AGRICULTURAL BIOTECHNOLOGY FOR DEVELOPING COUNTRIES - RESULTS OF AN ELECTRONIC FORUM

John Ruane
Maria Zimmermann

Forum Coordinators

Report of the first six e-mail conferences of the FAO Electronic Forum on Biotechnology in Food and Agriculture

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EXECUTIVE SUMMARY

The global population size is increasing by roughly 80 million annually and almost all population growth is in developing countries. Since the amount of agricultural land available is limited, the increases in food production needed to feed the world's growing population must come from increasing the amount of food produced per hectare. Biotechnology includes a range of scientific tools that can be applied to different aspects of agriculture, food production and nutrition and may play a role in this challenge.

However, biotechnology includes tools that are sometimes considered controversial, with the result that in some areas (e.g. involving genetically modified food and crops), the debate on the value and consequences of agriculture biotechnology has become polarized. There is therefore an increased need for quality, balanced information and to better understand and clarify the issues and concerns resulting in this polarization. It was in this spirit that FAO, acting as an “honest broker”, established the Electronic Forum on Biotechnology in Food and Agriculture.

The Forum hosted six e-mail conferences (each lasting approximately two months) from March 2000 to May 2001. The first four conferences dealt with the appropriateness of currently available biotechnologies in the crop, forestry, livestock and fishery sectors, respectively for food and agriculture in developing countries. The last two conferences dealt with the implications of agricultural biotechnology for hunger and food security in developing countries and the impact of intellectual property rights on food and agriculture in developing countries.

Before each conference took place, a document was written to provide an easily understandable background to the conference theme. After the conference, the participants’ views and comments were summarized in a concisely structured document. These documents constitute the major part of this publication. The conferences were open to everyone but were moderated to ensure that the messages circulated were relevant to the conference themes and were neither offensive nor too long.

About 1 300 people joined the Forum and over 400 e-mail messages were sent by participants from 47 different countries. More than 40 percent of messages were from people living in developing countries. Participants came from a wide range of walks of life, with 75 percent of messages sent by individuals in research organizations/institutes, universities and NGOs.

Regarding biotechnology in the different sectors (crop, fishery, forestry or livestock), the Forum members showed greatest interest in the crop sector. In addition, genetic modification was the single biotechnology that, by far, attracted the greatest interest and discussion and which dominated the crop, fishery and forestry sector conferences.

A wide range of topics concerning the appropriateness, importance and implications of biotechnology for food and agriculture in developing countries was dealt with in the conferences. Some of the major issues that participants raised repeatedly in different conferences were:

- The potential of biotechnology: that biotechnology had considerable potential to address the issues and problems facing food and agriculture in developing countries but that it was currently only catering for farmers in developed countries and should be re-directed to also consider the specific requirements and problems of small holders in developing countries.
- Biosafety and the environmental impact of GMOs: that the release of genetically modified fish or animals or the growing of genetically modified crops or forest trees might have a negative impact on the environment and that the potential risks were greater in developing countries as the application and monitoring of biosafety regulations concerning GMOs would be less rigorous than in developed countries.

- Impact of intellectual property rights: that there were concerns about, firstly, biotechnology companies in developed countries patenting genetic resources in developing countries and secondly, the negative impacts of IPR on agricultural biotechnology research, both in developing countries and by public sector institutes. (There was also fruitful discussion on strategies to avoid or alleviate the negative impacts of IPR on food and agriculture in developing countries).
- Domination of agricultural biotechnology by developed countries and the private sector: that agricultural biotechnology is dominated by the private sector in developed countries because development of biotechnology products is generally expensive and may require an extensive IPR portfolio and highly-qualified human resources and that, consequently, this situation
  a) could make developing countries dependent on developed countries (or on private companies from developed countries); and
  b) meant that the needs of small, food-insecure farmers in developing countries were being overlooked as these farmers do not represent an important market for the private sector in developed countries.
- Biotechnology is not a "magic bullet": that biotechnology alone could not solve the serious problems facing farmers in developing countries and it should only be used when basic management or infrastructural requirements were first in place or well established.

From the six conferences, it was clear that there is large interest in receiving and sharing information about agricultural biotechnology for developing countries. It can be hoped that by providing people with this opportunity to share their views and experiences, the Forum may have contributed in some way to a reduction in polarization and to an increased understanding of other viewpoints in this debate.

