Science and the Future of Mankind
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STUDY-DOCUMENT ON THE USE OF 'GENETICALLY MODIFIED FOOD PLANTS' TO COMBAT HUNGER IN THE WORLD

I. Introductory Note by President Nicola Cabibbo

During the closed session of the Academy held during the Plenary Session many Academicians expressed deep concern at the distorted way in which recent scientific results, and in particular those relating to genetically improved plant varieties, have been presented to the public. It was decided to establish a committee with the task of producing a document on this subject. The chairman of the committee was A. Rich and its other members were W. Arber, T-T. Chang, M.G.K. Menon, C. Pavan, M.F. Perutz, F. Press, P.H. Raven, and R. Vicuña. The document was examined by the Council at its meeting of 25 February 2001, submitted to the members of the Academy for their comments, and then sent to the committee for the preparation of the final version.

The document, which is included in the Proceedings, expresses the concerns of the scientific community about the sustainability of present agricultural practices and the certainty that new techniques will be effective. At the same time, it stresses the need for the utmost care in the assessment and evaluation of the consequences of each possible modification, and on this point we cannot but recall the exhortation of John Paul II regarding biotechnologies made in his speech of 11 November 2000 on the occasion of the Jubilee of the Agricultural World: 'they must be previously subjected to rigorous scientific and ethical control to ensure that they do not give rise to disasters for the health of man and the future of the earth'.

The document also expresses concern about excesses with regard to the establishment of 'intellectual property' rights in relation to widely used crops – excesses which could be detrimental to the interests of developing nations.

A further recommendation, clearly stated in the document, is that the examination of the safety of newly developed cultivars should be based on well-documented methods and that the methods and results should be openly discussed and scrutinised by the scientific community.

The Academy will devote an *ad hoc* meeting to the subject of genetically modified food plants. This meeting will provide an opportunity to examine in depth many issues which are raised in the document and which are of special concern: the methods used in the testing and licensing of the new cultivars; the comparative risks associated with different methods of pest control; and the many scientific, ethical and social issues raised by the introduction of a new and powerful technology directed towards agricultural improvement.

II. Recommendations

The Challenge

1. The rapid growth of the world population requires the development of new technologies to feed people adequately; even now, an eighth of the world's people go to bed hungry. The genetic modification of food plants can help meet part of this challenge.

2. Agriculture as it is currently practiced is unsustainable, as is indicated by the massive losses of topsoil and agricultural land that have occurred over the past few decades, as well as by the unacceptable consequences of massive applications of pesticides and herbicides throughout most of the world. Techniques to genetically modify crop plants can make important contributions to the solution of this common problem.

The Potential of Genetically Modified Food Plants

3. Virtually, all food plants have been genetically modified in the past; such a modification is, therefore, a very common procedure.

4. The cellular machinery of all living organisms is similar, and the mixing of genetic material from different sources within one organism has been an important part of the evolutionary process.

5. In recent years, a new technology has been developed for making more precise and specific improvements in strains of agricultural plants, involving small, site-directed alterations in the genome sequence or sometimes the transfer of specific genes from one organism to another.

6. Genetically modified food plants can play an important role in improving nutrition and agricultural products, especially in the developing world.

Conditions for the Beneficial Use of this New Technology

7. The scientific community should be responsible for the scientific and technological research leading to the advances described above, but it must also monitor the way it is applied and help ensure that it works to the effective benefit of people.

8. There is nothing intrinsic about genetic modification that would cause food products to be unsafe. Nevertheless, science and scientists are - and should further be – employed to test the new strains of plants to determine whether they are safe for people and the environment, especially considering that current advances can now induce more rapid changes than was the case in the past.

9. The methods used for testing the safety of new genetically modified strains (or more precisely, cultivars) of plants should be publicly available, as should the results of these tests, in both the private and public sectors.

10. Governments should have the responsibility for ensuring that the tests and their results are conducted in line with the highest criteria of validity. The protocols of evaluation should be made widely accessible.

11. Governments should increase their funding for public research in agriculture in order to facilitate the development of sustainable and productive agricultural systems available to everyone.

12. Intellectual property rights should not inhibit a wide access to beneficial applications of scientific knowledge. In the development of this modern genetic technology for agriculture, efforts should be made to facilitate cooperation between the public and private sectors and to secure the promotion of solidarity between the industrialised and developing worlds.

13. Special efforts should be made to provide poor farmers in the developing world with access to improved crop plants and to encourage and finance research in developing countries. At the same time, means should be found to create incentives for the production of vegetable strains suitable to the needs of developing countries.

14. Research to develop such improvements should pay particular attention to local needs and to the capacity of each country to engage in a necessary adaptation of its traditions, social heritage, and administrative practices in order to achieve the success of the introduction of genetically modified food plants.

