PAS Study Week, Vatican City, 15-19 May 2009

Transgenic Plants for Food Security in the Context of Development

A Study Week on the subject of 'Transgenic Plants for Food Security in the Context of Development' was held under the sponsorship of the Pontifical Academy of Sciences at its headquarters in the Casina Pio IV in the Vatican from 15 to 19 May 2009. During the course of the meeting, we surveyed recent advances in the scientific understanding of novel varieties of genetically engineered (GE) plants, as well as the social conditions under which GE technology could be made available for the improvement of agriculture in general and for the benefit of the poor and vulnerable in particular. The spirit of the participants was inspired by the same approach to technology that Benedict XVI expressed in his new Encyclical, in particular that 'Technology is the objective side of human action (1) whose origin and *raison d'être* is found in the subjective element: the worker himself. For this reason, technology is never merely technology. It reveals man and his aspirations towards development, it expresses the inner tension that impels him gradually to overcome material limitations. *Technology, in this sense, is a response to God's command to till and to keep the land* (cf. Gen 2:15) that he has entrusted to humanity, and it must serve to reinforce the covenant between human beings and the environment, a covenant that should mirror God's creative love'. (2)

Main Scientific Conclusions

We reaffirm the principal conclusions of the Study-Document on the Use of '"Genetically Modified Food Plants" to Combat Hunger in the World', issued at the end of the Jubilee Plenary Session on 'Science and the Future of Mankind', 10-13 November 2000. Summarised and updated, these include:

1. More than 1 billion of the world population of 6.8 billion people are currently undernourished, a condition that urgently requires the development of new agricultural systems and technologies.
2. The expected addition of 2-2.5 billion people to reach a total of approximately 9 billion people by 2050 adds urgency to this problem.

3. The predicted consequences of climate change and associated decreases in the availability of water for agriculture will also affect our ability to feed the increased world population.

4. Agriculture as currently practised is unsustainable, evidenced by the massive loss of topsoil and unacceptably high applications of pesticides throughout most of the world.

5. The appropriate application of GE and other modern molecular techniques in agriculture is contributing toward addressing some of these challenges.

6. There is nothing intrinsic about the use of GE technologies for crop improvement that would cause the plants themselves or the resulting food products to be unsafe.

7. The scientific community should be responsible for research and development (R&D) leading to advances in agricultural productivity, and should also endeavour to see that the benefits associated with such advances accrue to the benefit of the poor as well as to those in developed countries who currently enjoy relatively high standards of living.

8. Special efforts should be made to provide poor farmers in the developing world with access to improved GE crop varieties adapted to their local conditions.

9. Research to develop such improved crops should pay particular attention to local needs and crop varieties and to the capacity of each country to adapt its traditions, social heritage and administrative practices to achieve the successful introduction of GE crops.

Further Evidence

Since the preparation of that earlier study document, evidence that has been subjected to high standards of peer-reviewed scientific scrutiny, as well as a vast amount of real-world experience, has accumulated about the development, application and effects of GE technology. During our study-week we reviewed this evidence and arrived at the following conclusions:

1. GE technology, used appropriately and responsibly, can in many circumstances make essential contributions to agricultural productivity by crop improvement, including enhancing crop yields and nutritional quality, and increasing resistance to pests, as well as improving tolerance to drought and other forms of environmental stress. These improvements are needed around the world to help improve the sustainability and productivity of agriculture.

2. The genetic improvement of crop and ornamental plants represents a long and seamless continuum of progressively more precise and predictable techniques. As the U.S. National Research Council concluded in a 1989 report: 'As the molecular methods are more specific, users of these methods will be more certain about the traits they introduce into the plants and hence less liable to produce untoward effects than other methods of plant breeding'.

