SDR/TAC:IAR/98/6.1

CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH

TECHNICAL ADVISORY COMMITTEE

REPORT OF THE CGIAR PANEL

ON GENERAL ISSUES IN BIOTECHNOLOGY

TAC SECRETARIAT

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

April 1998

Consultative Group on International Agricultural Research (CGIAR)

TECHNICAL ADVISORY COMMITTEE
Donald L. Winkelmann, Chairman

15 April 1998

Dear Mr. Serageldin,

I have the pleasure of transmitting to you the report of the CGIAR Panel on General Issues in Biotechnology. This report, together with TAC's Commentary on the Panel's findings, responds to the process that began at MTM'97, when the Group decided to create two expert panels under the auspices of TAC to assist the Group in formulating policy on biotechnology and protection for intellectual property, as well as for materials held in trust.

The Panel began its work in September 1997, engaged intensively in electronic exchange of ideas, identified key questions on which it sought views from a wide range of CGIAR stakeholders and others, and held two meetings. The report reflects the diverse opinions derived from broad consultation. As well, TAC solicited comments from a number of outside experts. The report and solicited comments were considered at TAC 74, with one panel member in attendance.

The Panel saw its primary role as assessing the current and future application of molecular genetics and other developments in biotechnology to those aspects of CGIAR work that relate to germplasm improvement.

The Panel's recommendations include a strong role for the CGIAR in genomics, i.e., developing and supplying molecular biological information, pertaining to its key crops, pests, pathogens, and livestock of importance to the poor. As a part of this, the Panel recommends that CGIAR be instrumental in a "Genome Summit", take the lead in an expanded network approach to biotechnological research, and review its in-house expertise in relation to the preceding initiatives and to its broader research mission.

Mr. Ismail Serageldin
CGIAR Chair
World Bank
1818 H Street, NW
Washington, DC 20433
USA

355 E. Palace Avenue, Santa Fe, NM 87501 Tel: (1-505) 988-1284 FAX: (1-505) 988-1285
email: tacwink@newmexico.com

As well, the Panel recommends a policy framework on biosafety and gene deployment, a Center-based "duty of care" committee to support the effort on biosafety, and the creation of a CGIAR Biotechnology Service Unit. The "duty of care" committee, in particular, has several novel aspects, which are treated in the Report.

The Panel concludes that "there are widespread opportunities for the greater involvement of the world scientific community to assist in the application of biotechnology to the needs of developing countries. The CGIAR is in a strong position to act as a catalyst to foster these contributions, while progressively strengthening its own role as a significant user of biotechnology to further the aims of its mission."

TAC welcomes this report from the Panel and is pleased to pass it on to you and to the Group. The Committee thanks the Panel's distinguished members for their valuable contribution to our better understanding of the vital issues in a fast-moving field. I trust that the report will provide you and the Group with information and counsel needed for making the policy decisions confronting the CGIAR.

Sincerely yours,

Donald L. Winkelmann
TAC Chair

TAC COMMENTARY ON THE REPORT OF THE CGIAR PANEL ON GENERAL ISSUES IN BIOTECHNOLOGY

TAC is grateful to Dr. Richard Flavell, Panel Chair, and to the Members of the Panel on General Issues in Biotechnology for a concise and thought-provoking report that brings out the clear perception of biotechnology as a key instrument for genetic improvement. TAC concurs with the Panel that were the term "biotechnology" further defined, more useful discussion of the topic would result . TAC noted that the Panel gave strong emphasis to genomics and bio-informatics while recognizing the CGIAR strength in germplasm collections, knowledge of the mandate crops, collaborative arrangements, testing sites, and partnership with NARS. The Panel highlighted the potential role that the CGIAR Centres can play in serving the poor as foci on genomic information pertaining to crops, livestock, trees, fish, insect pests and pathogens.

TAC reiterates that the CGIAR's use of molecular genetics and other biotechnological techniques should be strategically grounded in its responsibility as trustee for the genetic materials being held. The fulfillment of these trust responsibilities should be clearly linked to its mission and to the entire range of stakeholders that the System serves. This establishes the moral, ethical and rational foundation for a mandate to fully utilize all appropriate scientific tools in serving CGIAR's ultimate beneficiaries.

The Committee endorses in general the views set out by the Panel and urges the CGIAR Members to carefully consider the report as a whole as it contains many useful recommendations and perceptions. TAC endorses in general the recommendations of the Panel and offers the following comments to supplement the Panel's work.

The Panel, for a variety of reasons, decided to concentrate its study on the applications of biotechnology for germplasm improvement. TAC recognizes that the Centres currently, and increasingly, will use molecular genetic tools for a broad range of purposes. So, while TAC recognizes the current advantage of the Panel's concentration on germplasm improvement, the ultimate scope of work of the System's work will be in terms of its mission and the opportunities through molecular science. Any policy and network activity should therefore be able to accommodate a more comprehensive use of molecular genetics. Like the Panel, TAC also considers it expedient that the CGIAR Centres have sufficient capabilities to interact effectively with others engaged in biotechnology in order to be able to incorporate and make the best use of molecular genetics and emerging technologies.

The Committee notes that the Panel has recommended that the CGIAR be instrumental in bringing about the "Genome Summit". TAC interprets this to be a Summit at a policy and administrative level rather than at a scientific level. If so, then TAC wonders whether there are other sponsors who could play a facilitating role, with the CGIAR participating where it can best serve.

TAC endorses the recommendation on biotechnology networks as a practical mechanism to strengthen information flows. If the Group endorses the recommendation, it is TAC's view that the Centres should be requested to propose models for organization (the Panel describes one model), Centre roles, and mechanisms for implementation, e.g., for coordination.

TAC recognizes that biotechnology is becoming increasingly important as a tool for genetic improvement and that the CGIAR Centres need to have in-house capabilities to make best use of these new genetic tools. The Committee would like to stress, however, that the Centres must ensure that germplasm conservation and improvement programmes continue to receive adequate attention, and that, as the Panel recommends, biotechnology and molecular genetics should be integrated with these programmes both in terms of planning and funding.

Finally TAC notes that while the Panel did not focus on biosafety issues but referred to the Report of the World Bank Panel on transgenic crops, "Bio-engineering of Crops", by Kendall et al., the Panel has strongly advocated the implementation of "Duty of Care" Committees whose task would include the assurance that appropriate safeguards are being met. TAC is impressed with the role that such Committees could play.

TABLE OF CONTENTS

SUMMARY AND RECOMMENDATIONS

Background

Following a decision at its mid-term meeting in May 1997, the CGIAR appointed two expert panels to advise on the way forward in biotechnology, one focusing on general issues and the other on legal aspects. The two panels were designed to work in liaison, three members being common to both panels. Accordingly, while fully recognizing the importance of proprietary and legal issues for the CGIAR System, the Panel on General Issues has not included them in this report.

Introduction

The CGIAR mission statement emphasizes the alleviation of poverty and the protection of natural resources for sustainable food security. Within these broad aims, the CGIAR makes its contributions largely, but not exclusively, through improved technology that increases productivity while conserving biodiversity, land and water. It is dependent for its success on close collaboration with national research systems in the developing countries.

The CGIAR Centres have progressively invested in biotechnology and applied its tools to their work in areas such as germplasm improvement. However, recent developments, especially rapid advances in the molecular characterization of genes, have given new impetus to the case for expanding CGIAR investment in selected biotechnological approaches (Section 1.1).

It is against this background that the Panel has prepared its report and recommendations.

Biotechnology and the CGIAR Mission

The term "biotechnology" is commonly used in a very broad and general way to mean the application of biological discoveries to the development of new products. Concerns about some aspects, however, make it essential for assessments to be made, and strategies defined, in relation to specific applications. The Panel considers that the CGIAR System should avoid using the term "biotechnology" when the aspect in question can be described with greater precision using other terms (Section 2.1.).

Many aspects of biotechnology that are important for the CGIAR mission are based on the identification, construction and deployment of genes. The pace and scale of gene discovery, characterization and manipulation have been greatly increased in recent years, leading to significant decreases in the cost of the operations involved. All phases of genome research are interconnected by sophisticated bioinformatics and database capabilities. As a result, the future holds the promise of new approaches to germplasm conservation, analysis and improvement that combine information on hundreds of thousands of genes with a broadly applicable transformation strategy. It is reasonable to infer that any organization committed to these tasks must exploit the new opportunities to be efficient, competitive and viable in the future. It is this vision that the Panel wishes to commend to the CGIAR (Section 2.2).

Nonetheless, the Panel re-emphasizes the view, frequently expressed by others, that retaining a balanced approach within the total CGIAR research portfolio will be an essential pre-requisite for further progress. Any expansion of biotechnology by the Centres will be an evolutionary process that will proceed at different rates, depending on the organism, the nature of the problems and the available infra-structure (Section 2.3).

The CGIAR currently allocates more than 20% of its resources to germplasm improvement and conservation and has agreed that this proportion will be somewhat increased in future. The links between germplasm improvement and the broader CGIAR mission have been firmly established. Consequently, the Panel has seen its primary role as assessing the current and future application of molecular genetics to those aspects of CGIAR work that relate to germplasm improvement. In doing so, however, the Panel does not discount the value of biotechnology to other areas of research relevant to the CGIAR mission (Section 2.4).

Future Strategy

A new strategy is required to harness the skills of public and private sector research capacity on a global basis, to contribute to the CGIAR mission. The Panel considers it unrealistic to suppose that the Centres could undertake, by themselves, the desired research on the scale required to meet the future needs of their work (Section 3.1).

In the Panel's view, the CGIAR should regard the Centres as major foci for molecular biological information pertaining to the key crops, pests, pathogens and livestock that are important for the poor. The Centres are likely to remain appropriate places to assay and improve germplasm for the properties required to serve their clients and to assist in identifying the genes associated with particular traits. They should therefore build partnerships and networks with key laboratories and databases to ensure that the new knowledge is generated and applied. Nonetheless, biotechnology should always be seen as a means of facilitating problem-solving research, rather than as a force affecting its direction (Section 3.1).

It will also remain essential to take into account concerns about the potential risks associated with the release of transgenic organisms. The Panel ***recommends*** that the CGIAR establishes a policy framework on biosafety and gene deployment such that mechanisms are always in place to ensure that the benefits and risks associated with the release of transgenic organisms are assessed and that the regional and national regulations and priorities are fully observed (Section 3.2.1).

Regarding new approaches, the Panel ***recommends*** that the CGIAR should develop a new strategy that would include three different, but interrelated, types of activity. One would be designed to position the CGIAR System alongside others committed to a greater understanding of germplasm. Another would foster the evolution of international networks for biotechnological research on problems directly associated with the CGIAR mission, while a third would be internal and designed to ensure that Centres have the capacity to apply the increasing pool of knowledge to meet the needs of their client countries (Section 3.2.1).

Implementation

The Panel ***recommends*** that the CGIAR should be instrumental in bringing about a "Genome Summit" involving representatives of multinational companies, major funding agencies, charitable institutions and other organizations, at the highest level. The forum created would bring together existing genome initiatives, stimulate collaboration, raise the profile of the CGIAR mission and bring more information into the public domain (Section 3..2.2).

