The Scientific Legacy of the 20th Century
Pontifical Academy of Sciences, Acta 21, Vatican City 2011
www.pas.va/content/dam/accademia/pdf/acta21/acta21-raven.pdf

Transgenic Crops and the Future of Agriculture

Peter H. Raven

One of the frustrations and joys of science is that we try to be objective, to offer hypotheses and test them, and to discover, to the extent of which we are capable, what is true and what is not true. It would be a serious mistake to claim that science is not affected by its context, as the case of Galileo Galilei illustrates so dramatically! Importantly, however, science does not in itself instruct us whether or not to jump off a tall building or provide moral judgments even about serious matters such as whether it is wise to pollute the atmosphere beyond the point at which our civilization can survive in something resembling its present form. What is does do is to tell us what is likely to happen as a consequence of particular actions. Given that information, we are free to take whatever course of action we wish.

It is often frustrating for scientists, however, when a situation is as clear as it can be from a scientific point of view, and yet counter opinions are offered without any basis in fact by non-scientists and regarded by the general public and the media as equal in value to scientific conclusions published in peer-reviewed journals. In science, not all opinions are equal, a relationship that the general public and the media all too often forget.

A particular case in point has to do with the adoption of GE crops as an important element in improving the efficiency and productivity of agriculture worldwide. Last year, our Academy held a study week on the use of GE crops in development worldwide, and concluded that, in general, they would be highly beneficial. This view basically reflected and recapitulated the findings of our Academy, other academies, and scientists generally in appraising the use of such crops to improve productivity and to help alleviate hunger throughout the world. What then is the rational basis for continuing to regard the use of such crops as questionable and even dangerous?

With some regional exceptions, virtually every bit of the world's land surface that can be cultivated is cultivated now, and it is exceedingly important – a matter of survival for many people – to make the productivity of this scarce resource as high as it can be, consistently with its sustainability. Of the 6.8 billion people in the world, one billion are malnourished to the point that their bodies and brains do not develop properly and are literally wasting away, with 100 million of them on the verge of starvation at any given time. It is projected that 2.5 billion people will be added to the world population during the next four decades, and clear that they will join the poorest fringes of society. Nearly 99% of them will be born in countries that are considered to be in the 'developing' category. Global Footprint (see http://globalfootprint.org) currently estimates that we are using 140% of what the world can produce on a sustainable basis. As a result, the world is inevitably becoming more uniform, less interesting, less healthy, and with less potential than it has today. To counter this trend, we clearly need to achieve a stable human population, to adopt conservative and reasonable levels of consumption around the world; and to develop and use new technologies that will help to save us from reducing the quality of our civilization even more drastically over the decades to come.

In our attempt to feed people adequately, however, we need to adopt all the tools available to modern agriculture: more efficient use of water; limited use of pesticides and fertilizers; integrated pest management; precision farming; and the continued genetic improvement of our crops to fit the needs of the present and the future. Curiously, a particularly knotty problem has arisen around the use of the available modern methods to improve the characteristics of plants and animals. Called into question is the production of GE (genetically enhanced) plants and animals with traits by virtue of which they perform better than they would otherwise. At the same time, we are content to continue to use traditional, relatively imprecise breeding methods for plants, as for example to irradiate their whole genomes and let the parts of those genomes come together in any combination that they would. In contrast, we are afraid to use precise methods that involve transferring one or a few carefully selected genes from one kind of organism to another. Before they are released for us, the products of GE technology are tested much more carefully than any crop varieties we have adopted in the past, and we understand their features with much more precision; but strangely that does not seem to be sufficient to satisfy a host of critics of the methodology. Why is this so, particularly when the scientists of the world are essentially fully united in their conclusion that such crops are not only harmless to human health and to the environment, but that they will contribute substantially to the huge problem of feeding people adequately?

The potential of improving the characteristics of organisms through genome manipulation was opened up through the experiments of Boyer and Cohen in 1973, about a decade after we first began to understand the genetic code. These scientists transferred a gene successfully from the bacterium *E. coli* to the African clawed toad, the first time that a gene was moved successfully from one kind of organism to another that was unrelated to the donor. Scientists were concerned with the consequences of producing this kind of newly-constituted organism, hurriedly organized a major conference at Asilomar, California. There they laid down rules for dealing carefully with the new kinds of organisms in laboratories until they were better understood. As our knowledge base improved over the subsequent years, we began to apply these techniques to the production of often-improved versions of various items that we use.