Recommendation for the Scientific Community

15. In order to help governments, state-funded researchers, and private companies to meet the above conditions, and in order to facilitate the development of common standards and approaches to this problem in both developing and industrialised countries, the scientific community, represented by its established worldwide umbrella organisations, should offer its expertise. A suitably composed international scientific advisory committee could be entrusted with this all-important task.

III. Background

The Pontifical Academy of Sciences has traditionally stressed the application of science to world food problems. Most recently, the study week proceedings on "Food Needs of the Developing World in the Early Twenty-First Century" and "Science for Survival and Social Development," two conferences held in 1999, emphasized the special role of modern biotechnology in improving the characteristics of plants. Here, the members of the Pontifical Academy are considering newer aspects of these applications in a global context.

The world's people have grown in number from 2.5 billion to more than 6 billion over the past fifty years. One out of four lives in extreme poverty, and one out of eight is chronically malnourished. These problems are in part related to patterns of distribution of the available food, in part to the low productivity of agriculture in certain regions, including the loss of crops to pests, and in another part to an unbalanced nutritional value in the daily diet. Enhanced production of qualitatively improved food under sustainable conditions could greatly alleviate both poverty and malnutrition. These are goals that will become even more urgent as our numbers increase by an estimated two billion additional people over the next few decades. Modern science can help meet this challenge if it is applied in an appropriately constructive social and economic context.

Historical Use of GM Plants

Genetically modified (GM) plants can play an important role in alleviating world food problems. Recent discussions concerning GM plants have often overlooked the fact that virtually all commonly used foods have been genetically modified, often extensively, during the long history of agriculture. Ever since the start of agriculture about 10,000 years ago, farmers have selected plant variants that arose spontaneously when they offered increased productivity or other advantages. Over time, new methods for producing desirable genetic variants were introduced, and have been used extensively for some two centuries. Cross-breeding of different plant varieties and species, followed by the selection of strains with favorable characteristics, has a long history. That process involves exchanging the genetic material, DNA, from one organism to another. DNA contains genes, and genes generally act by expressing proteins; thus the newly modified plant obtained by genetic crossing usually contains some proteins that are different from those in the original plant. The classical method of crossing plants to bring in new genes often results in bringing in undesirable genes as well as desirable ones since the process could not be controlled.

New Technology to Develop GM Plants

Almost 30 years ago scientists developed a new technology called recombinant DNA that made it possible to select the particular gene that one wanted to transfer to a plant. This process is very specific and avoids the inclusion of genes that are undesirable. A number of useful new plant strains have been developed in this way. Even though such strains are considered to be genetically modified (GM), the same label could be applied equally appropriately to all strains that have been modified genetically by human activities — a process that owes its success to selection for desirable properties.

We now know a great deal about the DNA in organisms. It contains the codes for manufacturing different proteins. At the molecular level, the products of genes, usually proteins, are made from the same materials in plants, animals and microorganisms. The recent development of technical means for sequencing the components in DNA gives us insight into the similarities among organisms. All living organisms share genes because of their common evolutionary descent. For example, the sequence of a small worm was completed recently, and it was found that the worm shares some 7,000 of its estimated 17,000 genes with humans.[1] Likewise, the genes found in microorganisms are often very similar to those found in humans as well as in plants.[2]

[1] The C. elegans Sequencing Consortium, 1998. 'Genome Sequence of the Nematode C. elegans: A Platform for Investigating Biology'. *Science* 282: 2012-18.

[2] The Arabidopsis Genome Initiative. 2000. Analysis of the Genome Sequence of the Flowering Plant *Arabidopsis thaliana. Nature* 408:796-815.

A large number of genes in all placental mammals are essentially the same, and about a third of the estimated 30,000 genes in humans are common to plants, so that many genes are shared among all living organisms.

Remarkably, one has discovered another reason for the similarities between DNA sequences in different organisms: DNA can at times move in small blocks from one organism to another, a process that is called lateral transfer. This occurs at a relatively high rate in microorganisms, and it also occurs in plants and animals, albeit less frequently. Once this has taken place, the genetic material that has been transferred becomes an integral part of the genome of the recipient organism. The recent sequence of the human genome revealed that over 200 of our estimated 30,000 genes came from microorganisms,[3] demonstrating that such movements are a regular part of the evolutionary process.

The new technology has changed the way we modify food plants, so that we can generate improved strains more precisely and efficiently than was possible earlier. The genes being transferred express proteins that are natural, not man-made. The changes made alter an insignificantly small proportion of the total number of genes in the host plant. For example, one gene may be introduced into a plant that has 30,000 genes; in contrast, classical cross-breeding methods often generated very large, unidentified changes in the selected strains.