The Panel also ***recommends*** an expanded networking approach to biotechnological research for development in agriculture, fisheries and forestry, in which the Centres would participate together with public and private sector organizations throughout the world. Such an initiative would require, as a minimum, a new fund, a broadly based steering committee and a secretariat. The basic philosophy would be to harness and augment the resources already being applied to biotechnology in these areas through collaborative and networking approaches. Expert groups would be established to award grants and fellowships on a competitive basis and reinforce the Centres' own activities in building networks (Section 3.2.3).

The Panel ***recommends*** that the Centres review their in-house expertise in relation to the proposed new strategy. Each Centre would need to review its expertise in genomics and bioinformatics, as well as its capacity for assessing, more widely, the potential contributions of biotechnology to its research programmes. Strategies for the greater use of biotechnological approaches should give appropriate weight to in-house contributions as well as to external, collaborative and contractual approaches. Senior staff skills in business management and related matters might need strengthening and similar skills would be desirable at board level. Centres would also need to review their advisory and training roles in biotechnology and related matters and build their capacities accordingly (Section 3.2.4).

The Panel considers that procedures for evaluating the potential role of transgenics in any new product, and for assessing the associated benefits and risks, should be conducted within an agreed CGIAR policy framework, on a case-by-case basis. Such procedures should take into account the findings of relevant research, including that at the farmer level, and should recognize the views of the client countries (Section 3.2.4).

The Panel ***recommends*** that each Centre should have an independent committee exercising a "duty of care" to make sure that, for each product, benefits and risks are assessed, clients consulted and regulatory procedures strictly adhered to (Section 3.2.4).

In the Panel's view, biotechnology should not be treated separately for purposes of planning, funding or assessment, either by the Centres or by TAC, but should be fully integrated into the broader programmes to which it relates (Section 3.2.5).

To assist the Centres to expand their work in biotechnology, the Panel ***recommends*** the creation of a central CGIAR Biotechnology Service Unit capable of giving professional advice to the Centres on the proprietary, biosafety and gene deployment considerations of their project proposals. It could also help the Centres in their negotiations with potential collaborators (Section 3.2.5).

Conclusion

The Panel concludes that there are widespread opportunities for the greater involvement of the world scientific community to assist in the application of biotechnology to the needs of developing countries. The CGIAR is in a strong position to act as a catalyst to foster these contributions, while progressively strengthening its own role as a significant user of biotechnology to further the aims of its mission (Section 4).

1. INTRODUCTION

1. 1. Background

The CGIAR mission statement emphasizes the alleviation of poverty and the protection of natural resources for sustainable food security. Within these broad aims, the CGIAR makes its contributions largely, but not exclusively, through improved technology that increases productivity while conserving biodiversity, land and water. It is dependent for its success on close collaboration with national research systems in the developing countries.

The CGIAR Centres have progressively invested in biotechnology and applied its tools to their work in furthering the CGIAR mission. However, recent developments, especially rapid advances in the molecular characterization of genes and genetic variation, have given new impetus to the case for greater use of selected applications of biotechnology. It was against this background that the CGIAR decided to look in depth at its future strategy on biotechnology and related activities.

The adequacy of its investment in biotechnology was discussed at the Mid-Term Meeting in May, 1997 and again in October at ICW97. Several documents provided background information and analyses for these discussions. This report does not attempt to summarize these documents nor the proceeding of the two meetings. For ease of reference, however, a few of the salient points are recapitulated from three of these papers in the following paragraphs.

"A Report on the Highlights of a Stakeholders Consultation", convened in April 1997 concluded that the CGIAR was under-investing in biotechnology and conveyed the following "messages":

- recognizing the potentials of biotechnology as an added tool, the CGIAR should proceed with efforts to enhance its capacity for biotechnology research with a special emphasis on such technologies as molecular markers and a strong link to breeding, farming systems at the smallholder level and ecological considerations,

- investment in biotechnology research will need to be increased by a significant amount, a multiple of the current allocation,

- stronger partnerships and collaboration are required within the CGIAR System as well as between CGIAR Centres and others engaged in biotechnology research,

- the CGIAR should position itself to ensure that advances in biotechnology can be harnessed for the benefit of the poor and for the protection of the environment; it should vigorously promote public awareness of the context in which biotechnology programs are carried out.

A background paper compiled by the CGIAR Private Sector Committee under the title: “Strengthening CGIAR-Private Sector Partnerships in Biotechnology”, came (*inter alia*) to the following conclusions.

- At a minimum, Centres need the capacity to *access knowledge* and evaluate its potential usefulness for their own or their partners’ research.

- Centres need the *capacity to use* knowledge obtained from the outside and build on it for their own purposes.

- The Centres’ in-house capacity in biotechnology is important, but without a strong *co-operative research* dimension this capacity is not likely to lead to rapid learning and innovation.

Views from a small-farmer perspective were portrayed in a paper by the Chairman of the CGIAR-NGO Committee entitled: “The CGIAR and Biotechnology: Can the Renewal Keep Promise of a Research Agenda for the Rural Poor”. The paper drew attention to the importance of maintaining the CGIAR research effort on the agro-ecological aspects of crop productivity. He outlined the potential contributions of biotechnology to alleviating the problems of resource-poor farmers, the limitations of technology promoted by the private sector and the risks inherent in the release of transgenic organisms. He also emphasized the role of participatory research at the farmer level in developing new agricultural technology and improved varieties.

As a consequence of the discussions generated by these and other inputs at the mid-term meeting in May 1997, two expert panels were appointed to advise on the way forward in biotechnology, one focusing on general issues and the other on legal aspects. The two panels were designed to work in liaison, three members being common to both panels. Accordingly, while fully recognizing the importance of proprietary and legal issues for the CGIAR System, the Panel on General Issues has not included them in this report.

Terms of reference, Panel membership and an outline of the programme of work are given in Annex I.

1. 2. Consultation

Before meeting to consider its recommendations, the Panel consulted widely among stakeholders and others. In addition, Panel members contacted a range of individuals by telephone. The questions posed are listed in Annex II, together with a summary of the salient points made and a list of those who responded. The Panel is conscious that scientists in the developing countries, as well as NGOs, are under-represented in the list. No attempt was made to include farmer organizations in the survey.

2. BIOTECHNOLOGY AND THE CGIAR MISSION

2.1. Biotechnology, Bioethics and Biosafety

The term "biotechnology" is frequently used in a very broad and general way to mean the application of biological discoveries to the development of new products. The Panel considers it essential that assessments are made, and strategies defined, in relation to individual areas of biotechnology and that the CGIAR promotes and defends its position on the basis of specific scientific applications, not in terms of "biotechnology" in its generic sense.

This distinction is particularly important because some areas of biotechnology are controversial, such as the release of transgenic organisms, whereas others are not, such as the use of molecular techniques for the assessment of germplasm in the laboratory. Hence, the use of only the generic term by the CGIAR in debates, public awareness programmes and discussions with stakeholders is likely to be unhelpful, can be confusing and should be avoided.

The Panel has not discussed in detail those aspects of biotechnology that relate to bioethics, biosafety, or gene deployment, but recognizes that the CGIAR needs to develop and observe a code of conduct for the application of biotechnology that is explicit, transparent and widely publicized. The Panel notes that the CGIAR is giving attention to bioethics through a committee established for that purpose. The Panel considers that the CGIAR and the Centres should develop formal procedures for deriving regionally and locally acceptable biosafety and gene deployment protocols, in consultation with the countries concerned (see also Section 3.2.4).

2.2. Developments and Prospects in Genetics

Germplasm analysis and improvement, as well as the development of many diagnostic techniques and vaccines, are based upon genetic variation, inheritance patterns and the association of desired characteristics with genetic determinants. The convergence and massive scale-up of the strategies and techniques of molecular biology and genetics are underpinning unparalleled increases in precision and efficiency in this work. Two principal subfields are discernible: (a) the characterization of gene and genome structure by DNA sequencing and associated activities, such as the development of molecular markers for every chromosomal region and, (b) the characterization of gene function, gene regulation and the control of complex traits, through the use of novel approaches.

All phases of genome research today are critically dependent upon, and interconnected by, sophisticated bioinformatics and database capabilities. As a result of these developments, the pace of gene discovery, characterization and manipulation has been vastly accelerated. Current estimates indicate that the entire Arabidopsis genome will be sequenced by the year 2000. Moreover, because of the commonality of the genetic code and conservation or convergence of structures to perform similar tasks across all biological kingdoms, the pool of interpretable genomic information is expanding at an exponential rate, as the complete genomes of many organisms are being sequenced, analyzed and deposited in databases.

These molecular genetic analyses are being carried out in many public sector laboratories around the world, in large multinational corporations and also in small specialist companies which do contract research for other organizations. As the scale of these operations increases so the cost of the information decreases. It is therefore projected that the molecular genetic analysis of any genome will become a routine, highly automated procedure within the next two decades.

Translating this genomic knowledge into improved germplasm requires the creation of new gene combinations, whether achieved through classical plant breeding or by introduction of genes in the laboratory. Improvements in this transformation technology are also being developed at a rapid rate and for many crops including cereals, such as rice, wheat and maize. Transformation technology is already being widely used for the introduction of single-genes to enhance, for example, disease-resistance.

Thus, the future holds the promise of combining information on hundreds of thousands of variant genes from many species with a generic, broadly-applicable transformation strategy. As a consequence, it is reasonable to infer that any organization committed to germplasm conservation, analysis and improvement must gain and exploit these innovations to be efficient, competitive and viable in the future. It is this vision that the Panel wishes to commend to the CGIAR.

2.3. The Overriding Need for a Balanced Approach

The development and dissemination of the improved technology through which the CGIAR seeks to further its mission is undertaken in a holistic context that encompasses all the relevant natural and social sciences. Any expansion of molecular genetic approaches within the CGIAR must constantly be viewed in this context and the Panel re-emphasizes the view, frequently expressed by others, that retaining a balanced approach within the total CGIAR research portfolio will be an essential pre-requisite for further progress. The Panel also concurs with the view, expressed in the report to the World Bank of the Panel on Transgenic Crops, that any increased investment in new agricultural technology must be accompanied by significant investment in ecological and sociological research to ensure support for safe and sustainable food production.

The Panel recognizes that any expansion of molecular genetics and transgenics by the CGIAR will be an evolutionary process that will proceed at different rates, depending on the organism, the nature of the problem and the available infrastructure. In some instances there will be a shortage of trained personnel or inadequate infrastructure in terms of the supply, on a regular and reliable basis, of the necessary materials and reagents to meet laboratory requirements. Equally, in some countries, there may not be adequate facilities for servicing and repairing complex equipment. In the Panel's view, these considerations should not deter the CGIAR from putting in place the suggested internal and external structures. It would then be possible to expand the selected biotechnological approaches as and when it becomes feasible to do so, recognizing that the appropriate balance will vary with each set of circumstances.

2.4. Relevant Applications of Biotechnology

Those who responded to the Panel's survey described many applications of biotechnology that would accelerate progress in CGIAR projects. These responses are summarized in Annex II (questions 1 and 2). They cover applications related to the productivity of crops, livestock and aquatic organisms as well as to problems related to ecology, environmental conservation and germplasm banks. Some of these applications and the transgenic crops currently adopted into agriculture are elaborated in Annex III and Annex IV for the reader who has no specialist knowledge of biotechnology.