There are many different terms used to describe the processes involved in plant breeding. All living organisms are made up of cells in which are contained their genes, which give them their distinctive characteristics. The complete set of genes (the genotype) is encoded in DNA and is referred to as the genome; it is the hereditary information that is passed from parent to offspring. All plant breeding, and indeed all evolution, involves genetic change or modification followed by selection for beneficial characteristics from among the offspring. Most alterations to a plant's phenotype or observable traits (such as its physical structure, development, biochemical and nutritional properties) result from changes to its genotype. Plant breeding traditionally used the random reshuffling of genes among closely-related and sexually compatible species, often with unpredictable consequences and always with the details of the genetic changes unexplored. In the mid-twentieth century this was supplemented by mutagenesis breeding, the equally random treatment of seeds or whole plants with mutagenic chemicals or high-energy radiation in the hope of generating phenotypic improvements; this, too, gave rise to unpredictable and unexplored genetic consequences from which the plant breeder selected the beneficial traits. Most recently, techniques have been developed allowing the transfer of specific, identified and well characterised genes, or small blocks of genes that confer particular traits, accompanied by a precise analysis of the genetic and phenotypic outcomes: this last category is called 'transgenesis' (because genes are transferred from a donor to a recipient) or 'genetic engineering' (abbreviated to GE in this report) but, in truth, this term applies to all breeding procedures.

3. The benefits have already been of major significance in countries such as the U.S., Argentina, India, China and Brazil, where GE crops are widely grown.

4. They also can be of major significance for resource-poor farmers and vulnerable members of poor farming communities, especially women and children. Insect-resistant GE cotton and maize, in particular, have greatly reduced insecticide use (and hence enhanced farm safety) and contributed to substantially higher yields, higher household income and lower poverty rates (and also fewer poisonings with chemical pesticides) in specific small-farm sectors of several developing countries, including India, China, South Africa and the Philippines.

5. The introduction of resistance to environmentally benign, inexpensive herbicides in maize, soybean, canola, and other crops is the most widely used GE trait. It has increased yields per hectare, replaced back-breaking manual weeding and has facilitated lower input resulting in minimum tillage (no till) techniques that have lowered the rate of soil erosion. This technology could be especially useful to farmers in the developing world who, for reasons of age or disease, cannot engage in traditional manual weed control.

6. GE technology can combat nutritional deficiencies through modification that provides essential micro-nutrients. For example, studies of provitamin A-biofortified 'Golden Rice' have shown that standard daily diets containing this biofortified rice would be sufficient to prevent vitamin A deficiency.

7. The application of GE technology to insect resistance has led to a reduction in the use of chemical insecticides, lowering the cost of some agricultural inputs and improving the health of agricultural workers. This relationship is particularly important in areas such as many European nations, where applications of insecticides are much higher than in most other regions, which may damage ecosystems generally as well as human health.

8. GE technology can reduce harmful, energy consuming, mechanical tilling practices, enhancing biodiversity and protecting the environment, in part by reducing the release of CO_2, the most important anthropogenic greenhouse gas, into the environment.

9. The predicted impact of climate change reinforces the need to use GE coupled with other breeding techniques appropriately and purposively, so that traits such as drought resistance and flooding tolerance are incorporated into the major food crops of all regions as quickly as possible.

10. GE technology has already raised crop yields of poor farmers and there is evidence of its generating increased income and employment that would not otherwise have taken place.

11. Costly regulatory oversight of GE technology needs to become scientifically defensible and risk-based. This means that regulation should be based upon the particular traits of a new plant variety rather than the technological means used to produce it.

12. Risk assessments must consider not only the potential risks of the use of a new plant variety, but also the risks of alternatives if that particular variety is not made available.

13. Significant public-sector efforts are currently underway to produce genetically improved varieties or lines of cassava, sweet potatoes, rice, maize, bananas, sorghum, and other major tropical crops that will be of direct benefit to the poor. These efforts should be strongly encouraged.

14. The magnitude of the challenges facing the world's poor and undernourished must be addressed as a matter of urgency. Every year nutritional deficiencies cause preventable illness and death. The recent rise in food prices throughout the world has revealed the vulnerability of the poor to competition for resources. In this context, forgone benefits are lost forever.

15. Given these scientific findings, there is a moral imperative to make the benefits of GE technology available on a larger scale to poor and vulnerable populations who want them and on terms that will enable them to raise their standards of living, improve their health and protect their environments.