Thus, many of the drugs now used in industrialized countries are produced by GE organisms. For example, virtually all of our insulin is produced in this way, and it is cheaper; the derived product is dependably purer than insulin derived from collecting and extracting cow thymuses, the earlier practice, and much less expensive. Virtually all of the beer and all of the cheese produced in the world is produced using enzymes from GE organisms. Nobody worries about these processes at all! As Per Pinstrup Anderson has pointed out so well, however, while we who live in Europe and North America may use drugs from GE organisms because our lives are at stake, for a mother in Africa the disease she faces is starvation for her children, and the medicine she needs is food – food that we may deny to her as a result of our suspicious and irrational fears, and by a disregard for the underlying science. Pinstrup Anderson then went on to point out that the world's poor spend 60 to 80 percent of their incomes on food, and even then there often isn't enough to alleviate starvation. It seems morally wrong for rich people to block others from using GE crops when the evidence is so clear that they are helpful in elevating productivity and thus that they will contribute substantially to the welfare of poor people all over the world. We need to remember the unfortunate spectacle, played out a few years ago, of Zambia turning back hundreds of tons of maize in food aid from the U.S. because some of it was GE. At the same time, hundreds of millions of people in the world consume such maize with not a single case of sickness or any other problem ever having been detected; many thousands of people were starving to death in Zambia but were denied access to the food because of ill-founded concerns with its safety. The memory of that tragic event should become a moral burden for those who created the false impression on which the decision to deny the use of that food was based.

Let us now consider the facts about GE organisms that have been established clearly. First, the horizontal transfer of genes between different kinds of organisms, as our distinguished chair Werner Arber has continually stressed, is common in nature. Thus there is no rational basis for considering such transfers to be unnatural or avoiding there use for that reason.

Second, there is no known mechanism that makes gene transfer generally dangerous or potentially harmful. Obviously it is possible to transfer dangerous genes from one kind of organism to another (for example, genes associated with the production of toxins), but why would anyone do so? Further, GE crops are more carefully tested than any other products of plant breeding before being released into the trade. This relationship seems a bit ironic since it is perfectly possible to produce, for example, poisonous tomatoes or poisonous potatoes by conventional breeding, but for obvious reasons we do not choose to do so. There is nothing generally dangerous about substituting one segment of DNA for another in the genome of another kind of organism. The genes that are introduced may or may not become incorporated and function well in their new environment, but if they fail to do so, they clearly could not be released for agricultural use.

Third, with about one-sixth of all of the world's cropland devoted to GE crops, and hundreds of millions of people consuming them every day, there has not been a single example of any problem for human health arising from eating such foods. Why then is this one of the great bugaboos posed by those who resist the introduction of GE crops in their own or other countries, regardless of how needy hungry people may be? How can anyone reasonably assume that something unexpected and awful would happen later, with no evidence whatever for such an assertion?

Fourth, the major crop strains that are now produced as a result of GE techniques have one of two features: they are either insect resistant or herbicide resistant. Many other products are in prospect for the future, including drought resistance or the production of higher yields, and many of them will be made available during the coming decade. There are certainly problems associated with industrial-scale agriculture, such as those arising from planting huge areas with a single crop genotype. When this is done, the whole crop may be susceptible to one kind of pathogen, which may harm or even kill it over wide areas. The problem here is, however, that of planting design, which has nothing to do with the choice of techniques used to produce the particular uniform crop strain in the first place. Planned variation in the genotypes of crops planted over large areas is an important strategy in any case, and should be employed generally. We should remember further that a large majority of the farmers who are using GE crops at the present day are smallholders, and not industrial-scale farmers; the idea that GE crops are inevitably planted on a large scale is a myth that should be removed from consideration. It is of great importance to consider how we can modify our crops relatively rapidly and precisely to adapt them to the altered climates of the future, an even more serious problem for feeding people than those we face now.