The CGIAR currently allocates more than 20% of its resources to germplasm improvement and conservation, and has agreed that this proportion will be somewhat increased in future. The links between germplasm improvement and the broader CGIAR mission have already been firmly established and summarized in various documents produced by TAC. Consequently, the Panel has seen its primary role as assessing the current and future application of molecular genetics to those aspects of CGIAR work that relate to germplasm improvement. In doing so, the Panel does not in any way discount the value of biotechnology to other areas of research that are also relevant to the CGIAR mission.

Many biological techniques, such as those associated with tissue culture, have been widely used for many years. The Panel has not regarded such applications as part of its study, but has concentrated on molecular and biochemical aspects. Within these applications, the Panel has given greatest attention to the application of molecular genetics to crop improvement, recognizing that many of the topics discussed are also relevant to trees, livestock and fish

2.5. The Application of Molecular Genetics to Crop Improvement

The Panel concludes that there are widespread opportunities for assisting developing countries through the application of molecular genetics to crop improvement. The Panel is aware, however, of the concerns that are commonly expressed about some of these applications, whether soundly based or not. For example, there is strong opposition from those who see biotechnology as a vehicle for acquiring unjustified proprietary rights, while practicing plant breeders have been critical of the cost-effectiveness of some of the techniques on offer. In addition, criticisms have arisen because of unwarranted and unfulfilled claims of what is achievable through biotechnology within a given time frame.

Although the Panel recognizes such concerns, it notes that there will be many opportunities to take advantage of those aspects of biotechnology for which the benefits greatly outweigh the risks. There will also be applications to which the concerns do not apply, such as marker assisted selection. Such techniques, used for screening breeders' material, have no adverse environmental implications and plant breeders' criticisms are increasingly being met by the dramatic reductions in cost and the increased scale on which they can be applied. Moreover, any proprietary rights attached to the techniques do not necessarily threaten the release, as public goods, of the improved germplasm derived from them.

The development of these techniques is dependent on genome mapping. The Panel is concerned that investment in genomics by the CGIAR is very small compared with similar investment by the private sector. Although the private sector is motivated partly by the rush to acquire proprietary rights, the Panel considers that the CGIAR is already being left behind in this work, as related to future requirements for the improvement of its mandated crops, as well as for the maintenance and use of its germplasm banks (see Annex III).

Many of the concerns surrounding biotechnology are more specifically related to genetic engineering and the release of transgenic organisms than to other applications. The Panel recognizes the need both for more research aimed at assessing the benefits and risks of such releases and for adequate precautions to overcome any risks identified. Nevertheless, the potential benefits to be derived from transgenic plants, especially to resource-poor farmers, cannot be ignored.

In routine plant breeding aimed at the needs of the small farmer, the transfer of desirable genes from gene-bank accessions to important cultivars within the same species can be accelerated by marker assisted selection and genetic engineering. Similarly, through transformation, desirable traits that cannot be found within the same species can be transferred from sources outside it. Such traits include complex characters under polygenic control, such as the components of yield.

The Panel discusses the implications of these and similar developments in later sections of this report, insofar as they relate to the need for a revised CGIAR strategy.

3. REQUIREMENTS FOR THE FUTURE

3.1.   The need for New Approaches

New approaches are required that harness the skills of public and private sector research capacity on a global basis, to contribute to the common purpose. Centre involvement could be seen as providing hubs for a networking approach in which each commodity Centre continues its role in germplasm enhancement, expands its role as the repository of information on its mandated crops and assists in the transfer of biotechnology to its partners in the developing world.

Taking into account the strengths and weaknesses of the multitude of organizations and institutions involved in biotechnological research, the Panel considers it unrealistic to suppose that the Centres could undertake, by themselves, the desired research on the scale required to meet the future needs of their work. The cost of developing adequate in-house capacity would be prohibitive and would inevitably detract from other vital activities. These considerations apply whether the required facilities were to be developed at each Centre, or at one or more Centres as shared facilities.

Given some of the projected changes in research approaches, the Panel considers that there will remain a major long-term role for the Centres to apply state-of-the-art research, knowledge and technology relating to problems in germplasm improvement. In the Panel's view, the CGIAR should regard the Centres as major foci for molecular biological information pertaining to the key crops, pests, pathogens, livestock and fish that are important for the poor.

To fulfill such a role, the Centres would need to be major players at the leading international tables concerned with policies on the acquisition and utilization of information on molecular genetics for the analysis, conservation and enhancement of germplasm. They would also need to develop capabilities in bioinformatics to gather, use and disseminate the information acquired in these areas.

The primary information on commercial crop genomes is being generated in public and private sector laboratories on a global basis. Much of it is directly or indirectly useful to the Centres. The CGIAR needs to negotiate the means, and establish the mechanisms, to have direct access to present and future information. Additional mechanisms will be required to acquire information on the orphan crops within the CGIAR mission. Many laboratories and especially the large multinational companies are well provided with both human and technical resources to generate molecular characterizations of complex genomes. The CGIAR should use these resources and seek to take advantage of such facilities to further its own mission.

However, the Centres are likely to remain the appropriate places to assay and improve germplasm for the properties required to serve their clients and to assist in identifying the genes associated with particular traits. They should therefore build partnerships and networks with key laboratories and databases to ensure that relevant new knowledge is generated and applied.

Similar considerations apply to the use of molecular genetics in Centre programmes in areas of research other than germplasm improvement, such as applications to research on agro-ecosystems. Full integration of relevant molecular genetics into each programme or project would continue to be essential. Molecular genetics should be seen as a tool for facilitating problem-solving research, rather than as a force affecting its direction.

3.2. A New CGIAR Strategy

3.2.1. The Basic Framework

For the CGIAR to remain abreast of developments in biotechnology and to take full advantage of them to further its mission, new structures and administrative arrangements will be needed. It will also remain essential to take into account concerns about the potential risks associated with the entry of transgenic crops into agriculture and food chains. Consequently, there is an urgent need to work towards universally acceptable biosafety and gene deployment protocols and to promote the research needed to refine and implement them.

The Panel ***recommends*** that the CGIAR establishes a policy framework on biosafety and gene deployment such that mechanisms are always in place to ensure that the benefits and risks associated with the release of transgenic organisms are assessed and that the regional and national regulations and priorities are fully observed.

Regarding new approaches, the Panel has not attempted to be prescriptive, but has discussed the principles involved. The Panel ***recommends*** that the CGIAR should develop a new strategy that would include three different, but interrelated, types of activity. One would be designed to position the CGIAR alongside others committed to a greater understanding of germplasm. Another would foster the evolution of international networks for biotechnological research on problems directly associated with the CGIAR mission, while a third would be internal and designed to ensure that Centres have the capacity to apply the increasing pool of knowledge to meet the needs of their client countries. Although these three types of activity would be separate in conception, there would be close links between them.

3.2.2. Global Collaboration

The rapidly advancing fields of genomics and bioinformatics, while becoming extremely competitive areas for the private sector, also present new opportunities for the CGIAR System. The Panel considers it vital that the mission of the CGIAR, the work of its Centres and the needs of the developing countries are more widely recognized at all levels in the relevant scientific structures. These already include initiatives such as the Human Genome Project, the International Arabidopsis Genome Programme, the International Rice Genome Programme and the National Genome Initiative of the USA (see Annex V).

The Panel therefore ***recommends*** that the CGIAR should be instrumental in bringing about a "Genome Summit" involving representatives of multinational companies, major funding agencies, charitable institutions and other organizations, at the highest level. The forum created would establish the broad goals and standards required for greater understanding of the genomes of the principal organisms on which the planet depends and thus strengthen the role of the CGIAR in making such information more readily available to the developing countries.

In the first instance, such a forum need not be distracted by issues of intellectual property, since these are fast changing issues that can be resolved through specific negotiations. The aims of the "genome summit" would be to:

- bring together existing genome initiatives into a common perspective;
- define the global needs, goals and standards;
- define policies that will stimulate collaboration at all levels within the relevant scientific communities; and
- ensure that the CGIAR's mission and activities are recognized as of crucial importance in the field of genomics.

The Panel sees such a summit as a means of pulling potentially large amounts of additional resources and information, relevant to the CGIAR, into the genomics arena, thus advancing the CGIAR mission and benefiting the other collaborators. Ideally, much of the information stemming from such a global effort would be seen as international public goods from which all countries, all institutions and all people could eventually benefit. To get such a programme off the ground would require vision and universal goodwill. The Panel considers that the CGIAR could have an important role in meeting this challenge.

3.2.3. International Networks for Biotechnological Research

The Panel also ***recommends*** an expanded networking approach to biotechnological research for development in agriculture, fisheries and forestry. Such an initiative would require, as a minimum, a new fund, a broadly based steering committee and a secretariat. The basic philosophy would be to harness and augment the resources already being applied to biotechnology in these areas through collaborative and networking approaches. Expert groups would be established to award grants and fellowships on a competitive basis and reinforce the Centres' own activities in building networks.

Some of its activities might well build on the experience already gained from initiatives such as the International Rice Biotechnology Programme sponsored by the Rockefeller Foundation (see Annex V). Although networks of this type need to be backed by a fund to provide seed money, the value of the collaborative work far exceeds the cost of the central input. Participation in this type of network creates a group of scientists who develop a feeling of common ownership that leads them to contribute in ways that far exceed their formal commitment. The networking approach also has an important training function and can incorporate numerous ways of drawing on existing skills and facilities.

The association of the Centres with all such activities would be similar to the association of IRRI, CIAT and WARDA with the Rockefeller Foundation's programme. The Centres would contribute to the work of the networks and draw on their products. They would also be competitors for grants alongside other applicants and would help to identify candidates from national programmes for fellowships, sabbatical leave and other similar arrangements.

If this idea finds favour, detailed thought would have to be given to whether or not it would be feasible to promote and assist the multiplicity of different networks implied through one administrative agency. The central steering committee and secretariat would have the tasks of helping to find donors for a central fund for the award of grants and fellowships, as well as for the support of individual projects. The Panel's view is that to establish a semi-independent central mechanism for these functions would be preferable to imposing these tasks on Centre staff.

3.2.4. Centre Roles and Capacities

The Panel ***recommends*** that each Centre should review its in-house expertise in relation to the proposed new strategy.

Centres involved in germplasm improvement will require sufficient expertise to monitor progress within the relevant global genomics community, participate in the overall effort and make decisions on how information and resources on molecular genetics should be used. Internal skills in bioinformatics (see Annex III) will become increasingly important for the effective use of genomic data generated within the informal global networking system. Existing networks in genomics consist of scientists and institutions, both public and private, with common interests in acquiring and interpreting information. They are typically supported by bioinformatics through the WWW and databases, and are funded from a variety of sources. These networks and their constituent scientists and institutions will be the engines of discovery for the CGIAR needs in genomics. Guiding their outputs towards the needs of the poor will be an important role for the Centres.