CHAPTER 1. INTRODUCTION

FAO established the Electronic Forum on Biotechnology in Food and Agriculture in March 2000 to provide quality balanced information on agricultural biotechnology in developing countries and to make a neutral platform available for people to exchange views and experiences on this subject so that it might be possible to better understand and clarify the issues and concerns behind polarization of the debate on agricultural biotechnology for developing countries.

This publication presents a report on the first six conferences of the Forum that took place from March 2000 to May 2001. Some background to the Forum and its conferences are provided in this chapter.

1.1 Definition of biotechnology for the purposes of the Forum

Firstly, how is biotechnology defined for the purposes of the Forum? According to the Convention on Biological Diversity (CBD), biotechnology means "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use". Interpreted in this broad sense, the definition covers many of the tools and techniques that are commonplace today in agriculture and food production. Interpreted in a narrow sense, as is often done and as is done in the Forum, biotechnology mainly covers technological applications involving reproductive biology or, secondly, the manipulation, or use, of the genetic material of living organisms for specific uses. This definition covers a wide range of diverse technologies including, for example, the use of molecular DNA markers, gene manipulation and gene transfer, vegetative reproduction (crops and forest trees), embryo transfer and freezing (livestock) and triploidization (fish).

1.2 Background to the establishment of the Forum at FAO

FAO was founded in 1945 with a mandate to raise levels of nutrition and standards of living, to improve agricultural productivity, and to better the condition of rural populations. It is an intergovernmental organization with 183 member countries. One of the most important tasks that FAO carries out is to collect, analyse, interpret and disseminate relevant information. FAO serves as a clearing-house, providing farmers, scientists, government planners, traders and non-governmental organizations (NGOs) with the information they need to make rational decisions on planning, investment, marketing, research and training.

FAO should play an active part in disseminating information and promoting information exchange regarding biotechnology. It is important that member countries know which biotechnologies are available, what they can be used for, how and in which wider strategy they can be applied, and what the cost-benefit implications of using them are. The global population size has passed the six billion mark and is increasing by roughly 80 million annually. Almost all population growth is in developing countries. Since the amount of agricultural land available is limited, the increases in food production needed to feed the world's growing population must come from increasing the amount of food produced per hectare. Biotechnology, which is a collection of diverse tools that can be applied to many areas of food and agriculture, may play a role here. This collection includes scientific tools (such as genetic modification) that are sometimes considered to be highly controversial. The tools may pose ethical problems and require substantial debate among policy-makers, researchers and the public at large. Particularly in some areas of agricultural biotechnology (e.g. involving cultivation of genetically modified crops), the debate has become quite polarized and there is therefore an increasing need for quality, balanced, neutral and factual information.

To consider specifically the background to the establishment of the Forum, the biennial meeting of FAO's Committee on Agriculture (COAG), held in Rome from 25-29 January 1999, was of key importance because, among other areas, it set the direction for FAO's future involvement in biotechnology. [Note, the main purpose of COAG is to review and appraise issues in food and agriculture, and make recommendations on them to the FAO Council, which in turn reports to FAO's highest governing body, the FAO Conference]. The report of the Committee "stressed FAO's role in providing a forum for countries to monitor food and agriculture biotechnologies".

At its 116th session (14-19 June 1999), the FAO Council subsequently endorsed the COAG report, stating that it "appreciated the need for FAO to have a coherent programme on agricultural biotechnology to assist Member Nations in obtaining the full benefits of new developments while minimizing risks. FAO's role as a forum for the discussion of issues and for standard-setting, and as an 'honest broker' of quality science-based information, through mechanisms such as the International Plant Protection Commission (IPPC) and Codex Alimentarius, was underscored in general, and in relation to biotechnology in particular". Later, at the 30th session of the FAO Conference (12-23 November 1999), Members stated that one of the substantive areas to which they attached particular importance was the active contribution of FAO to current debates on biotechnology and genetically modified organisms. It was therefore in this spirit that FAO established the Forum. It is coordinated by the FAO Inter-Departmental Working Group on Biotechnology (IDWGB) that was established in 1999 following the recommendations of the 1999 COAG meeting.

1.3 Operation and structure of the Forum

The Forum has an open structure that allows various parties - policy-makers, people from universities, NGOs, the public, etc. - to discuss and exchange views and experiences about specific issues concerning biotechnology and its applications in the animal, fishery, forestry and plant sectors in developing countries. The principal activity of the Forum is to run moderated e-mail conferences (each lasting roughly two months) about specific topics concerning biotechnology in food and agriculture for developing countries. To register for any conference, individuals must first be members of the Forum.

