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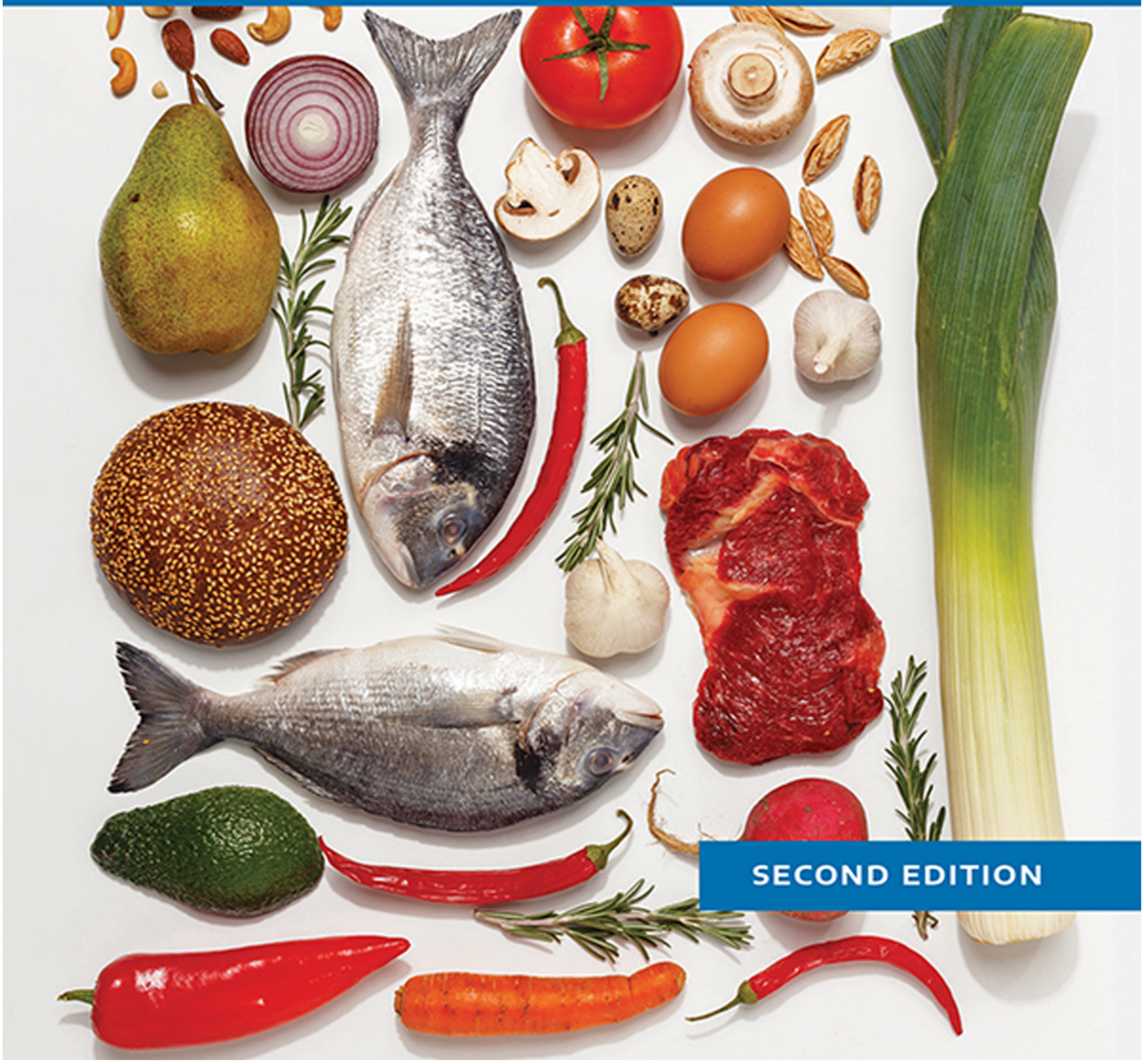
David E. Newton



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A REFERENCE HANDBOOK

Second Edition

David E. Newton

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3 Perspectives

Introduction

This chapter provides individuals with an opportunity to write brief essays on some specific aspects of genetically modified crops and foods. These essays cover a wide variety of topics, from recent developments in the technology of genetic engineering to reasons to support or oppose the expanded use of GMO foods in the United States and other parts of the world.