In addition to reviewing its skills in genomics and bioinformatics, each Centre would also need to review its capacity for assessing, more widely, the potential contributions of biotechnology to its research projects and to re-consider its strategies for exploiting new discoveries. Such strategies should give appropriate weight to in-house contributions as well as to external, collaborative and contractual approaches.

For example, a Centre could contract an industrial company to map the molecular diversity within 20,000 accessions of its germplasm collection using 1,000 markers, or perform the molecular diagnostics work in its marker-assisted breeding programmes using state-of-the-art efficiencies present nowhere else in the world. Leading scientists at advanced research institutes could be given "joint appointments" or be formally affiliated to the Centres to help ensure a long-term commitment. Exchange of resources and personnel could be formalized

Where proprietary rights are involved and the material or technique is not freely available for use in developing countries, the Centres should consider promoting research to circumvent such restrictions. However, there will also be many aspects of biotechnology of importance to the CGIAR mission that will remain of little interest to profit-making organizations in the short and medium terms. It is these aspects, in particular, that could be developed as international public goods.

Senior staff skills in business management and related matters might well need strengthening and similar skills would be desirable at board level. Centres would also need to review their advisory and training roles in biotechnology and related matters and build their capacities accordingly.

The Centres should also be prepared to undertake research to examine the potential risks in cases where there would be significant benefits in releasing transgenic organisms. The Panel considers that procedures for evaluating the potential role of transgenics, and for assessing the associated benefits and risks, should be conducted within the agreed CGIAR policy framework (see Section 3.1), on a case-by-case basis. Such procedures should take into account the findings of relevant research, including that at the farmer level, and should recognize the concerns of the client countries.

The Panel ***recommends*** that each Centre should have an independent committee exercising a "duty of care" to make sure that, for each product, benefits and risks are assessed, clients consulted and regulatory procedures strictly adhered to.

The scope for greater inter-Centre collaboration in the use and exchange of biotechnological experience and information was mentioned in several of the returns to the Panel's questionnaire. Various suggestions were made for networking and other collaborative activities. The Panel strongly endorses the principles described and considers that the possibilities should be explored further, perhaps through an inter-Centre meeting on biotechnology. (The Panel understands that the last such meeting was held in 1989.)

3.2.5. Administrative Implications for the CGIAR

Within the CGIAR administrative structure, the Panel sees TAC as encompassing biotechnology in its routine consideration of Centre programmes. Hence, it will need to draw on appropriate expertise from within or outside its regular membership. In the Panel's view, however, biotechnology should not be treated separately for purposes of planning, funding or assessment, either by the Centres or by TAC, but should be fully integrated into the broader programmes to which it relates.

To assist the Centres to expand their work in biotechnology, the Panel ***recommends*** the creation of a central CGIAR Biotechnology Service Unit capable of giving professional advice to the Centres on the proprietary, biosafety and gene deployment considerations of their project proposals. It could also help the Centres in their negotiations with potential collaborators.

The Panel sees this Central Service Unit as commenting on all proposed Centre projects that involve aspects of biotechnology. The existence of such a unit would automatically help in sharing experience and information among the Centres and the countries they serve. In the context of the more general dissemination of information on policies and practices, the Panel sees scope for creating a Web site for information on bioethics, biosafety and gene deployment. An appropriate organization might be commissioned to run such a site.

4. CONCLUSIONS

The Panel has considered ways in which the CGIAR might advance its mission through greater use of the tools of biotechnology. Earlier reservations about the potential benefits of biotechnology are now being overtaken by the increased rate of discovery of new knowledge, the development of new techniques and the scale on which they can be applied. The Panel concludes that the CGIAR must take appropriate action to ensure that it is not left behind in the new approaches rapidly becoming possible. At the same time it must not lose sight of the overriding need to retain an appropriate balance in the totality of its activities.

The Panel also concludes that there are widespread opportunities for the greater involvement of the world scientific community to assist in the application of biotechnology to the needs of the developing countries. The CGIAR is in a strong position to act as a catalyst to foster these contributions, while progressively strengthening its own role as a significant user of biotechnology to further the aims of its mission.

ACKNOWLEDGEMENTS

The Panel is most grateful to those who responded to the ten questions; to those who provided information for Annex III; to the Rockefeller Foundation for hosting the meeting in New York; and to Jeni Fox of the John Innes Centre, Norwich, UK, for secretarial and administrative assistance.

ANNEX I

TERMS OF REFERENCE, PROGRAMME OF WORK AND PANEL MEMBERSHIP

1. Terms of Reference

The Panel on General Issues in Biotechnology was given the following terms of reference:

The Panel will:

1. Identify issues of major concern to the CGIAR that will facilitate positioning the CGIAR in the global agricultural research system.

2. Provide advice and guidelines on immediate or long-term needs with respect to: comparative advantage analysis; risk management; strategic alliances; and strategy and resources.

3. Prepare a draft strategy on biotechnology for the CGIAR, taking into consideration needs of the Centres and stakeholders, identifying options for the strategic involvement of the CGIAR in the use of biotechnological approaches to solving problems relative to its mission.

4. Prepare a report and recommendations to be presented to TAC for commentary and for consideration by the Group at its mid-term meeting scheduled for May 25-29, 1998.

2. Programme of Work

An initial meeting of the Panel was held in Singapore on 21 September 1997. Six Panel members (Flavell, Dryden, Quail, Toenniessen, Uchimiya and Zhang) were able to attend, together with Tim Roberts (Chairman of the panel on proprietary issues). Dr Roca (CIAT) and Dr Bennett (IRRI) joined this group for part of the meeting.

Discussion at the meeting led to drawing up a framework for the study and formulating ten questions that were used for a survey conducted by mail and telephone early in 1998. The initial responses to these ten questions provided background information for the second Panel meeting held in New York on 26 - 27 January. This meeting was attended by nine Panel members (Flavell, Dryden, Padmanaban, Toenniessen, Goodman, ole-MoiYoi, Seitzer, Uchimiya and, through a conference telephone, Altieri). The Panel Secretary also attended.

The meeting identified the issues to be included in the report and reached consensus on the main conclusions. Thereafter, the work was continued through correspondence, mainly by e-mail.

3. The Panel

Professor Richard B. Flavell (Chair),
Director, John Innes Centre,
Norwich Research Park,
Colney,
Norwich, Norfolk NR4 7UH, UK

Professor Miguel A. Altieri,
Professor of Agroecology,
ESPM-Center for Biological Control,
201 Wellman Hall # 3112,
Berkeley, CA 94720-3112, USA

Dr. R. N. (Sam) Dryden,
Big Stone Partners,
1634 Walnut Street,
Suite 301, 1630 Linden Drive,
Boulder, CO 80302-5400 USA

Professor Robert M. Goodman,
Chair, Undergraduate Program in Molecular Biology,
Russell Laboratories, Room 687A,
University of Wisconsin,
Madison, WI 53706, USA

Dr. Michael Hansen,
Research Associate,
Consumer Policy Institute,
101, Truman Avenue,
Yonkers, NY 10703-1057, USA

Dr. Onesmo ole-MoiYoi,
Biochemistry/Molecular Biology Laboratory,
c/o ILRI - PO Box 30709,
Nairobi, Kenya

Professor Govindarajan Padmanaban,
Director,
Indian Institute of Science,
Bangalore 560 012,
India

Professor Peter H. Quail,
Director of Research,
Plant Gene Expression Center,
800 Buchanan Street,
Albany, CA 94710, USA

Professor Jozef Schell,
Max-Planck-Institut für Züchtungsforschung,
Carl-von-Linne-Weg 10,
D-50829 Köln,
Germany

Dr. Josef-Franz Seitzer,
KWS Kleinwanzlebener Saatzucht AG,
Grimsehlstr. 31,
37574 Einbeck,
Germany

Dr. Gary Toenniessen,
The Rockefeller Foundation,
420 Fifth Avenue,
New York,
NY 10018 USA

Professor Hirofumi Uchimiya,
Institute of Molecular and Cellular Biosciences,
University of Tokyo,
Yayoi, Bunkyou-ku,
Tokyo 113, Japan

Professor Qifa Zhang,

Dr. Michael H. Arnold (Panel Secretary),

National Key Lab. of Crop Genetic Improvement,
Huazhong Agricultural University,
Wuhan 430070,
China

"Hamlec",
4 Shelford Road,
Whittlesford,
Cambridge, CB2 4PG, UK

ANNEX II

SALIENT POINTS FROM RESPONSES

TO THE

PANEL'S TEN QUESTIONS

1. Introduction

Before meeting to discuss its recommendations, the Panel (through its Chairman) invited responses to ten questions. The questions were distributed to a wide range of CGIAR stakeholders and others. The Panel is conscious that the replies do not necessarily constitute a fully representative sample of all stakeholders. Nonetheless, reasonably wide coverage was achieved using names suggested by the Chairman of TAC, Panel members and others. In addition, Panel members consulted widely by telephone on the same questions.

This Annex summarises the responses. They have not been analysed quantitatively, but an attempt has been made to reflect the diversity of opinions expressed, as well as to indicate the main areas of common ground.

2. General Impressions

Perceptions of the appropriate level of future CGIAR investment in biotechnology differ widely. Many are strongly supportive of biotechnology; others remain unconvinced that there should be increased investment in this area. A few are strongly opposed to any additional investment in biotechnology, while several make the point that the CGIAR should stick to its problem-solving, bottom-up philosophy and should not apply a top-down (technology-push) approach. Some emphasize the importance of agro-ecological approaches backed by participatory research at the farmer level. Mention is also made of the practical difficulties of rapid expansion in biotechnology, such as staffing, training, infrastructure, supplies and services.

Many, unfamiliar with the details of the technology, tended to relate "biotechnology" to the generation of transgenic organisms and the control of their ownership by patents. Those more familiar with the details emphasized the opportunities for applying the new analytical techniques to germplasm improvement and other ventures.

Against this background, the word “caution” featured in various different contexts but especially in those related to biosafety and other risks. At the same time there was general agreement that the CGIAR should position itself so as not to miss emerging opportunities in biotechnology, which are seen as extending well beyond genetic improvement. Some see increased emphasis on biotechnology as essential for the survival of the Centres as credible research institutes. Some donors support increased investment by the CGIAR in biotechnology; others await guidance from the two Panels.

3. The Ten Questions

1. What developments are likely to emerge in biotechnology from the advanced public institutions and major companies, over the next 10 years, that should be exploited to fulfil the CGIAR mission?

Developments identified in the responses to this question are many and varied. Genomic characterisation, and its application to identifying desirable genes, is generally regarded as a key area, whether stated explicitly or by implication. Marker-aided selection and transformation feature strongly as providing new ways of enhancing desirable characteristics or of inserting special traits into well adapted genotypes. Among lists of desirable traits, the most commonly cited are resistance to biotic and abiotic stresses, as well as the quality of harvested products. Gene promoters allowing their expression in particular tissues also receive attention. Several responses mention the potential value of apomixis and induced male sterility in the final production of improved crop varieties, while both apomixis and clonal production feature for trees. Diagnostic techniques are mentioned in a wide range of contexts.