In general, the application of GE technology has demonstrated its importance for improving agricultural productivity throughout the world, but it is still only one part of what must be a multifaceted strategy. As the Holy Father Benedict XVI has observed: 'it could be useful to consider the new possibilities that are opening up through proper use of traditional as well as innovative farming techniques, always assuming that these have been judged, after sufficient testing, to be appropriate, respectful of the environment and attentive to the needs of the most deprived peoples'. (3) Nevertheless, we recognise that not all developments of GE technology will realise their original promise, as happens with any technology. We must continue to evaluate the potential contribution of all appropriate technologies, which together with conventional plant breeding and additional strategies must be used to improve food security and alleviate poverty for future generations. (4) Many of them can be used synergistically with GE technologies. Strategies include the retention of topsoil through no-till and other conservation practices, the appropriate application of fertilizers, the development of new kinds of fertilizers and environmentally friendly agrochemicals, water conservation, integrated pest management, conservation of genetic diversity, the adoption of new kinds of crops where appropriate and improving existing crops (particularly 'orphan crops' (5)) for wider use through public-private investment and partnerships. Other factors of vital importance to increasing food security or particular importance to resource-poor countries include improvements in infrastructure (transport, electricity supply and storage facilities), capacity building by way of the provision of knowledgeable and impartial advice to farmers about seed choice through local extension services, the development of fair systems of finance and insurance, and the licensing of proprietary technology. However, awareness that there is no single solution to the problem of poverty and discrimination against the poor in many regions should not prevent our use of GE varieties of crops where they can make appropriate contributions to an overall solution.

The Broader Public Debate

GE technology has aroused general public interest and debate around the world about the contribution of science in addressing many of the health and food related challenges that face society in the twenty-first century. This debate on the power and potential role and range of uses to which it can be applied is welcomed, but the discussion must rely on peer-reviewed or otherwise verifiable information if the science and technology are to be appropriately evaluated, regulated, and deployed for the benefit of mankind. Doing nothing is not an option, nor can science and technology be switched on and off like a tap to provide appropriate solutions to problems as they arise: if anything, the task of science is to foresee possible damage in order to avoid it and secure the greatest possible good. In this context, there are six domains of action that need attention: the public understanding of science; the place of intellectual property rights; the role of the public sector; the role of civil society; cooperation between governments, international organisations and civil society; and appropriate and cost-effective justifiable regulatory oversight.

The Public Understanding of Science

Participants at our meeting called attention repeatedly to the widespread misapprehensions about GE technology that pervade both public discussion and administrative regulation. For example, often ignored in the public debate is that all forms of plant breeding involve genetic modification and that some examples of what is called 'conventional' breeding – for example mutagenesis induced by radiation – have outcomes that are intrinsically much less predictable than the application of GE technologies.

All participants in the Study Week are committed to playing their part in contributing to public dialogue and debate in such a way that it is informed and enlightened. It is an obligation for scientists to make themselves heard, explain their science, and demystify technology, and make their conclusions widely available. We urge those who oppose or are sceptical about the use of GE crop varieties and the application of modern genetics generally to evaluate carefully the science involved and the demonstrable harm caused by withholding this proven technology from those who need it the most. The common good can be served only if public debate rests upon the highest standards of scientific evidence and the civil exchange of opinion.

The Place of Intellectual Property Rights

Proprietary rights play an important role in developing any technology, including medical and agricultural biotechnology, as they do in all aspects of modern society. We are aware that the best practices of the commercial sector have made a significant contribution to the goals of eliminating poverty and food insecurity. However, in line with the social teaching of the Church, which indicates as a primary right the universal destination of the goods of the earth for all mankind, (6) we urge both private and public actors to recognise that the legitimate claims of their property rights should, as much as possible, be subordinated, often beyond the existing norms of civil society, to this universal destination and not allow unjust enrichment or the exploitation of the poor and vulnerable.