In a recent National Research Council study of the farm-level effects of the cultivation of GM crops in the U.S., where virtually all maize, soybeans, and cotton are genetically modified, we encountered a few instances of insect resistance arising in connection with properties of the GE crops. In a similar way, herbicide resistance had become widespread in some regions where particular herbicides were sprayed over wide areas. The study also demonstrated the substantial economic and ecological advantages associated with the use of such improved crops, advantages that account for their widespread adoption. Some reviews of our study highlighted the herbicide resistance, without mentioning the obvious fact that using any herbicide widely will result in the appearance of weed strains resistant to it.

If those weeds do not belong to the same species as the crop, they can be controlled by building resistance to other herbicides into the crop, or by building 'stacked' resistance to several different herbicides in a single crop strain. If as in a few cases, however, the weeds do belong to the same species as the crop – examples are sugarbeets, rice, and sunflowers – special care needs to be taken, because the weeds will tend to pick up the resistance genes as a result of hybridization with their cultivated relatives. This situation arises especially when the crops are grown in areas where their wild relatives or weedy relatives occur mixed with the crop or in the areas where it is being cultivated. Hybridization is a normal feature of the evolution of plant species and an important feature of their evolution. When no wild or weedy relatives are present, as in the case of most crops in the U.S. and Europe, this situation does not pose a problem. The recent legal rulings prohibiting the cultivation of GE sugarbeets and alfalfa in the U.S. are illogical for reasons that I shall discuss subsequently. In rice, GE technology has nothing to do with the appearance of the troublesome weedy varieties. And there is certainly no conceivable, much less demonstrated, rational basis for prohibiting the cultivation of GE maize in Europe, or GE brinjal in India: recent rulings barring them can only be attributed to the effects of runaway, effective propaganda.

Considering the problem of 'land races' as a whole, it is important to remember that in Mexico, for example, maize yields in the milpas of the southern part of the country amount to no more than one-fiftieth of the yield per hectare that is achieved on the intensively cultivated fields in the north. This, coupled with the rapid growth of the population of Mexico to its present 111 million people, with 18 million more people projected to be added by 2050, has forced to the country to import large amounts of maize from the U.S., much of it of GE origin.

The people who cultivate the 'land races' of corn on the milpas of southern Mexico are in general very poor. At the same time, the composition and nature of their 'land races' changes like the pattern in a slowly revolving

Kaleidoscope. If we want to save the strains that are being grown there today, we will either need to subsidize the people growing them so that they can overcome the poverty that is inherent in their situation, or else put samples of the seeds away in seed banks, or adopt both strategies. As is the case generally, there is no saving a way of life, tragic as that fact is for the survival of precious human diversity, by denying people the advantages of the modern world. The poor will find the means to change their lives anyway, or continue to live at a level that we should collectively reject purely for reasons of morality.

What about the general environmental effects of cultivating GE crops? Our farm-level study in the U.S. found cleaner soils with richer soil biotas and cleaner water occurred in areas where GE crops were cultivated than elsewhere. Additional sampling needs to be carried out, but there is certainly no sign of adverse environmental in these or other respects.

Taken together, these analyses bring us back to the question of why so many Europeans, particularly, are so concerned about the adoption of GE strains of crops that they are willing to cite a great deal of flawed science in support of their negative positions. Certainly some environmental organizations campaign on this issue, which apparently, presented as they do, provides a dependable source of cash to support their operations. Much of their argument seems to arise from an anti-corporate stance, which for various reasons is appealing to many people concerned with moral justice. Justifiable moral concern continues to be raised about a justifiable level of corporate profits, but these are problems for the whole array of products supplied from wealthy countries to poor ones, and not just food crops. Everyone seems to agree that desirable traits or products of all kinds need to be made available to the poor to the extent that they will prove helpful, but those also are considerations that lie beyond the realm of consideration of GE crops. About one-sixth of the world's farmland is now devoted to their cultivation, with no harmful effects related to the genetic traits involved having been demonstrated other than what I have just reviewed. Can we not stop using bad science to justify our anti-corporate inclinations?

A peculiar problem in the U.S. concerns our legal classification of GE crops as 'non-organic'. What this means is that while huge vats of *Bacillus thuringiensis* can be freeze-dried and the resulting substance broadcast, killing all of the target insects in the area whether they are harmful to crops or not, that is regarded as 'organic'. If the genes that produce the toxin are placed in the crop so that they will affect only the actual herbivores on that crop, that is classified as 'non-organic'. The logic eludes many of us, but what it means in practice is that if genes spread from better-producing GE alfalfa, for example, to 'organic' crops of alfalfa by means of cross-pollination by insects, that the other crops would become 'non-organic' and therefore sold at a lower premium. The same is true of rapeseed, for example, where some weeds have also become herbicide resistant, causing further problems, but as far as 'organic' classification goes, the distinction is simply a legal one, and the 'problem' caused by the laws, not the biological facts of the matter.