The topics all have biotechnology as the core subject and may cover themes such as biosafety, public/private agricultural research, biodiversity, capacity-building, food safety, poverty alleviation, benefit sharing, intellectual property rights and food production. The emphasis is on developing countries. As the Forum covers the broad range of activities found within the area of food and agriculture, it covers topics both of specific relevance to those interested in the animal, crop, fish or forestry sectors or of general relevance to all sectors.

The Forum was officially launched on 9 March 2000. The launching was marked by sending an e-mail "letter of invitation" to a list of people and institutions that might have been interested in this initiative. An important source of e-mail addresses was a report on biotechnology networks in developing countries, prepared for FAO's Research and Technology Development Service (SDRR) in September 1999. The list also included Permanent Representatives to FAO and all FAO country representatives and was supplemented by additional addresses provided by members of the IDWGB. In the letter of invitation, people were requested to also forward the information to anyone that they considered might be interested.

The number of Forum members rose to over 700 within the first month, to over 1 000 after three months and to nearly 1 300 by the time the sixth conference was finished more than one year later (see Table 1.1). Once they joined, very few people left the Forum. Forum members may not send messages to each other (although if they register for a conference they may send a message to all other participants in the conference) and may only receive messages from the Forum Administrator, who is responsible for all contact with the Forum members. They have so far (November 2001) received 31 messages i.e. roughly two a month from the Forum Administrator.

Forum members are not automatically registered for any e-mail conference, but instead have to do this themselves. Thus, they participated to varying degrees in the different conferences. Some did not register for any conference, but instead only received key documents from the Forum Administrator. Others instead, registered for several conferences and received all the e-mail messages posted. See Chapter 8 for further details on participation.

Table 1.1 Sequence of key events regarding the Forum, including the number of Forum members at each date

Date	Event	No. Forum Members
9 March 2000	1) Forum launched 2) Forum website launched	0
20 March	Conference 1 begins	519
25 April	Conference 2 begins	814
26 May	Conference 1 ends	932
12 June	Conference 3 begins	1 008
30 June	Conference 2 ends	1 086
1 August	Conference 4 begins	1 158
25 August	Conference 3 ends	1 182
8 October	Conference 4 ends	1 205
1 November	Conference 5 begins	1 217
17 December	Conference 5 ends	1 208 *
20 March 2001	Conference 6 begins	1 240
14 May	Conference 6 ends	1 282

*The drop in numbers is due to removing some non-valid e-mail addresses in December

When the Forum was launched, a website to complement and support the Forum was also launched (www.fao.org/biotech/forum.htm). The website was implemented in collaboration with FAO's information management group, WAICENT. Note, however, that the primary communication medium of the Forum is e-mail, so to be a Forum member and participate actively in any of its conferences, the only thing that is required is an e-mail account. The website merely gathers together in one place all the information about the Forum, as well as all the documents and individual messages related to the different conferences. The website has been recognized as a valuable resource. It was selected by the Internet Scout Project for inclusion in the Scout Report (26 May 2000), a weekly current awareness publication that highlights new internet resources of interest to researchers and educators (see www.scout.cs.wisc.edu/report/sr/2000/scout-000526.html); was chosen as a "Hot Pick" in the Netwatch section of the journal Science (www.sciencemag.org/cgi/content/summary/289/5479/503b) (28 July 2000); as well as the "site of the Day" by New Scientist (29 December 2000) (www.newscientist.com/weblinks/categories/agriculture2.jsp).

It was a conscious decision to operate the Forum with e-mail as the base communication medium (rather than, for example, running the conferences on the web) to try and facilitate participation from developing countries. Although both typically require access to a computer, modem, phone line and an account with an internet service provider, full internet access with browsing on the web tends to be more expensive and more difficult in practice than simply receiving and sending e-mail messages. The analyses carried out (Chapter 8), showing that individuals from developing countries were actively involved in the Forum conferences but very seldom visited the Forum website, strongly support this decision.

Individuals wishing to join the Forum, have to register themselves. This is done by sending an e-mail message to an automatic FAO mail server. Using the server, people can automatically subscribe or unsubscribe themselves from the Forum, or they can receive messages previously posted by the Forum Administrator. Registration is also possible from the Forum website.