Genetic Engineering in Agriculture: Uncertainties and Risks
Debal Deb

Genetic engineering (GE), or transgenics, is a brilliant tool to transmit genes across reproductive barriers between different taxonomic groups, enabling biologists to "create" novel organisms not found in nature. In 1986, University of California scientists transferred genes from the firefly into tobacco to create a novel tobacco plant that glows in the dark. This novel genetically modified (GMO) tobacco was created for purely scientific curiosity, but different crops have also been developed to yield agronomic benefits. With an aim to protect crop plants from insect pests, genetic engineers have transferred a suite of genes

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A hybrid corn plant, Pioneer 33G26, a genetically modified variety developed by Pioneer Hi-Bred International Inc. (Dpimborough/Dreamstime.com) coding for insecticidal toxins from the soil bacterium *Bacillus thuringiensis* (Bt) to common plants to create Bt crops.

Another group of GMO crops has been created to promote agrochemical business. A prominent example is Monsanto company's GMO Roundup Ready crops, which are designed to resist the lethal effect of the company's proprietary herbicide Roundup, so farmers can freely apply this herbicide on their farms to control weeds without harming the GMO herbicide-tolerant (GMHT) crop.

Uncertainties in GE

Because the transgenic process bypasses the evolutionary ontology of the host organism, GE is fraught with a host of uncertainties on molecular, organismal, and ecological levels. The different types of uncertainty, which undercut the claims of precision in GE, are as follows.

Molecular Level

"Gene silencing" or gene expression failure is common when more than one transgene is inserted in the GMO plant (Pérez-González and Caro 2018). If the Bt transgene in Bt corn is silenced, the insecticidal toxin is no longer produced in the plant tissues, so no pest insects will be controlled. Conversely, a transgene may be "overexpressed," so that the cell manufactures an unregulated excess of gene products, which may interfere with other unrelated signaling pathways. This may disrupt many cellular biochemical processes (Nakai et al. 2013).

"Co-suppression" of host genes may also occur in transformants that are homozygous for a transgene. Insertion of the transgene into an ectopic position of the genome may result in inactivation of the native genes in the GMO (Meyer 1988).

Finally, the transgene may be expressed differently in different tissues and organs. "Variable expression" of the transgene would result in another unintended effect: If the Bt gene is expressed in the roots and leaves of the Bt cotton plant, but not in its flowers or bolls then the pest bollworms will not be affected by the Bt toxin, resulting in cotton production loss. This, in addition to pest insects evolving resistance to Bt toxin, is the major reason for Bt cotton yield losses in several states of India (Sahai and Rahman 2003).

The same transgene may behave differently in different crops, for reasons yet unknown. For instance, overexpression of a gene involved in pectin synthesis has no effect in tobacco, but caused premature leaf shedding in apple trees. Bt toxin is known to exude from the roots of Bt corn and Bt rice, but not of Bt cotton, Bt canola, and Bt tobacco. Many studies have also detected unintended changes in the transcriptome, proteome, and secondary metabolites of GMO plants.

Organismal Level

After incorporation of a transgene, the native genes, small interfering RNA (siRNA) molecules, and different proteins in the GMO plants may coordinate in unpredictable manners, resulting in either co-suppression, silencing, or overexpression of the transgene and some unrelated native genes, leading to unpredictable effects on the organism's growth and reproduction. Dwarfism of transgenic tomato plants expressing phytoene synthase gene is one of the most striking examples of such unintended morphological effect (Fray et al. 1995). More recently, the much-debated Golden Rice plants, developed to produce β-carotene in rice endoplasm, showed unintended drastic reduction in photosynthesis rates, panicle size, grain counts, plant height, and delaying of flowering than the non-GMO parental isoline. The transgene in the homozygous lines disrupted the native OsAux1 gene in the host plant, thereby disturbing the fine balance of plant growth regulators namely, auxins, gibberellic acid, and abscisic acid, leading to abnormalities in the growth and development of the plants (Bollinedi et al. 2017).