CIFOR and IIMI do not see a compelling need to become heavily involved in biotechnology as they both have natural resources mandates. ICRAF explains the potential for domestication in tree species and the wide differences in the nature of the problems encountered compared with those of arable crops. IPGRI has special aims related to germplasm banks; ICLARM sets out its vision of the use of biotechnology in relation to aquatic organisms; and ILRI covers applications to livestock improvement and disease control (see Annex III for amplification of these aspects).

2. What biotechnological developments are client countries seeking and expecting?

Developing countries wish to take advantage of any developments in biotechnology that they perceive as beneficial, such as cheap and reliable selection techniques based on molecular markers. Some are already active in the main areas of research involved and others are moving in that direction.

The role of Centres in forming bridges for the transfer of biotechnology and assisting with capacity building, is a recurring theme. There is general recognition that developing countries vary in the extent to which they are currently geared up to incorporate biotechnology into their research programmes. The need for training, information services and advice (especially on biosafety and proprietary rights) is commonly cited.

3. Who should decide what biotechnology products are produced by CGIAR initiatives?

Some considered existing processes of strategic planning and priority setting to be adequate for integrating biotechnology into current programmes. Some argue that all CGIAR stakeholders, including donors, should be involved in decision-making or that decisions should be made by an independent panel. There seems to be a majority view, however, that decisions should be de-centralised. Centres should operate within a broad policy framework determined by the CGIAR and then be free to make their own decisions based on a bottom-up approach in which the developing countries have full participation. There is also a view that market forces will influence what the Centres do. Central (CGIAR) scrutiny would be through the processes already in place (budgets, medium-term plans, external reviews, etc.). There is a view that TAC should find ways of remaining in closer touch with biotechnology.

4. What are the implications for client countries, NGOs and consumers of the recommended adoption of biotechnology by the CGIAR, and what part should IARCs play in facilitating the acceptance of agreed biotechnology products?

Implications for client countries are broadly seen as positive. However, several responses emphasize the importance of establishing recognized biosafety mechanisms in developing countries and the need for appropriate delivery systems for the products of biotechnology. There is a view that this may not be possible without full participation of the private sector. Client countries will need to invest in laboratory facilities and personnel if they are to make full use of biotechnology in their own research programmes and to enable them to collaborate actively with Centres and others.

An important role of the CGIAR is seen as catalytic, as a provider of information and advisory services to create greater awareness of both the benefits and the risks. CGIAR Centres could help client countries and NGOs to keep fully in touch with the scientific, legal and biosafety aspects.

5. What biotechnology partnership models should be developed between IARCs, NARSs, NGOs and industries to deliver the mission of the CGIAR more effectively and efficiently?

There is strong support for partnerships and involvement of the private sector both in research collaboration and in delivery systems. The replies tend to be in terms of broad generalizations, with recognition that models cannot be determined in advance and are better developed on a case-by-case basis. There is strong support for networking approaches. One reply suggests central co-ordination with, perhaps, a new Centre.

6. What kinds of partnerships, networks and business agreements need to be developed and adopted to ensure the best technology can be exploited by IARCs?

Many different arrangements are described in the responses. There is general recognition of the need for Centres to have access to the latest developments in biotechnology and hence the need to form alliances (preferably of mutual benefit) with other organizations in both the public and private sectors. Attention is drawn to the opportunities for contracting some of the work to outside organisations, rather than the Centres attempting to do all of it themselves. Several respondents mention the need for some form of central capacity within the CGIAR to give advice on the various types of alliance.

One specific idea (CIMMYT) is for a CGIAR-sponsored information network that could establish a database for molecular data relating to accessions in the various germplasm banks. Greater and more frequent interchange of ideas and experience among Centres also features in some responses.

7. What investments and management changes would be required in the IARCs to enable them to implement the desired changes as new opportunities emerge from biotechnology?

Responses vary. Some see no need for a "big bang" but regard the Centres as being on an evolutionary pathway that will gradually incorporate more biotechnology as appropriate. Others see the need for major new investments in personnel and equipment. Special-project funding is regarded by many as inappropriate for much of the work. The importance, at senior staff and board level, of skills in business management, proprietary rights and related matters is mentioned by many.

8. What are the implications for the IARCs for senior appointments, staff cohorts, training and turnover if the recommended levels of biotechnology are adopted by the CGIAR

There is general recognition of the need (where not already met) for a member of the senior management staff to hold responsibility for monitoring developments in biotechnology and guiding Centre strategies and priorities. Most see changes being made through evolutionary processes, rather than by a dramatic change.

IPGRI describes the value of its Honorary Fellows embedded in advanced research institutions, an idea that has much in common with other suggestions for ways of drawing upon the expertise and facilities of other organisations to help with Centre programmes. There was a suggestion, for example, that there might be technology units within universities, funded to work explicitly on CGIAR problems.

9. What will be the best structure, funding mechanisms and management systems for the IARCs in the future in order to make best use of biotechnology?

Current de-centralised structures are, in general, regarded as suitable. Additional skills will be required, such as in business management, IPR etc. especially for collaboration with the private sector. Some argue that this capacity should be centralised as a CGIAR special unit to negotiate with the private sector on behalf of all Centres. Greater inter-Centre collaboration is mentioned (including sharing facilities where appropriate) but there is little support for a central laboratory serving all Centres.

There is widespread support for networks in advanced science, involving the best laboratories in the world being linked to the Centres. Increased and long-term funding is regarded as essential and might be provided through special arrangements involving the World Bank, Foundations and other donors.

10. What are the risks for the IARCs and the CGIAR in developing germplasm using the systems, tools and information of biotechnology and, conversely, in not exploiting biotechnology adequately?

(a) Greater use of biotechnology: Possible distortion of CGIAR priorities. Might be perceived as a “technology push”. Exposure to criticism if products are released in countries with inadequate biosafety monitoring mechanisms. The consequences of mistakes could be severe. Possible loss of public goodwill. Some products might prove difficult to deliver to resource-poor farmers.

(b) No expansion in biotechnology: Loss of valuable opportunities to assist research programmes in developing countries and further the CGIAR mission. Loss of scientific and funding opportunities. Loss of credibility of the CGIAR as a leading research organisation. Private sector ownership of biotechnology and its products would predominate.

4. List of Those Who Responded

Arntzen Professor Charles, Boyce Thompson Institute for Plant Research Inc. (USA)
Aveldano Dr Rodrigo, INIFAP-SARH (Mexico)
Bedbrook, Dr. J., DNA Plant Technology Corporation (USA)
Bennett Dr. John, IRRI
Bennett Mr Andrew J, Department for International Development (DFID) UK
Bie Dr. Stein, ISNAR
Brader Dr. Lukas, IITA
Briggs, Dr. Steve, Pioneer Hi-Bred International Inc. (USA)
Buchanan Dr Alex, Crawford Fund for International Agriculture Research (Australia)
Büchting Dr A, KWS Kleinwanzlebener Saatzucht AG (Germany)
Carsalade Mr Henri, Food and Agriculture Organization of the UN

Coffman Professor W. Ronnie, Director, Cornell Agri. Exp. (USA)
Dalodom Dr Ananta, Department of Agriculture, (Thailand)
Davis Dr. Jeremy, International Development Manager, PBIC (UK)
El-Beltagy Dr. Adel, ICARDA
Evans Dr. David, Zeneca Agrochemicals (UK)
Fisher Dr. Ken, International Rice Research Institute (IRRI)
Fitzhugh Dr. Hank, ILRI
Friedrichsen Dr J, GTZ (Germany)
Gowda Dr. C., ICRISAT
Hall, Prof. T., Texas A & M (USA)
Hardy, Dr. Ralph, Ex DuPont and Ex Boyce Thompson Institute (Canada)
Hawtin Dr. Geoffrey, IPGRI
Hoisington Dr. Dave, CIMMYT
Hopper, Mr. David, Ex World Bank and Ex Chair, CGIAR (Canada)
Izard Mr Maurice, Sous-direction du dev. economique et de l’environment (France)
Jacobsen Prof H-J, Universität Hannover (Germany)
James Dr. Clive, ISAAA (Cayman Islands)
Kürschner Dr. E., GTZ (Germany)
Lampe Dr K, ex DG IRRI (Germany)
Lewis Mr John V, US Agency for International Development (USA)
MacGillivray Mr Iain C, CIDA (Canada)
Maeno Dr Nobuyoshi, Japan Int. Research for Agri. Sciences (Japan)
Mazur Dr. Barbara, DuPont Agricultural Products (USA)
McCalla, Dr. Alex, Agriculture and Natural Resources, World Bank
McConnell R., Pioneer Hi-Bred International Inc. (USA)
McCouch Prof. Susan, Plant Breeding Department, Cornell University (USA)
Mellon, Dr. Margaret, Union of Concerned Scientists, Washington (USA)
Miflin Professor Ben, Institute of Arable Crops Research (UK)
Ndiritu Dr. Cyrus, Kenya Agriculture Research Institute (Kenya)
Noome Dr C., Advanta (USA)
Nwanze Dr. Kanayo, WARDA
Padolina Dr. W., Dept. of Science & Technology, (Philippines)
Peacock, Prof. J., CSIRO (Australia)
Petit Mr Michael J, The World Bank
Reeves Professor Timothy, CIMMYT
Röbbelen Prof G, Universität Göttingen (Germany)
Roca Dr. Willy, CIAT
Salamini Professor Francesco, Max-Planck-Institut für Zuchtungsforschung (Germany)
Sanchez Dr. Pedro, ICRAF
Sayer Dr. Jeffrey, CIFOR
Schilde Prof L, Universität Tübingen (Germany)
Scobie Dr. Grant, (with Roca response) CIAT
Seckler Dr. David, IIMI
Seratos-Hernandez Dr. Jose Antonio, INIFA (Mexico)
Shegal Dr. Suri, AgrEvo USA - PGS America (USA)

Strong, Mr. Maurice, Advisor to the President, World Bank
Thornstron Mr Carl-Gustaf, Director, SIDA, (Sweden)
Thrupp Dr. Lori Ann, World Resources Institute (USA)
Toenniessen Dr. Gary, The Rockefeller Foundation (USA)
Trigo Dr. Eduardo, President, Fundación ArgenINTA (Argentina)
Vasil Dr. Indra, University of Florida (USA)
Virgin Dr. Ivar, Stockholm Environment Institute (Sweden)
von Montagu Professor Marc, Laboratorium Genetika (Belgium)
Waffula Dr. James, Kenya Agricultural Research Institute (Kenya)
Weimin Mr Yang, Asian Development Bank (Philippines)
Wenzel Prof. Dr. G., Universität Weihenstephan (Germany)
Wettstein Professor Diter von, Washington State University (USA)
Williams Dr. Meryl, ICLARM
Winkel Mr Klaus, Danish Int. Dev. Assistance, Ministry of Foreign Affairs (Denmark)
Wolpers Dr K-H, GTZ (Germany)
Zandstra Dr. Hubert, CIP

ANNEX III

APPLICATIONS OF BIOTECHNOLOGY RELEVANT TO THE CGIAR MISSION

1. Introduction

Some donors suggested that the Panel's report should not only analyze the issues for decision-makers, but should also be informative for the layman. This Annex has been prepared with the second of these requests in mind but makes no attempt to cover the whole spectrum of possible applications. It elaborates some of the statements made elsewhere in the report and provides a few specific examples of relevant biotechnological applications.