Public-private partnerships have become increasingly important in encouraging the development and distribution of improved varieties of crops regularly consumed by poor people in developing countries. The humanitarian 'Golden Rice' project provides an excellent example of such collaboration, where the patents held by the private companies were readily licensed, at no cost, to the public enterprises developing the varieties now ready to be deployed in farmers' fields for the benefit of the societies of which they are part. A number of similar examples are under development; such progress accords well with the belief that all human beings have a claim upon the fruits of the earth. When the private sector shows willingness to make proprietary technologies available for the benefit of the poor it deserves our congratulations, and we encourage it to continue to follow the highest ethical standards in this field.

For that matter, when we consider the relationship between business and ethics, every private company, and in particular a multinational, in the agricultural sphere as well, should not confine itself solely to economic gain. Above all else it should transmit human, cultural and educational values. For this reason, *Caritas in veritate* welcomes recent developments towards a 'civil economy' and an 'economy of communion', a composite reality which does not exclude profit but sees it as a means for attaining human and social ends. Indeed this encyclical affirms that the 'very plurality of institutional forms of business gives rise to a market which is not only more civilized but also more competitive'. (7) These reflections are particularly valid as regards the quality and quantity of food available to a population.

The Role of the Public Sector

The development of new crop varieties that made possible the Green Revolution of the twentieth century was largely achieved by public sector research laboratories in a number of countries. Although the public sector no longer has a near monopoly on such developments, its role is vital and still highly significant. In particular, it can use such funds as it has from national revenues and donor agencies to promote research relevant to those crop needs of the poorest and most vulnerable groups of people. The public sector has an important role to play in making widely available the results of research, and it can innovate in ways that are very difficult for the private sector, where the development of crop varieties for commercialisation is the central goal. If cooperation between private and public sectors has proved beneficial in the development of many applications of science and technology for human benefit particularly in areas of health, agriculture should not be an exception. Unfortunately, we must recognise that, in the case of crop improvement by modern biotechnological approaches, an unscientific and excessive regulation inflates the costs of R&D without any concomitant increase in safety, and makes its application and use by public sector institutions difficult and often impossible for financial reasons.

The Role of Civil Society

Governments, learned societies, NGOs, charities, civil society organisations and religions can all play a part in promoting an informed dialogue and a broad public understanding of the benefits that science can provide, as well as working to improve all aspects of the lives of the less fortunate. They must help to protect the poor from exploitation of all kinds for any purpose, but they also bear the responsibility for ensuring that these communities are not denied access to the benefits of modern science, to prevent them from being condemned to poverty, ill health, and food insecurity.

Cooperation between Governments, International Organisations and Civil Society

As has already been observed, GE technology has already made a significant contribution to crop improvement and increased food security. Appropriate application of the technology in combination with other molecular approaches to plant breeding offers the potential to make further major contributions to improve both major commodity crops and so-called orphan crops in the developing world. The use of these proven scientific advances can thus be considered a Global Public Good.

Because of the high cost of R&D of these new approaches to crop improvement, coupled with the inflated regulatory costs of bringing new traits to market, these technologies have primarily only been applied by multinational companies to the major high volume commodity crops grown in the developed world. Public-good plant breeding using GE approaches has been limited for two major reasons:

1. The high cost involved and lack of investment by national governments. This has resulted in failure to apply this approach to the improvement and adaptation of locally grown crops, including important (so-called 'orphan') crops such as sorghum, cassava, plantains, etc., which are not internationally traded and have not justified commercial investment by multinational companies;
2. The excessive and unnecessary regulation of this technology compared with all others in agriculture has made it too expensive to apply it to 'minor' crops and those that cannot offer developers returns commensurate with the investment and risk undertaken. This, of course, does not apply solely to the private sector: all investment, private or public, has to be viewed in the light of likely returns. Therefore, the public sector as well as the private sector may refrain from developing products for limited use compared with major commodity crops as a result of the investment needed, problematic regulation and uncertainty of delivery.

Thus there is a need for cooperation between governments, international organisations and aid agencies and charities in this area. The potential benefits of such cooperation have already been demonstrated when multinational corporations have shown a willingness to negotiate with private-public partnerships that has led to the free donation of relevant patentable technologies for use in crop improvement. In the case of 'Golden Rice', this had led to technology transfers to many countries in Asia. Other examples include drought-resistant maize in Africa, insect-resistant vegetables and legumes in India and Africa, and many dozens of additional projects in Africa, Asia and Latin America.