Ecosystem Level

If the transgene products of a GMO crop are toxic, it would necessarily kill at least some organisms. The GMO plants containing insecticidal toxins are intended to kill phytophagous insects. There is a growing body of experimental evidence that GMO crops have unintended, deleterious effects on nontarget organisms. Bt toxin may have adverse effects on several insect taxa. Bt toxin runoff from the farm into water bodies may have deleterious effects on various aquatic organisms (Rosi-Marshall et al. 2007).

The GMHT crop cultivation propels increased herbicide application, leading to the elimination of broadleaved plants, butterflies, and birds. The use of Roundup herbicide also kills both aquatic and terrestrial amphibians (Relyea and Jones 2009). Elimination of organisms may trigger secondary extinction of several species in the agroecosystem, thereby disrupting the food web and ecosystem functioning, much of which is not yet fully understood. Furthermore, short-term elimination of pests may result in undesirable effects of pest outbreaks in the long term (Reilly and Elderd 2014).

Bt toxin resistance have been recorded in many insect populations (like the diamondback moth and cotton bollworm). Neither organic Bt spray nor Bt crops can now control the resistant pests, which compel farmers to apply more pesticides, driving waves of ecological destruction. Owing to the widespread cultivation of GMHT crops, the emergence of invasive herbicide-resistant weeds on six continents is causing huge crop yield losses. At least forty-two weed species have evolved resistance to glyphosate across six continents. The metabolic pathway of glyphosate resistance has recently been discovered (Pan et al. 2019).

Health Risks

"StarLink" corn is a prominent example of an unpredictable hazard from GMO foods. The product of a Bt gene encoding pesticidal Cry9c protein in this corn had an unintended, strong allergenicity in a large number of people who consumed this product. A similar allergenicity was elicited in U.S. consumers who ate methionine-rich GMO soya foods containing a transgene from Brazil nut (Zhang, Wohlhueter, and Zhang 2016). Effects of the transgene on the proteome may also cause unpredictable health hazards.

A series of GMO crops are being developed to address malnutrition among the poor. The GMO "Golden Rice" fortified with β-carotene is promoted as the solution to vitamin A deficiency (VAD) in the global South. A GMO vitamin A-fortified banana was also developed to combat VAD in Uganda. In 2014, Bill and Melinda Gates Foundation sponsored a human feeding trial with U.S. student volunteers, offering them a U.S. $900 fee. As this was the first human feeding trial of a GMO product that had not been tested on animals, the trial was strongly opposed on ethical and transparency grounds. Concerns were also expressed about the potential health risks for women of childbearing age. Critics of this project pointed out that Uganda is home to banana varieties that are already higher in β-carotene than the proposed GMO variety. Instead of introducing either Golden Rice or the GMO banana, the cultivation of foods that are two to fifty times richer in β-carotene content than Golden Rice and the GMO banana, for example, Ipomeoa aquatica leaves, Indian mustard flower, taro yam tuber, and certain types of fruit, offer affordable, healthy, culturally acceptable ways of avoiding nutrient deficiency. Even if the GMO foods contain high amounts of β-carotene and are cheap, GE cannot possibly eradicate VAD, unless (a) intestinal diseases like diarrhea is absent, and (b) the diet also contains triglycerols and zinc. Clearly, micronutrient deficiency is a public health problem, requiring multiple approaches, such as safe drinking water supply and access to dietary diversity. Besides, the unpredicted low productivity of the Golden Rice (Bollinedi et al. 2017) is a more formidable obstacle to its commercial release than opposition by anti-GMO activists.

Three GMO rice lines, with transgenes for fungicidal and insecticidal toxins, show unintended drastic reduction in protein, amino acids, and vitamin E, which provided "alarming information with regard to the nutritional value of transgenic rice" (Jiao et al. 2010), and underscores the need of detailed biosafety assessment prior to release of GMO food crops.