Some of those who responded to the Panel's questions on present and future contributions of biotechnology (see Annex II), did so primarily in relation to improved products (such as drought tolerant plants), rather than to new techniques that can be used in their development (such as marker assisted selection). The Panel has not attempted to forecast in detail what improved products are likely to emerge as a result of greater CGIAR investment in biotechnology. Rather, it has focused on the technology that will increasingly become available for accelerating the development of improved products, and on the steps that will be needed for such technology to become readily available for use by the Centres and the developing countries they serve.

2. Genomics, Synteny and Bioinformatics

Molecular biology is providing new insights into the structure of the genome at an exponential rate of growth. Such studies and the knowledge they generate are broadly referred to as "genomics".

The term "synteny" was originally applied to genes presumed, from the results of marker analysis, to occur on the same chromosome. More recently, however, the term has been used in the same sense as "collinearity of genetic maps" to mean the similarity in the order of genes that occurs along chromosome segments over a wide range of organisms.

The insights provided by genomics have been likened to the understanding of hieroglyphics provided by studies of the Rosetta stone. Thus, knowledge of the mouse genome, for example, provides valuable information on the human genome, while more closely related organisms, such as rice and wheat, show remarkable similarities in gene organisation, sequence and function. It follows that, because of genomic synteny, there is enormous potential for sharing and exchanging information across a wide range of organisations and individuals working on different organisms. The computerised accumulation and interpretation of this knowledge has acquired the new name of "bioinformatics".

3. The Relevance of Genomics

Just as classical genetics provides indirect knowledge of whether genes are linked or inherited independently, so genomics provides direct information on the sequence, function, activity, position and grouping of genes on the chromosome. The techniques of molecular biology and genetics that have evolved since the dawn of the recombinant DNA era have given rise to systematic, high throughput, whole-genome sequencing and associated activities, such as the development of molecular markers for detecting the presence of genes or groups of genes, directly or by genetic linkage.

The future will see substantial reductions in cost and increased speed of large-scale sequencing through automation, robotics and, eventually, microarray chip-based techniques. These offer the prospect of capturing vast amounts of genomic information on a single chip and using it to determine how the activity of each and every gene varies with the environment and genetic background.

Once the complete catalogue of all genes in a plant has been determined (year 2000) then it will be relatively simple to find the equivalent gene in any plant. Similarly, the sequence of the human genome will lead to relatively rapid identification of genes in the principal farm animals. Once a gene has been shown to play a role in controlling a trait in one species, it will be straightforward to investigate the equivalent trait in another species. The development of such activities is already accelerating and the Centres need to remain aware of the new opportunities that are constantly emerging.

4. Gene Transfer

Improvements in the technology required to design genes, insert them into plant cells and regenerate transformed, fertile plants, continue to be made, even for the more difficult crops such as wheat and maize. However, many of the orphan crops of critical importance to the CGIAR remain to be transformed efficiently and some general problems associated with the expression of inserted genes remain to be solved. Nevertheless, the recent commercial introduction of transgenic crops gives grounds for supposing that such problems will eventually be solved.

Although arguments have been raised against the release of transgenic crops, in many cases there is no reason why, ultimately, they should present a greater hazard to the environment than varieties produced as a result of classical hybridisation techniques. Perceived dangers, such as the use of antibiotic markers to select transformed cells, will be overcome by improved methods already in the pipeline.

The extent to which transgenic crops are now entering agriculture is illustrated by the following table extracted from ISAAA Briefs (1997), and by Annex IV.

Traits already Commercialised in Field Trials, and under Development for Selected Crops, 1997

Crop	Traits already commercialised	Traits in Field Trials/Development
Canola	1. Herbicide Tolerance 2. Hybrid technology 3. Hybrid technology and herbicide tolerance 4. High lauric acid	1. Improved disease resistance 2. Other oil modifications
Corn	1. Control of Corn-Borer 2. Herbicide tolerance 3. Insect protected/herbicide tolerance 4. Hybrid technology 5. Hybrid/herbicide tolerance	1. Control of Asian Corn-Borer 2. Control of Corn Rootworm 3. Disease resistance 4. Higher starch content 5. Modified starch content 6. High lysine 7. Improved protein 8. Resistance to storage grain pests 9. Apomixis
Cotton multiple	1. Bollworm control with single genes 2. Herbicide resistance 3. Insect protected/herbicide tolerance	1. Bollworm control with genes 2. Control of Boll Weevil 3. Improved fibre/staple quality 4. Disease resistance
Potato	1. Resistance to Colorado Beetle	1. Resistance to Colorado Beetle + virus 2. Multiple Virus resistance (PVX, PVY, PLRV) 3. Fungal disease resistance 4. Higher starch/solids 5. Resistance to potato weevil/ storage pests
Rice		1. Resistance to bacterial blight 2. Resistance to rice-borers 3. Fungal disease resistance 4. Improved hybrid technology 5. Resistance to storage pests 6. Herbicide tolerance
Soybean	1. Herbicide tolerance 2. High oleic acid	1. Modified oil 2. Insect resistance 3. Virus resistance
Tomato	1. Delayed/Improved ripening	1. Virus resistance 2. Insect resistance 3. Disease resistance 4. Quality/high solids
Vegetables & Fruits	1. Virus resistance	1. Insect resistance 2. Delayed ripening

Source: Clive James, 1997, Global Status of Transgenic Crops, ISAAA Briefs 5

A few transgenic farm animals have been produced but it will be some time before this technology is suitable for widespread use.

5. Applications to Germplasm Improvement

Knowledge of the genome enables molecular markers to be developed. Breeders make progress through selection among varying genotypes often based, during the early stages of selection, primarily on phenotypic differences. At best, they can only estimate the genotypic variation, using the results of replicated progeny tests. However, molecular markers permit direct assessment of genotypic variation and they can be used to detect the presence of both single genes and polygenic complexes. This applies whether the genes are dominant or recessive. Moreover they can be used at the juvenile stage, such as seedlings, to detect genes that are not expressed until maturity. Provided the marker techniques are reliable and can be applied on a large enough scale, they provide valuable tools for the plant breeder and accelerate selection processes. They are also extremely helpful in characterising germplasm collections (see below).

Numerous examples of how the tools of biotechnology are being used to improve crop varieties, have been given above and in Annex IV. In addition the following have been selected simply to give a few examples of the types of approach that are now possible across a wide range of crops and problems.

(a) Recognition of Valuable Genes and Marker Assisted Selection

The rapid break-down of single gene resistance through changes in the pathogen is well known. Its consequences are loss of yield, which can be avoided only through the use fungicides that may not be accessible to the poor. In the past, some progress has been made towards achieving "durable" resistance by breeding two or more resistance genes into the same variety, through prolonged schemes of crossing and selection. However, biotechnology gives new impetus to such approaches. Insights into the genomics of both host and pathogen are providing greater understanding of host-pathogen interactions which, together with techniques such as marker assisted selection, are providing new strategies for building multigenic resistance into crop plants.

For example, recent work on rice blast disease by CIAT scientists and their collaborators has focused on genes resistant to "lineages" of pathotypes rather than on those resistant to specific isolates, as revealed by traditional pathotype analysis. Biotechnology has provided ways of defining the genetic organization and distribution of diversity in the pathogen and has facilitated the incorporation of appropriate resistance genes into breeding lines. Such a strategy for attacking a formerly intractable problem could have wide application to other crops and diseases.

(b) Production of Transgenics

Although rice is the world's most important food crop, it is not a good source of vitamins or iron. Vitamin A deficiency is a serious problem in many rice dependent poor populations, with children who are weaned on rice gruel at particularly high risk. The carotenoid biosynthetic pathway is now well understood and genes for all steps have been cloned from plants and microbes. It is now possible to manipulate the pathway in rice through genetic engineering with the objective of increasing the beta carotene content of the grain. Similar approaches could be applied to other crops in which the harvested product is deficient in vitamin A.

Another example of nutritional improvement relates to the iron. Several different strategies are being pursued for increasing the bio-available iron in rice. The most advanced involves adding the gene for a protein such as ferritin which accumulates iron and makes it available. It has been shown that rice seeds transformed with a ferritin gene from soybean store up to three times more iron than normal seeds. Other strategies focus on phytate, a derivative of phytic acid, which binds iron in a non bio-available form. It may well be possible to reduce the phytate content in the grain or to introduce the gene for phytase which breaks down the phytate and releases iron in an available form.

(c) <u>Rhizomania-resistant Sugarbeet</u>

Although sugar beet does not feature strongly in the agriculture of developing countries, recent work on Rhizomania provides a good example of the application of molecular techniques to breeding for resistance to a disease in which expression is strongly influenced by the environment.

Rhizomania (root madness or bearded root) is a destructive disease of sugar beet (*Beta vulgaris* L.) caused by the beet necrotic yellow vein virus whose vector is a soil borne fungus. Rhizomania is widespread in the temperate regions of Europe and Asia and occurs in USA. The disease causes losses as high as 80% in some parts of Europe and reductions of 20-50% in sugar yield and juice purity are common in infested fields. Viruliferous resting spores of the vector have been reported to survive in uncultivated fields for as long as 15 years. No chemical control of the virus is possible.

Breeding for resistance to Rhizomania began in the eighties when a single source of tolerance to the virus was discovered. Tolerance was weakly expressed and the trait was found to be inherited through many genes. The level of tolerance was difficult to maintain when introducing it into the then elite lines. Early recognition of the environmental hazards of using fungicides and the then intractable nature of breeding for high levels of tolerance led Kleinwanzlebener Saatzucht (KWS) to mount a two-pronged effort, one through conventional breeding methods and the other through molecular approaches, to search for a means to introduce Rhizomania resistance into sugarbeet. Both methods have since yielded results.

New sources with higher levels of tolerance found later were used successfully to introduce, through backcrossing, Rhizomania tolerance into elite varieties. These varieties suffer no significant damage when the crop is attacked by the virus. However, they do not inhibit virus replication. With the development of molecular techniques, investigations showed that plants expressing viral coat protein genes interfere with the multiplication of this virus. A viral gene that synthesizes the beet necrotic yellow vein virus coat protein and inhibits its replication has been successfully incorporated into sugarbeet. Transgenic sugarbeet now offers cross protection against Rhizomania. These transformants compare well with the results of classically bred sugarbeet hybrids for plant growth and yield. Early tests have shown that hybrids that combine transgenic resistance and classical tolerance perform better than current classically bred Rhizomania-resistant varieties under heavy infection.

The basis for Rhizomania-resistance breeding at KWS was and continues to be the identification of genetic sources of high level resistance that can be inherited easily, an efficient selection for resistance which includes both screening methods and marker-aided selection, and short breeding cycles. Through the use of various kinds of molecular markers closely linked to the Rhizomania resistance genes, screening for the presence of the gene and fingerprinting parental genotypes is achieved. Conventional breeding techniques combined with biotechnological ones offer an efficient means to produce Rhizomania-resistant varieties that have high yield and sugar content.

Biosafety aspects related to the release of transgenic sugarbeet have been investigated by independent agencies. No negative effects have been reported.