Defining an Appropriate Approach to Regulatory Oversight

The realization of the benefits of any new technology requires an appropriate approach to regulation. Overly stringent regulation developed by wealthy countries and focused almost exclusively on the hypothetical risks of GE crops discriminates against developing and poor countries, as well as against smaller and poorer producers and retailers. This has placed the poor people of the world at an unacceptable disadvantage. The harm deriving from not being able to use more precise and predictable production technologies is irreversible, in the sense that the opportunity costs of lost investment, R&D and products (and their benefits) cannot be recovered.

The evaluation of new and improved crop varieties should be based on the traits of plant varieties and not on the technologies used to produce them: they should be judged in the light of their actual characteristics. This would facilitate the exploitation of the potential of the technology for our common benefit by delivering novel varieties of both major and local crops with improved traits.

This is emphatically not a matter of using the poor for experimentation, but of ensuring that the poor have access to technologies that have been proven to be safe, widely accepted and beneficial, in most of the developed and developing world. We cannot become more risk averse about science and technology – and the consequent risks of food and farming – than what we see as acceptable in the rest of our daily lives.

The hypothetical hazards associated with the genetic engineering of crop plants do not differ from those associated with other instances of the application of such genetic technology to other organisms (e.g., those used in medical biotechnology or biotechnology-enhanced enzymes used in cheese or beer processing). Short-term risks arising from the presence of toxic or allergenic products can be studied and excluded from new crop varieties, a procedure that is more precautionary than is usually the case in the cultivation of crop varieties produced by conventional breeding. As to longer-term evolutionary consequences, the present understanding of molecular evolution as it occurs at low rates in nature by spontaneously arising genetic variation, clearly shows that genetic modifications engineered into a genome can only follow the well-studied natural strategies of biological evolution. Viable modifications are only possible in small steps. This becomes understandable if one bears in mind that land plant genomes are like large encyclopaedias of several hundred books, while genetic modifications using modern genetic techniques affect only one or a few genes out of c. 26,000 genes in the average plant genome. Therefore, the possible evolutionary risks of genetic engineering events cannot be greater than the risks of the natural process of biological evolution or of the application of chemical mutagenesis, both responsible for generating extensive and poorly characterised degrees of genetic change. Statistical records show that the undesirable effects of such genetic change are extremely rare and, in the case of conventional breeding, selected against.

Given the developments in scientific understanding since the adoption of the Cartagena Protocol on Biosafety in 2000, it is now time to reassess that protocol in the light of a science-based understanding of regulatory needs and benefits.

Faith, Scientific Reason and Ethics

For a believer, the point of departure for the Christian vision is the upholding of the divine origin of man, above all because of his soul, which explains the commission that God gives to human beings to govern the whole world of living creatures on the earth through the work to which they dedicate the strength of their bodies guided by the light of the spirit. In this way human beings become the stewards of God by developing and modifying natural beings from which they can draw nourishment through the application of the methods of improvement. (8) Thus, however limited the action of humans may be in the infinite cosmos, they nevertheless participate in the power of God and are able to build their world, that is to say an environment suited to their dual corporeal and spiritual life, their subsistence and their wellbeing. Thus new human forms of intervention in the natural world should not be seen as contrary to the natural law that God has given to the Creation. Indeed, as Paul VI told the Pontifical Academy of Sciences in 1975, (9) on the one hand, the scientist must honestly consider the question of the earthly future of mankind and, as a responsible person, help to prepare it, to preserve it for subsistence and wellbeing, and eliminate risks. Therefore, we must express solidarity with the present and future generations as a form of love and Christian charity. On the other hand, the scientist also must be animated by the confidence that nature has in store secret possibilities that are for human intelligence to discover and make use of, in order to achieve that level of development which is in the plan of the Creator. Thus, scientific intervention should be seen as a development of physical or vegetal/animal nature for the benefit of human life, in the same way that 'many things for the benefit of human life have been added over and above the natural law, both by divine law and by human laws'. (10)

Recommendations

1. Enhance the provision of reliable information to regulators, farmers and producers around the world so that they will be enabled to make sound decisions based on up-to-date information and knowledge about all aspects of farm management for productivity and sustainability.