Many of the statements made here in abbreviated form have been dealt with more thoroughly in a number of publications. Among the more significant is a report entitled “Transgenic Plants and World Agriculture”, which was prepared by a committee representing the academies of sciences of Brazil, China, India, Mexico, the U.K. the U.S, and the Third World Academy of Sciences. In summary, it reached the conclusion that foods produced from genetically modified plants were generally safe, that any new strains needed to be tested and that further investigation of the potential ecological problems associated with such new strains also needed further consideration. The French Academy of Science also issued a very useful report, commenting on many aspects of this issue and dealing especially with the problems of deployment of GM plants in developing countries. The accumulating literature in this field has become quite extensive.

Traditional methods have been used to produce plants that manufacture their own pesticides, and thus are protected from pests or diseases.

[3] Venter, J. Craig *et al.* 2001. ‘The Sequence of the Human Genome’. *Science* 291:1304-51.

They have also been employed to produce herbicide-resistant plants. When such plants are grown, specific herbicides are used to efficiently control the weeds growing among them without harming the basic crop. Another goal of traditional agriculture has been the nutritional enhancement of foods, either in terms of amino acid balance or in enhancing the presence of vitamins or their precursors. All of these goals can be attained more efficiently and precisely with the use of methods that are now available involving the direct transfer of genes. Newer goals, mostly unattainable earlier, include the development of plant strains that can manufacture desired substances, including vaccines or other drugs.

How to Make Sure GM Plant Products are Safe

These goals are highly desirable, but the questions that have arisen often concern the method of genetic modification itself, not its products. The appearance of these products has generated a legitimate desire to evaluate carefully their safety for consumption by human beings and animals, as well as their potential effects on the environment. As is usual for complicated questions, there are no simple answers, and many elements need careful consideration.

Contrary to common perception, there is nothing intrinsic to the genetic modification of plants that causes products derived from them to be unsafe. The products of gene alteration, just like the products of any modification, need to be considered in their own right and individually tested to see if they are safe or not. The public needs to have free access to the methods and results of such tests, which should be conducted not only by companies that develop the genetically altered plants, but also by governments and other disinterested parties. Overall, widely accepted testing protocols need to be developed in such a way that their results can be understood and can be used as a basis for consumer information.

One of the present concerns is that new genetically modified plants may include allergens that will make them unhealthy for some people. It is possible to test these plants to determine whether they have allergens. Many of our present foodstuffs, such as peanuts or shellfish, have such allergens, and they represent a public health hazard to that part of the population with corresponding allergies. It is important that any genetically modified crop varieties, as well as others produced by traditional breeding methods, be tested for safety before they are introduced into the food supply. In this connection, we also note that the new technologies offer ready methods for removing genes associated with allergens, both in present crops and newly produced ones.

Another issue concerns the potential impact of genetically modified plants on the environment. Cultivated plants regularly hybridize with their wild and weedy relatives, and the exchange of genes between them is an important factor in plant evolution. When crops are grown near relatives with which they can produce fertile hybrids, as in the case of maize and its wild progenitor teosinte in Mexico and Central America, genes from the crops can spread to the wild populations. When this occurs, the effects of these genes on the performance of the weeds or wild plants needs to be evaluated. There is nothing wrong or unnatural about the movement of genes between plant species. However, the effects of such movement on the characteristics of each plant species may vary greatly. There are no general reasons why we should fear such gene introductions, but in each case, scientific evaluation is needed. The results should be verified by the appropriate government agency or agencies, and full disclosure of the results of this process should be made to the public.

Improved Foods

There are many opportunities to use this new technology to improve not only the quantity of food produced but also its quality. This is illustrated most clearly in the recent development of what is called "golden rice",[4] a genetically modified rice that has incorporated in it the genes needed to create a precursor of Vitamin A. Vitamin A deficiency affects 400 million people,[5] and it often leads to blindness and increased disease susceptibility. Use of this modified rice and strains developed with similar technologies will ultimately make it possible to help overcome Vitamin A deficiency. "Golden rice" was developed by European scientists, funded largely by the Rockefeller Foundation and using some methods developed by a private company. However, that company has agreed to make the patents used in the production of this strain freely available to users throughout the world. When successfully bred into various local rice strains and expressed at high enough levels, it offers the possibility of helping to alleviate an important nutritional deficiency. This is just one of several plant modifications that has the potential for producing healthier food.

[4] Potrykus, Ingo. 2001. 'Golden Rice and Beyond'. *Plant Physiology* 125: 1157-61.

[5] Ye, Xudong *et al.* 2000. 'Engineering the Provitamin A (b-Carotene) Biosynthetic Pathway into (Carotenoid-Free) Rice Endosperm'. *Science* 287: 303-5.