6. Applications to Germplasm Banks

Genomic knowledge is fundamental to the classification and utilisation of germplasm collections. Without such knowledge, germplasm banks have been likened to "stamp collections" which spend most of their time in unopened albums. Over the next few years, there will be major technical advances that will facilitate the automated screening of chromosomal segments in large numbers of samples.

Molecular genetics also opens up entirely new avenues for the transfer of desirable genes from germplasm accessions to advanced cultivars, through transformation and marker assisted selection. Recent work has shown that, as well as providing genes for resistance to pests and diseases, primitive ancestors of crop plants also contain genes, not present in advanced cultivars, that can enhance yield and quality. These can be recognised through molecular assays.

In this general context, IPGRI comments on the rapid technical advances in gene transfer, in-vitro conservation and diversity analysis. Key technologies include cryopreservation and artificial seed development, as well as a range of molecular genetic methods. Further advances in sequencing technologies and in chip-based analyses are likely to be of considerable significance in the analysis of diversity and in determining useful traits. Other important applications relate to the rationalisation of germplasm management, such as the identification of duplicate samples within and between collections, as well as the development of core collections.

7. Applications to Agroforestry

The following outline is based on information supplied by ICRAF.

An important aspect of agroforestry is the domestication of tree species, in contrast to the unsustainable exploitation that has typified their use in the past. Some 2,500 tree species are known to be used in agroforestry systems in one way or another, making it essential to focus on a few carefully chosen species. The large number of species involved is only one of several ways in which the problems of agroforestry differ from those of crop productivity. ICRAF does not see biotechnology as being amongst its top priorities in the immediate future but recognises the potential for biotechnology to contribute to certain specific problems.

For example, most trees are outbreeding and heterozygous and also have a prolonged generation time. The most useful techniques in the foreseeable future are likely to be molecular markers for selection at the juvenile stage, methods for the large-scale multiplication of selected trees, such as by cloning or apomixis, and techniques for inducing flowering to shorten the generation cycle.

8. Applications to Livestock Improvement

ILRI points out that, in considering the future exploitation of biotechnology for livestock research and development, it is important to note the major differences between livestock and plants. Many aspects of biotechnology that are relevant to crop improvement also apply to livestock improvement. These include genome analysis, molecular genetics and marker assisted selection. These techniques are even more beneficial in livestock improvement, however, because the generation time for livestock is generally longer than in crops, the number of offspring per generation is relatively small and the consequent cost of breeding programmes is high.

Other important applications to livestock improvement include a wide range of diagnostic techniques, vaccines and new drug technologies, as well as transfection/transgenics for livestock, forages and rumen micro-organisms.

9. Applications to Aquatic Organisms

The following outline of applications of biotechnology to aquatic organisms has been condensed from information provided by ICLARM.

ICLARM draws attention to the growing importance of molecular markers for biodiversity research, genome mapping and trait selection in fish and other aquatic organisms. International groups are already collaborating on genetic maps of tilapia and common carp (of most direct relevance to ICLARM) as well as maps for salmonids, catfish, zebrafish and pufferfish. Maps for commercially important invertebrate species including shrimp and oysters are being initiated.

ICLARM is not currently working on transgenesis, but several other institutes and companies in the fisheries and aquaculture sectors are conducting such research on various species including tilapia. It is anticipated that there will be an increase in the number of species and strains into which genes are introgressed, and the number of gene constructs available for transgenesis (governing biological functions in addition to growth) will also be increased. Transgenesis may become a cost effective means of enhancing indigenous species important to one or a few countries and not covered by international breeding efforts.

Sex manipulation (e.g. the production of all male populations of fish, especially tilapia) is also an active area of research, designed to avoid the detrimental production effects of early maturation and cessation of growth. In carp species, however, all-female populations are required and are being requested by developing countries. It is also anticipated that sex reversal will be used more widely in breeding programmes to increase the speed of production of inbred lines. Haploid fish will be important for similar reasons.

A wide range of diagnostic techniques is being developed for applications such as disease diagnosis, sexing of juvenile fish and for assessing progeny relationships in large populations of fish raised together to reduce environment-specific variations in production. Other techniques include tissue culture, or other manipulations of embryos or embryonic cells, for the isolation of viruses, bacteria and fungi pathogenic to fish.

10. Additional Information

To supplement the information in this Annex, the reader might wish to refer to some of the earlier reports and publications that cover relevant biotechnology in the context of developing countries. Among these, a paper by Gary Toenniessen (1995) and two reports edited by Gabrielle Persley (1990) are particularly informative in the context of this report. Other reports are mentioned in the introduction to the main text.

REFERENCES

Persley, G. J. (ed.) (1990a). Agricultural Biotechnology: Opportunities for International Development. CAB International, Wallingford, UK.

Persley, G. J. (1990b). Beyond Mendel’s Garden: Biotechnology in the Service of World Agriculture. CAB International, Wallingford, UK.

Toenniessen, G. H. (1995). Plant Biotechnology and Developing Countries. TIBTECH 13, 404-409.

James, C. (1997). Global Status of Transgenic Crops in 1997. ISAAA Briefs 5.

ANNEX IV

EXECUTIVE SUMMARY OF GLOBAL STATUS OF TRANSGENIC CROPS IN 1997

C. James
Excerpts from ISAAA Briefs 5, 1997

Transgenic Field Trials 1986-1997

During the twelve years period 1986 to 1997, approximately 25,000 transgenic crop field trials were conducted globally on more than 60 crops with 10 traits in 45 countries. Of this a total of 25,000 tests, 15,000 field trials (60 percent) were conducted during the first ten year period, 1986 to 1995, and 10,000 (40 percent) in the last two year period, 1996-1997. Seventy-two percent of all the transgenic crop field trials were conducted in the USA and Canada followed in descending order by Europe, Latin America and Asia, with the few conducted in Africa limited to South Africa. The most frequent crops featuring in transgenic crop field trials during the period were corn, tomato, soybean, canola, potato, and cotton. The most frequent traits were herbicide tolerance, insect resistance, product quality and virus resistance.

It is noteworthy that 25,000 transgenic crop trials were conducted without encountering any significant constraints that did not lend themselves for successful and responsible management during experimentation at the field level. This reflects well on regulators and experimenters who worked together effectively to conduct and manage 25,000 trials in a responsible manner and ensured that the results were communicated in a transparent mode and open for scrutiny and discussion by the scientific community and the lay public. The continued sharing of information from transgenic crop trials and their performance during commercial deployment is important and will contribute to a better understanding of transgenic crops and enhance public acceptance of products that can make a critical contribution to future global food security. As of year-end 1997, 48 transgenic crop products, involving 12 crops and 6 traits, were approved for commercialization in at least one country by 22 proprietors of technology, of which 20 were private sector corporations.

1996 Commercialized Transgenic Crops

The People's Republic of China was the first country to commercialize transgenics in the early 1990s with the introduction of virus resistant tobacco, which was later followed by a virus resistant tomato. In 1994, Calgene obtained the first approval in the USA to commercialize a genetically modified food product, when the company marketed its Flavr

Savr™ delayed ripening tomato. By 1996, approximately 2.8 million hectares of 7 principal transgenic crops were grown commercially on a significant area in the following 6 countries, listed in descending order of area planted with transgenics: USA, China, Canada, Argentina, Australia and Mexico.

In 1996, on a global basis, 57 percent of the area of transgenic crop was grown in the industrial countries and 43 percent in the developing countries. USA grew most of the transgenic crops, equivalent to 1.5 million hectares (51 percent), followed by China, 1.1 million hectares (39 percent), with Canada and Argentina at the same level of 0.1 million hectares (4 percent), and the balance in Australia (1 percent) and Mexico (1 percent).

In 1996, the principal transgenic crop grown was tobacco which accounted for 35 percent (equivalent to 1.0 million hectares) of the global area, followed by cotton (27 percent) on 0.8 million hectares, and soybean 18 percent (0.5 million hectares); the balance of 20 percent was made up of corn (10 percent), canola (5 percent), tomato (4 percent), with less than 1 percent of global transgenic area occupied by potatoes.

By trait, virus resistance accounted for 40 percent of the 1996 acreage of transgenic crops, followed by insect resistance, synonymous with insect-protected (37 percent), herbicide tolerance (23 percent), with quality traits accounting for less than 1 percent.

1997 Commercialized Transgenic Crops

In 1997, the global area of transgenics increased 4.5 fold from 2.8 million hectares in 1996 to 12.8 million hectares with 7 crops grown in 6 countries, as in 1996, with 48 transgenic crop products approved in at least one country. The countries listed in descending order of area of transgenic crops were: the USA, with 8.1 million hectares representing 64 percent of the global acreage with transgenic crops, China with 1.8 million hectares equivalent to 14 percent, Argentina with 1.4 million hectares representing 11 percent of global acreage, Canada with 1.3 million hectares representing 10 percent of global area and Australia (50,000 hectares) and Mexico, 30,000 hectares, both representing less than 1 percent of the global acreage with transgenic crops.

On a global basis, the proportion of acreage with transgenic crops grown in industrial countries increased from 57 percent in 1996 to 75 percent in 1997, and it decreased accordingly in developing countries from 43 percent in 1996 to 25 percent in 1997. The largest expansion in area of transgenic crops in 1997 occurred in the USA (6.7 million hectares) where the increase was more than fivefold (5.6) the 1996 levels, followed by Argentina (1.3 million hectares) where there was a 13 fold increase, and Canada with an increase of 1.3 million hectares, representing a 9.2 fold increase. The USA continued to be the principal grower of transgenic crops in 1997 and its share of global acreage planted to transgenic crops increased from 51 percent in 1996 to 64 percent in 1997, equivalent to 8.1 million hectares. Whereas China, in 1997, still retained its 1996 ranking as the country with the second largest area, its percentage of global acreage of transgenic crops decreased sharply from 39 percent in 1996 to 14 percent in 1997. Argentina's area of transgenic crops increased from 4 percent of global area in 1996 to 11 percent in 1997, and similarly Canada expanded its share from 4 percent to 10 percent.

There were also significant changes in the absolute and relative area occupied by the 7 transgenic crops in 1996 and 1997. Transgenic soybean ranked first in 1997, accounting for 40 percent of global acreage sown to transgenic crops, and replaced tobacco (13 percent in 1997) which was the highest ranking crop in 1996 with 35 percent of the global area. Corn, which only ranked fourth in 1996 (10 percent of global area of transgenics) moved up to second position in 1997 with 3.2 million hectares, equivalent to 25 percent of the global area planted to transgenic crops. The share occupied by transgenic canola increased from 5 percent in 1996 to 10 percent in 1997, whereas the area of cotton decreased from 27 percent to 11 percent, and tomato fell also, from 4 percent to 1 percent.

The relative areas occupied by the four transgenic traits were also significantly different in 1996 and 1997. Herbicide tolerance, the third ranking trait in 1996 and occupying 23 percent of the area, in 1997 moved to the top ranking position with 54 percent of the global area. Insect resistance was fairly stable with 37 percent in 1996 and 31 percent in 1997, with virus resistance decreasing sharply from 40 percent in 1996 to 14 percent in 1997; quality traits occupied less than 1 percent in both 1996 and 1997.