2. Standardise – and rationalise – the principles involved in the evaluation and approval of new crop varieties (whether produced by so-called conventional, marker assisted breeding, or GE technologies) universally so that they are scientific, risk-based, predictable and transparent. It is critical that the scope of what is subject to case-by-case review is as important as the actual review itself; it must also be scientific and risk-based.

3. Re-evaluate the application of the precautionary principle to agriculture, reframing it scientifically and practically and making the regulatory requirements and procedures proportional to the risk, and considering the risks associated with lack of action. It must be borne in mind that prudence (*phronesis* or *prudentia*) is the practical wisdom that should guide action. (11) Although this practical wisdom or prudence needs precaution in order to have such a grasp of good as to avoid evil, the main component of prudence is not precaution but prediction. This means that the primary feature of prudence is not refraining from acting to avoid harm but using scientific prediction as a basis for action. (12) Thus, Pope Benedict XVI, in his address to the Pontifical Academy of Sciences on the occasion of the 2006 Plenary Session on 'Predictability in Science', emphasised that the possibility of making predictions is one of the main reasons for the prestige that science enjoys in contemporary society and that the creation of the scientific method has given science the capability of predicting phenomena, studying their development and thus keeping the habitat of human beings under control. 'Indeed we could say', affirms Pope Benedict, 'that the work of predicting, controlling and governing nature, which science today renders more practical than in the past, is itself a part of the Creator's plan'. (13)

4. Evaluate the Cartagena Protocol, an international agreement that regulates international trade in GE crop varieties, developed at a time when less was known about the science of GE crops, to ensure that it is in line with current scientific understanding.

5. Free GE techniques, the most modern, precise and predictable ones for genetic improvement, from excessive, unscientific regulation, allowing their application to enhance the nutritional quality and productivity of crops (and eventually also the production of vaccines and other pharmaceuticals) everywhere.

6. Promote the potential of technology to assist small farmers through adequate research funding, capacity building and training linked through to appropriate public policy.

7. Encourage the wide adoption of sustainable sound and productive agricultural practices and extension services, which are especially critical for improving the lives of poor and needy people throughout the world.

8. In order to ensure that appropriate GE and molecular marker-assisted breeding is used to improve relevant crops grown in food-insecure, poor nations, where they can be expected to have an important impact on improving food security, we urge that governments, international aid agencies and charities increase funding in this area. Given the urgency, international organisations such as the FAO, CGIAR, UNDP or UNESCO have the moral responsibility to guarantee food security for the current and future world population. They must use all their endeavours to mediate the establishment of private-public cooperative relationships to ensure the cost-free exploitation of these technologies for the common good in the developing world where they will have the greatest impact. (14)

Background

The PAS Study Week from 15-19 May 2009 was organised, on behalf of the Pontifical Academy of Sciences, by academy member Professor Ingo Potrykus, with support from academy members Professor Werner Arber, and Professor Peter Raven. The organisers knew that since 2000, when an earlier Study-Document was published by the same Academy on '"Genetically Modified Food Plants" to Combat Hunger in the World', a great deal of evidence and experience had accumulated about genetically engineered crops.

The aim of the Study Week was, therefore, to evaluate benefits and risks of genetic engineering and of other agricultural practices on the basis of present scientific knowledge and of its potential for applications to improve food security and human welfare worldwide in the context of a sustainable development. The participants were also aware of the social teaching of the Church on biotechnology and accepted the moral imperative to focus on the responsible application of GE according to the principles of social justice.

Participation was by invitation only and participants were selected for their scientific merits in their respective fields of expertise and their engagement for scientific rigour and social justice. The organisers had to make a selection of participants, and based their choice on the need to advance the principal purpose of the meeting, which was to review experience to date. Although there were differences of opinions, points of view and emphasis among the participants, all agreed on the broad principles contained in this statement.