More Government-sponsored Research is Needed

Research involving the use of recombinant DNA technology to develop genetically modified plants is carried out worldwide. It involves government laboratories, independent institutes and private corporations. During the period following World War II, most international crop research was funded by the public sector and through charitable foundations. This led to a spectacular doubling or tripling of crop yields in large parts of Asia and Latin America. This "Green Revolution" met the needs of millions of poor farmers and consumers and alleviated starvation for tens of millions of people. The revolution was a consequence of the production of "dwarf" wheat and rice plants by the introduction of genes from dwarf varieties into high-yielding strains of grain. Substantial public sector agricultural research still exists in North America, Australia, Europe, China, India, Brazil and in the Consultative Group for International Agricultural Research which comprises 16 international research centers. In recent decades, however, public funding for agricultural research has dwindled, while funding from corporations has increased markedly. Governments should recognize that there is an important public interest element in this research, even in market-driven economies. Public contributions are important because the results of such research work are made available to everyone. At the same time it makes possible various opportunities for public and private collaboration, so that the benefits of the new technologies for genetic modification are brought to all of the people throughout the world. It is also important that such research not be inhibited by overprotective intellectual property measures.

Special Needs of Poor Farmers

A significant distinction must be made between the use of genetically modified plants in the developed world and their use in the developing world. In the developed world, farmers can often afford to pay for expensive seeds that yield disease-resistant crops that require lower levels of pesticides or that produce more food per hectare. This is also true for many farmers in the developing world. For poor farmers in the developing world, however, governments must intervene if they are to be able to obtain the benefits of modern crop improvement technology. Several private corporations engaged in agricultural research have indicated their willingness to make available the results of their research without charge for use in developing countries. Their willingness should be recognized and encouraged.

In this connection, we endorse the recommendation of the seven-academy group mentioned above that an international advisory committee should be established to assess the implications of genetically modified plants, especially in developing countries. The committee would identify areas of common interest and opportunity between institutions in the private and public sectors. This could be one way of assuring that the benefits of these new technologies are made widely available. Intellectual property issues are of special importance in this context. We recommend that this committee participate in the development of generally accepted standards for testing and approval of new plant strains and the foods derived from them, a development of great importance for world commerce.

The Crisis in Agriculture

The loss of a quarter of the world's topsoil over the past fifty years, coupled with the loss of a fifth of the agricultural land that was cultivated in 1950,[6] indicates clearly that contemporary agriculture is not sustainable. To become sustainable, agriculture will need to adopt new methods suitable for particular situations around the world. These include greatly improved management of fertilizers and other chemical applications to crops, integrated pest management to include improved maintenance of populations of beneficial insects and birds to control pests, and the careful management of the world's water resources. (Human beings currently use 55% of the renewable supplies of fresh water, mostly for agriculture.) It will also be necessary to develop strains of crop plants with improved characteristics to make them suitable for use in the many diverse biological, environmental, cultural and economic areas of the world.

Genetically modified plants can be an important component of efforts to improve yields on farms otherwise marginal because of limiting conditions such as water shortages, poor soil, and plant pests. To realize these benefits, however, the advantages of this rapidly growing technology must be explained clearly to the public throughout the world. Also, results of the appropriate tests and verifications should be presented to the public in a transparent, easily understood way.

[6] Norse, D. *et al.* 1992. 'Agriculture, Land Use and Degradation'. pp. 79-89. In Dooge, J.C.I. *et al.* (eds.). *An Agenda of Science for Environment and Development into the 21st Century*. Cambridge University Press, Cambridge.

An estimated 85 million birds and billions of insects[7] are killed annually in the United States alone, as a result of the application of pesticides on crops. Some 130,000 people become ill in this connection each year. Genetically modified plants currently in use have already greatly reduced the use of such chemicals, with great ecological benefits. It is expected that such benefits will be significantly enhanced as research and development efforts continue.

Hope for the Future

Finally, it is important that scientists make an effort to clearly explain to the public the issues concerning risk. All technological developments have elements of risk, whether we refer to the introduction of vaccines, new forms of therapy, new types of foodstuffs or new pesticides. Risk cannot be avoided, but it can be minimized. The long-term aim is to develop plants that can produce larger yields of healthier food under sustainable conditions with an acceptable level of risk. The latter can be determined by scientific studies, with the results made freely available to the public.

The developments we have discussed here constitute an important part of human innovation, and they clearly offer substantial benefits for the improvement of the human condition worldwide. They are essential elements in the development of sustainable agricultural systems capable of feeding not only the eighth of the world's population that is now hungry, but also meeting the future needs of the growing world population. To make the best use of these new technologies and the agricultural management opportunities they create is a moral challenge for scientists and governments throughout the world.

[7] Pimentel, D. *et al.* 1992. 'Environmental and Economic Costs of Pesticide Use'. *BioScience* 42: 750-59.