Major Changes 1996 to 1997

Considering the global share of transgenics for the respective countries, crops and traits, the major changes between 1996 and 1997 were correlated with the following features: growth in area of transgenics between 1996 and 1997 in the industrial countries was significant and almost 4 times greater than in developing countries (7.9 million hectares versus 2.0 million hectares); soybean and corn contributed 75 percent of the global growth in transgenics between 1996 and 1997; herbicide tolerance was responsible for 63 percent (6.2 million hectares) of the global growth in transgenics between 1996 and 1997, with insect resistance contributing 30 percent and virus resistance only 7 percent.

The principal phenomena that influenced the change in absolute area of transgenic crops between 1996 and 1997 and the relative global share of different countries, crops and traits were: firstly, the enormous increase in 1997 of herbicide tolerant soybean in the USA and to a lesser extent in Argentina; secondly, the significant increase in 1997 of insect resistant corn in North America; and thirdly, the large increase of herbicide tolerant canola in Canada in 1997. Collectively, these three phenomena resulted in a global acreage in 1997 that was 4.5 times higher than 1996, and the relative importance of transgenic tobacco and tomato in China, which was significant in 1996, decreased markedly in 1997 in a global context. In 1997, transgenic soybean, corn, cotton and canola represented 86 percent of the global transgenic area, of which 75 percent was grown in North America with herbicide tolerant soybean being the most dominant transgenic crop followed by insect resistant corn and herbicide tolerant canola.

Estimated Benefits from Transgenic Crops

More detailed information on the benefits associated with new transgenic crops will be available following a comprehensive analysis of 1997 data, when a substantial acreage of transgenics was planted globally. An initial assessment of the benefits from transgenic crops is reported here. Virus resistant tobacco in China increased leaf yield by 5 to 7 percent and resulted in savings of 2 to 3 insecticide applications. Insect resistant *Bt* cotton in the USA in 1996 resulted in insecticide savings, with 70 percent of *Bt* cotton planted in 1996 requiring no insecticides to control the targeted insect pest, and an average yield increase of 7 percent, this resulted in a net benefit of about US$ 80 per hectare for a total national benefit of US$ 60 million for the 730,000 hectares of *Bt* cotton in the USA in 1996.

Borer-resistant *Bt* corn in USA produced an average yield increase of 9 percent in 1996 and 1997. The benefits from the use of *Bt* corn on 285,000 hectares in the USA in 1996 were estimated at US$ 19 million and US$ 190 million for the 2.8 million hectares of *Bt* corn planted in 1997. About 50 percent of the 32 million hectares corn acreage in the USA, equivalent to 16 million hectares have been reported to be infested with European corn borer, with an estimated annual loss of US$ 1.0 billion.

In 1996, in the USA herbicide tolerant soybean resulted in 10 to 40 percent less herbicide requirements, improved yield dependability, no carry-over of herbicide residues, more flexibility in agronomic management and better control of weeds and soil moisture conservation.

In 1996, in Canada herbicide tolerant canola lowered herbicide requirements, increased yield by an average of 9 percent, with no carry-over of herbicide residues, more flexibility in agronomic management, and with a higher proportion of Grade #1 canola, i.e., 85 percent versus 63 percent, as well as better soil and moisture conservation. The benefits to Canada from the use of 125,000 hectares of herbicide tolerant canola in 1996 were estimated to be Can$ 6.0 million.

In 1996, in the USA insect resistant *Bt* potatoes resulted in effective control of Colorado beetle, with yield/quality benefits of US$ 34 and additonal insecticide savings of US$ 12, for a net benefit of US$ 46 per hectare. This translated to a total benefit of US$ 170,000 for the 3,650 hectares of *Bt* potatoes in the USA in 1996.

Thus, at a national level in the USA in 1996, the total benefits for *Bt* cotton, corn and potato were US$ 80 million, and US$ 190 million for *Bt* corn alone in 1997. Similarly, at the national level the benefits from herbicide tolerant canola in Canada in 1996 were Can$ 6 million. In general, transgenic crops have been well received in North America, with a very high percentage of farmers who planted transgenic crops in 1996 electing to plant them again in 1997. Many transgenic products were unavailable to potential growers in North America in

1997 because of shortage of transgenic seed supplies, thus reducing the potential area planted to transgenic crops.

The Future - Biotechnology Investments and Global Markets

Global sales for agricultural biotechnology will continue to be modest compared with biotechnology-based pharmaceutical products. In the USA in 1995 revenues from agricultural biotechnology were estimated at US$ 0.10 billion with R&D costs of US$ 2.0 billion, whereas revenue for biotechnology-based pharmaceuticals was US$ 7.0 billion with R&D costs of US$ 8.0 billion; in 1996 revenues for agricultural biotechnology products in the USA increased to US$ 304 million and to US$ 8.6 billion for biotechnology-based pharmaceuticals.

However, revenue from agri-biotech products is expected to increase significantly in the future as expansion of transgenic crops continues and as a shift occurs from the current generation of “input” agronomic traits to the next generation of “output” quality traits, which will result in improved and specialized nutritional food and feed products that will satisfy a high-value-added market; the recent US$ 1.7 billion joint venture between DuPont and Pioneer is probably directed at this market. Biotechnology-driven acquisitions, mergers and alliances will continue to prevail in the seed and pesticide industry which has invested US$ 8 billion in acquisitions in agri-biotechnology alone in the last few years, although the thrust in the future will change to vertical integration of food, feed and industrial products, and the current focus on genomics will catalyze new alliances.

The future for transgenic crops looks promising, with crop areas in North America likely to increase significantly in 1998, deeper market penetration in Latin America and Australia, new products in China and the advent of commercial transgenic crops in Europe. The global market for transgenic crops is projected to increase from less than US$ 0.5 billion in 1996, to a value between US$ 2.0 and US$ 3.0 billion in 2000, and to US$ 6.0 billion in 2005, and is forecasted to rise to about US$ 20 billion in 2010. During the next decade an increase in productivity of 10 to 25 percent from transgenic crops is feasible and realistic and this will be a critical and significant contribution to global food security, more nutritious food and feed, and to a safer environment.

ANNEX V

THE ROCKEFELLER FOUNDATION'S INTERNATIONAL PROGRAMME ON RICE BIOTECHNOLOGY

The organization and administration of the Rockefeller Foundation's International Programme on Rice Biotechnology has been discussed by Toenniessen (1995). The programme is described as an integrated set of research, training, technology-transfer and capacity-building activities. It is structured to produce improved rice varieties that will benefit low-income rice producers and consumers in developing countries. The grants and fellowships awarded under the Program are designed to contribute to one or more of its clearly defined aims. These include the development of biotechnology for application to tropical rice, the strengthening of biotechnology capacity in rice-dependent countries, the greater understanding of the consequences of technical changes in agriculture and the application of this knowledge to the production of improved seed and other materials used by farmers.

The programme operates within clearly defined policies on proprietary rights and biosafety. It is a condition of the award of grants that all materials and technology resulting from research supported within the programme should be freely available to all participants for use in developing countries. At the same time, grantees are encouraged to pursue intellectual property rights on their discoveries to obtain an economic return in developed countries to support further research and to maintain a strong bargaining position.

To help establish biosafety systems that are workable, effective and based on rigorous scientific evaluation, the programme includes contributions from professionals from agencies and organizations that have experience and responsibilities in these areas. In addition, the Foundation helped to establish the Biotechnology Advisory Commission, a unit of the Stockholm Environment Institute. The commission is designed to help developing countries assess the possible environmental, health and socio-economic effects of proposed biotechnology introductions.

It was recognised from the outset that creating the programme and its associated networking activities would be an evolutionary process and require a long-term commitment. From its beginnings in 1984, the programme has now clearly demonstrated the value of this approach. It has shown how relatively small inputs can act as "leverage" for larger contributions. Those who participate in the programme acquire a sense of ownership that induces them to help each other and to contribute in ways that far exceed their formal commitment. This long-term nature of the programme, with the prospect of renewed grants, has been one essential element of success. Another has been the rigorous scientific review of quality and progress that has been a feature from the outset.

Grants and fellowships are awarded within a semi-competitive framework and, in addition to the information they make available, they have also provided valuable training opportunities. Some proposals are submitted on the initiative of prospective grantees; others are solicited by the programme administrators. Workshops have proved useful in identifying important research areas. The programme has had close links with IRRI, CIAT and WARDA, but the Centres have not acted as implementing agencies.

Some of the principles developed in this programme have also been applied to other networks and other crops, but there is clearly scope for their wider application.

Reference

Toenniessen, G.H. (1995). The Rockefeller Foundation's International Program on Rice Biotechnology. In: Altman, D.W. and Watanabe, K.N. (eds.) *Plant Biotechnology Transfer to Developing Countries.* R.G. Landes Co.

ANNEX VI

EXECUTIVE SUMMARY OF US NATIONAL PLANT GENOME INITIATIVE

Publication of US National Science and Technology Council Committee on Science
January 1998

National Plant Genome Initiative
Executive Summary

The Need for a National Plant Genome Initiative: Recent scientific advances made through our nation's investments (private and public sector) in studying DNA structure and function in humans and model organisms have resulted in a new biological paradigm for understanding the traits of organisms. Through the National Plant Genome Initiative (NPGI), this paradigm can be extended to improving the useful properties of plants that are important to humanity. Solutions to many of our nation's greatest challenges can be met through the application of plant-based technologies. For example, the revitalisation of rural America will come from a more robust agricultural sector; reductions in greenhouses gases can be achieved from the production of plant biofuels for energy; chemically contaminated sites can be rehabilitated economically using selected plants; and world-wide malnutrition can be greatly reduced through the development of higher yielding and more nutritious crops that can be grown on marginal soil.

The Initiative's Goals: The long-term goal is to understand the structure and function of genes in plants important to agriculture, environmental management energy, and health. Reaching this goal will require a sustained commitment from the Federal government working in collaboration with other nations and with the private sector. The Initiative's short-term goals, to be achieved over the next five years, focus on building a plant genome research infrastructure by:

- completing the sequencing of the model plant species *Arabidopsis;*
- participating in an international effort to sequence rice;
- developing the biological tools (e.g., physical maps, expressed sequence tags, mutants) to study complex plant genomes (e.g., corn, wheat, soybean, cotton);
- increasing our knowledge of gene structure and function of important plant processes;
- developing the appropriate data handling and analysis capabilities; and
- ensuring this new information will be accessible to the broader community of plant biologists (e.g., growers, breeders, physiologists, biotechnologists) and maximising the training opportunities that will arise from the Initiative.

The Initiative's Operating Principles:

- The Initiative should be viewed as a long-term project, governed by a plan that will be updated periodically.

- All resources, including data, software, germplasm, and other biological materials should be openly accessible to all.

- The Federal portion of the Initiative should be co-ordinated by a National Science and Technology Council interagency working group.

- All awards should be made on a competitive basis with peer review.

- Partnerships with the private sector and with other nations are vital for success.

Funding: To accomplish the five year goals of the NPGI, at least US$ 320 million could be used by the Federal government in a targeted manner to leverage existing plant genome activities in the public and private sectors. Current estimates of cost could be decreased with advances in technology.