There has been no rigorous experiment to study long-term health effects of transgenic endotoxins in GMO food. The biotech corporations do not allow any publication of adverse effects of their proprietary crops (Scientific American 2009). A study that demonstrated serious health effects on rats was conducted by Seralini et al., whose peer-reviewed paper was nevertheless retracted a year later by a newly appointed associate editor of the journal, who was an ex-Monsanto employee. A comprehensive review of toxicity studies of GMO foods note that a majority of tests indicate no difference between GMO and non-GMO foods in health impacts, but "most of these studies have been conducted by biotechnology companies responsible of commercializing these GMO plants" (Domingo and Bordonaba 2011). Corporate control over GMO research, obfuscation and concealing of data, and public relations tactics are amply documented, fueling much of public mistrust of GMO research in general (Druker 2015).

In the absence of conclusive evidence, the rational option is to adopt the Precautionary Principle (PP), until some future experiments prove the GMO foods, case by case, to be safe beyond doubt.

The Precautionary Principle

When introducing a new drug, vaccine, or food product, it is a universal norm to follow the PP, which aims to reduce Type II error in experiments. Type I error consists in rejecting the Null Hypothesis ("no effect") when it is actually true. Type II error is the error of accepting the Null Hypothesis when it is actually false.

Either error may result from sampling error, faulty observation, or spurious analyses. Now suppose, we erroneously accept the Null Hypothesis of "no harm from a GMO food" when it is actually harmful. The consequence would be dangerous—consumers who will eat the food may fall sick, even die. By the time more rigorous experiments may prove the Null Hypothesis to be false, it will be too late. This is exactly what happened in the late 1980s with L-tryptophan food supplements (Mayeno and Gleicha 1994).

Conversely, if we commit Type I error, and stop eating the GMO food until future experiments prove the Null Hypothesis to be correct, we will have, at worst, postponed the benefits of eating the food. It is therefore safer to reduce Type II error than Type I error, and delay accepting the Null Hypothesis until it is conclusively proven to be true.

In the absence of conclusive evidence, it is unwise to presume GE foods to be safe. Indeed, the absence of evidence of an effect is not the evidence of "no effect." In the words of Belinda Martineau, the creator of the first GMO fruit "without further elaboration, 'no scientific evidence to the contrary' could be construed as 'no scientific evidence, period'" (Martineau 2001, 223).

Conclusion

The body of evidence of unforeseen behavior of transgenes in GMOs and their unpredictable impacts on the environment is not negligible. Therefore, application of the PP to GE research is imperative before the release of GMO crops. Putative nutritional benefits from GMO foods are unlikely to outweigh the potential risks. The lauded benefits of micronutrient enrichment in GMO foods appear less than the cheaper native foods, which national food policies ought to make more accessible to the poor. Development of metal-fortified GMO rice appears mostly unnecessary in view of the fact that at least seventy-six rice landraces in India are known to contain 30 to 150 μg/g of iron and fifty-two landraces with 48–210 μg/g of zinc in brown rice—a fact that is seldom acknowledged in GE research (Sen Gupta et al. 2017).

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Debal Deb is a biologist, with doctorate in ecology from Calcutta University. He conducted postdoctoral research in human ecology of estuarine resource use at the Indian Institute of Science, Bangalore (1988), and in ecological economics at University of California–Berkeley, as Ford Foundation Fellow (2001) and Fulbright Fellow (2009). In 1997, Deb founded Vrihi, India's largest open source rice seed bank, conserving 1,440 folk rice varieties, and a conservation farm Basudha. Deb has analyzed in his laboratory, for the first time, the nutraceutical properties of numerous uncultivated food plants and hundreds of rice varieties. His freelance research in agroecology, crop genetic diversity, forest ecology, and ecological economics have been widely published in international journals.

The Case for Teaching Food in Schools
Yussra MT Ebrahim

"What I learned about food in school is surprisingly little." Until I got to college and majored in it. These words are scrawled onto one of the thirty or so Post-its marking a passage in my copy of Carlo Petrini's movement-inspiring book "Slow Food Nation." Throughout my degree program in sustainable agriculture and food systems, I found myself walking from class to class in astonishment at my own ignorance. How did I not know? How did they let me graduate high school without knowing, how did they let me loose into society without teaching me first this most basic, most relevant, most crucial information? How could they waste my time like this?

In her passionate book about reconnecting with food, Barbara Kingsolver writes, "Most people of my grandparents'