The participants of the Study Week and their scientific competence are given below in alphabetic order

Members of the Pontifical Academy of Sciences:

Prof. em. Werner Arber • Switzerland, University of Basel: Microbiology, Evolution.

Prof. Nicola Cabibbo † • Italy, Rome, President Pontifical Academy of Sciences: Physics.

H.Em. Georges Cardinal Cottier, Vatican City: Theology.

Prof. em. Ingo Potrykus • Switzerland, Zurich, Swiss Federal Institute of Technology: Plant Biology, Agricultural Biotechnology.

Prof. em. Peter H. Raven • USA, St. Louis, President Missouri Botanical Garden: Botany, Ecology.

H.Em. Msgr. Marcelo Sánchez Sorondo • Vatican City: Chancellor Pontifical Academy of Sciences: Philosophy.

Prof. Rafael Vicuña • Chile, Santiago, Pontifical Catholic University of Chile: Microbiology, Molecular Genetics.

Outside Experts:

Prof. em. Klaus Ammann • Switzerland, University of Berne, Botany, Vegetation Ecology.

Prof. Kym Anderson • Australia, The University of Adelaide, CEPR and World Bank: Agricultural Development Economics, International Economics.

Dr. iur. Andrew Apel • USA, Raymond, Editor in Chief of GMObelus: Law.

Prof. Roger Beachy • USA, St. Louis, Donald Danforth Plant Science Center, now NIVA, National Institute of Food and Agriculture, Washington DC.,: Plant Pathology, Agricultural Biotechnology.

Prof. Peter Beyer • Germany, Freiburg, Albert-Ludwig University, Biochemistry, Metabolic Pathways.

Prof. Joachim von Braun • USA, Washington, Director General, International Food Policy Research Institute, now University of Bonn, Center for Development Research (ZEF): Agricultural and Development Economics.

Prof. Moisés Burachik • Argentina, Buenos Aires, General Coordinator of the Biotechnology Department: Agricultural Biotechnology, Biosafety.

Prof. Bruce Chassy • USA, University of Illinois at Urbana-Champaign: Biochemistry, Food Safety.

Prof. Nina Fedoroff • USA, The Pennsylvania State University: Molecular Biology, Biotechnology.

Prof. Dick Flavell • *USA*, CERES, Inc., Thousand Oaks: Agricultural Biotechnology, Genetics.

Prof. em. Jonathan Gressel • *Israel*, Rehovot, Weizmann Institute of Science: Plant Protection, Biosafety.

Prof. Ronald J. Herring • *USA*, Ithaca, Cornell University: Political Economy.

Prof. Drew Kershen • USA, University of Oklahoma: Agricultural Law, Biotechnological Law.

Prof. Anatole Krattiger • USA, Ithaca, Cornell University and Arizona State University, now: Director, Global Challenges Division, WIPO, Geneva, Switzerland: Intellectual Property Management.

Prof. em. Christopher Leaver • UK, University of Oxford: Plant Sciences, Plant Molecular Biology.

Prof. Stephen P. Long • USA, Urbana, Energy Science Institute: Plant Biology, Crop Science, Ecology.

Prof. Cathie Martin • UK, Norwich, John Innes Centre: Plant Sciences, Cellular Regulation.

Prof. Marshall Martin • USA, West Lafayette: Purdue University: Agricultural Economics, Technology Assessment.

Prof. *Henry Miller* • USA, Hoover Institution, Stanford University: Biosafety, Regulation.

Prof.em. Marc Baron Van Montagu • Belgium, Gent: President European Federation of Biotechnology: Microbiology, Agricultural Biotechnology.

Prof. Piero Morandini • Italy, University of Milan: Molecular Biology, Agricultural Biotechnology.

Prof. Martina Newell-McGloughlin • USA, Davis, University of California: Agricultural Biotechnology.

H.Em. *Msgr. George Nkuo* • Cameroon, Bishop of Kumbo: Theology.

Prof. Rob Paarlberg • USA, Wellesley College: Political Science.

Prof. Wayne Parrott • USA, Athens, University of Georgia: Agronomy, Agricultural Biotechnology.

