarantee in commodity grain, even using the most stringent channeling or identity preservation (i.p.) systems.

Meanwhile, as the EU focuses exclusively and absolutely on even minute trace amounts of GM materials in shipments, they seem to show no concern for a greater amount of arsenic and other known toxins and contaminants in the cargo. By focusing all of their biosafety resources on products never known to have caused harm, they ignore real threats to health and environment. This scientifically indefensible misplacement of priorities puts the European public and environment at risk, while unnecessarily increasing food and feed costs for European consumers [19].

Fortunately, there is hope. The European Commission recently approved cultivation of a GM potato (Amflora, with a modified starch profile), the first such approval in 12 years, along with import approvals for several GM maize varieties. As well, there are signs European officials are finally starting to listen to their own scientific experts in EFSA and elsewhere and may soon ease the rigidly enforced and unscientific zero tolerance policy for low level presence (LLP) of GM material in imported commodities (http://www.gmo-compass.org/eng/news/494.docu.html). Buttressed by recent surveys showing increasing consumer comfort in USA [20] and also seeing a concordant drop in the fear of agbiotech along with a rise in technical knowledge and scientific literacy of European schoolchildren [21], we remain cautiously optimistic that this trend will continue, so eventually knowledgeable and critical thinking consumers will make informed choices whether to support or reject agricultural biotechnology, organic or other farming activities.

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