Often countries are 'testing' GE strains prior to their 'release'. The problem is that we don't really know for which properties they should be tested. Will they escape? Will they provide higher yields? Why should they if farmers want them, and why should they alone be tested? There is simply no body of evidence that supports this extensive testing, and the harmful effects of not providing enhanced crops to those who really need them are evident. Isn't it time for the nations of the world to re-examine the Cartagena Protocol of the CBC and examine the facts on which it is based from a scientific perspective?

Let's look at some of the positive benefits of growing GE crops and improving the productivity of agriculture generally. The loss of biological resources has reached frightening levels and is highly significant for our future. Comparing the rate of loss of species observed in the fossil record with that documented now, we find that extinction rates have increased to thousands of times their historical rate. These losses, which are increasing rapidly, are resulting from habitat destruction, global climate change, selective hunting and gathering, and the unprecedented spread of invasive species to the extent that more than half of the species on Earth may disappear during the course of the 21st century. To a very large extent, we depend on these species for our opportunities to build sustainability throughout the globe, and have as yet recognized only a small fraction – perhaps no more than a sixth – of those we are losing. The loss of biological species and the productive systems of which they are a part is irreversible, and therefore, over the long run, is the most serious environmental problem that we confront. The more we encourage inefficient agriculture by discouraging the use of modern methods in the development of crop varieties, the faster biodiversity will disappear.

Another obvious benefit of GE crops is that their use has already achieved major reductions in pesticide applications, a highly desirable outcome for the environment in general and for human health in particular. Even by the year 2000, the use of GM soybean, oilseed rape (canola), cotton, and maize had reduced pesticide use by 22.3 million kilograms of formulated product, and the reductions have risen far above that level subsequently. Worldwide, there are at least 500,000 cases of pesticide poisoning and 5,000 deaths annually. Residues of pesticides are ubiquitous in foods sold in markets throughout the world, and we should be striving to reduce them. The use of GE crops has already had a large effect on these levels in all regions where they are grown at a commercial scale.

For Europe, it has been estimated that if half of the corn, oilseed rape (canola), sugar beet, and cotton raised were genetically modified to resist pests instead of being treated by spraying that there would be an immediate reduction of about 14.5 million kilograms of formulated pesticide product (4.5 million kilograms of active ingredient). The reduction of 7.5 million hectares of crops sprayed as a result of growing GM crops would save approximately 20.5 million liters of diesel and prevent the emission of 73,000 tons of carbon dioxide into the atmosphere, thus driving global warming. Along with other methods to decrease the application of fertilizers and pesticides, such as Integrated Pest Management, the use of transgenic crops clearly can confer great benefits in our quest for sustainable, productive agriculture. Against this background, the choice of many Europeans to avoid the use of GE crops against all scientific evidence seems as bizarre as it is environmentally damaging.

As the global climate changes, the need for the rapid adaptation of our cultivated crops to the new conditions has become increasingly evident. Food production can be maintained only by the use of the best available methods, including those that lead to water conservation. We cannot achieve such changes by assuming that modern methods are inevitably bad, while the crops developed by, say, 1890, through genetic selection, are good. Political infighting about methods of selection leads directly or indirectly to the starvation of millions, and alleviates no known problem. Therefore, I consider it morally unacceptable, and await reasons as to why it is justified.

So Europe's strong stand against GM crops, which have the potential to produce more food available, may seem ill advised to hungry people in developing countries who need food and not unsupported arguments about why it might not be safe. Serious discussions of the appearance of large-scale agriculture, the corporatization of food systems, or the globalization of trade are clearly desirable, but it is not GM crops that are driving these trends, which they are sometimes used to represent. We badly need to develop transgenic cassava and other crops that are vital for feeding the people who live in the tropics, and do not have the right to play with their welfare for ideological reasons. Let resolve here to try to find ways to move forward for human welfare with the tools that science has developed for these purposes, a resolution that would have much in common with the aims of our Academy.