Prof. Channapatna S. Prakash • USA, Tuskegee University: Genetics, Agricultural Biotechnology.

Prof. Matin Qaim • Germany, Georg-August University of Göttingen: Agricultural Economics, Development Economics.

Dr. Raghavendra S. Rao • India, New Delhi, Department of Biotechnology, Adviser to the Ministry of Science and Technology: Agriculture, Plant Pathology.

Prof. Konstantin Skryabin • Russia, Moscow, 'Bioengineering' Centre Russian Academy of Sciences: Molecular Biology, Agricultural Biotechnology.

Prof. Monkumbu Sambasivan Swaminathan • India, Chennai, Chairman, M.S. Swaminathan Research Foundation: Agriculture, Sustainable Development.

Prof. Chiara Tonelli • Italy, University of Milan: Genetics, Cellular Regulation.

Prof. Albert Weale • UK, Nuffield Council on Bioethics and University of Essex, now University College of London, Dept. of Political Sciences: Social & Political Sciences.

Prof. Robert Zeigler • Philippines, Metro Manila, Director General International Rice Research: Agricultural Biotechnology, Rice research and Development Policy.

Notes

1) Cf. John Paul II, Encyclical Letter *Laborem exercens*, 5: *loc. cit*., 586-589.

2) Caritas in veritate, § 69.

3) Caritas in veritate, § 27.

4) 'This is a principle to be remembered in agricultural production itself, whenever there is a question of its advance through the application of biotechnologies, which cannot be evaluated solely on the basis of immediate economic interests. They must be submitted beforehand to rigorous scientific and ethical examination, to prevent them from becoming disastrous for human health and the future of the earth' (John Paul II, *Address to the Jubilee of the Agricultural World*, 11 November 2000).

5) Orphan crops, also referred as neglected or lost crops, are crops of high economic value in developing countries. These crops include cereal crops (such as millet and tef), legumes (cow pea, grass pea and bambara groundnut), and root crops (cassava and sweet potato). Although orphan crops are vital for the livelihood of millions of resource-poor farmers, research in these crops is lagging behind that of major crops. To boost crop productivity and attain food self-sufficiency in the developing world, research on orphan crops should get more attention.

6) Centesimus annus, § 6.

7) Caritas in veritate, § 46.

8) 'God has sovereign dominion over all things: and He, according to His providence, directed certain things to the sustenance of man's body. For this reason man has a natural dominion over things, as regards the power to make use of them' (Thomas Aquinas, *Summa Theologica*, II-II, q. 66, a. 1 ad 1).

9) Cf. Paul VI, Address to the Plenary Session of the Pontifical Academy of Sciences of 19 April 1975, *Papal Addresses*, Vatican City 2003, p. 209.

10) St. Thomas Aquinas, *Summa Theologica*, I-II, 94, a.5. Cf. *loc. cit.* ad 3.

11) 'Prudence (*phronesis*) is a truth-attaining rational quality, concerned with action in relation to the things that are good for human beings' (Aristotle, *Eth. Nic*., VI, 5, 1140 b 20, Eng. tr. J. Bywater). Cf. also the rest of the chapter.

12) 'Prediction is the principle of prudence…Hence it is that the very name of prudence is taken from prediction [providential] as from its principal part' (St. Thomas Aquinas, *Summa Theologica*, II-II, q. 49, a. 6 ad 1).

13) Address of the Holy Father Benedict XVI to the Plenary Session of the Pontifical Academy of Sciences. Available online at http://www.vatican.va/holy-father/benedict_xvi/speeches/2006/november/documents/hf_ben-xvi_spec_20061106_academy-sciences_en.html

14) Cf. P. Dasgupta, 'Science as an Institution: Setting Priorities in a New Socio-Economic Context' in *World Conference on Science: Science for the Twenty-First Century, A New Commitment* (UNESCO, Paris, 2000).

The English Version represents the official Conference Statement of the Pontifical Academy of Science. It has been drafted and endorsed by all participants of the Study Week, and it was synthesized mainly by Ingo Potrykus, Peter Raven, Albert Weale and Chris Leaver.