1.4 Operation of the individual e-mail conferences

The six conferences were operated in the same way.

a) Before a conference

Before a given e-mail conference began, a Background Document, two to five pages in length, was prepared. In this publication, the six Background Documents are included. As the conferences took place in a time span covering over one year (see Table 1.1), the documents were written at different stages from March 2000 to March 2001.

The aim of the Background Document is to give an easily-understandable description of the conference theme, enabling potential participants to have a basic grasp of some of the main aspects of the theme. For example, the Background Document to Conference 2, on the appropriateness of current biotechnologies for the forestry sector in developing countries, provided a brief summary of the kinds of biotechnologies currently available for the forestry sector; some key elements or current trends in the forestry sector in developing countries and finally, certain factors that should be considered in the discussions. Before a conference began, the Background Document was sent to Forum members. In the same e-mail message, they were invited to join the conference and given instructions about doing so. They were requested to carefully read the document if wishing to participate in the conference.

b) During a conference

Involvement of Forum members in each conference is governed by the "Rules of the Forum" and "Guidelines for Participation in E-mail Conferences" that Forum members receive on joining the Forum. These specify, *inter alia*, that

- they should introduce themselves briefly in their first posting to a conference;
- they should exercise tolerance and respect toward other participants whose views may differ from their own, and remain courteous at all times;
- they should not submit messages longer than 600 words;
- people represent only themselves i.e. that "regardless of whether they identify the entity by whom they are employed, participants are assumed to be speaking in their personal capacity unless they explicitly state that their contribution represents the views of their organization. For this reason, participants should not quote the postings of other participants as representing the views of the organizations to which those other participants belong".

Each conference was moderated by the Forum Administrator. The Moderator's role is to screen all messages before they are posted to ensure that they follow the rules and guidelines of the Forum and that they are relevant to the theme of the conference. In addition, the Moderator plays an active role in the conference by ensuring that messages are understandable and, where appropriate, providing additional information of benefit to participants. Roughly 95 percent of messages received by the Moderator during FAO working hours were posted to the conference within an hour of receipt. Those received after working hours were usually posted first thing the following morning. Only a small minority of messages was refused for posting, coming mainly in Conference 1. Messages were refused primarily because they were not directly relevant to the theme of the conference. When required, IDWGB members provided technical support to the Moderator.

Midway through each conference, a brief Update Document was written and sent to Forum members, summarizing the kinds of messages posted, the subjects dealt with and pointing out some areas that should be addressed in the remaining time available. In some cases, as in Conference 1, more than one Update was written.

c) After a conference

After a conference is finished, two Summary Documents are written. The first version is longer (five to eleven pages), more detailed and contains references to specific e-mail messages. The second version is shorter (one to two pages) and does not contain references. Both documents attempt to provide an easily-readable summary of the main arguments and concerns discussed during the conference, based on the messages posted by the participants. In this publication, the longer versions of the Summary Documents are provided. References are made to specific e-mail messages that can be viewed on the Forum website.

1.5 The six conferences

The first conference began less than two weeks after the Forum was launched. It was the first of a four-conference block on the theme of the appropriateness of currently available biotechnologies in the crop, forestry, animal and fishery sectors respectively for food and agriculture in developing countries. The themes of the fifth and sixth conferences were chosen based on the interest shown in them by participants during the early conferences. The fifth conference dealt with the implications of agricultural biotechnology for hunger and food security in developing countries, while the sixth examined the impact of intellectual property rights on food and agriculture in developing countries. The titles and start/end dates of the six conferences are as follows:

Conference 1 (20 March to 26 May 2000): How appropriate are currently available biotechnologies in the crop sector for food production and agriculture in developing countries?

Conference 2 (25 April to 30 June 2000): How appropriate are currently available biotechnologies for the forestry sector in developing countries?

Conference 3 (12 June to 25 August 2000): The appropriateness, significance and application of biotechnology options in the animal agriculture of developing countries.

Conference 4 (1 August to 8 October 2000): How appropriate are currently available biotechnologies for the fishery sector in developing countries?

Conference 5 (1 November to 17 December 2000): Can agricultural biotechnology help to reduce hunger and increase food security in developing countries?

Conference 6 (20 March to 14 May 2001): The impact of intellectual property rights (IPR) on food and agriculture in developing countries.

The conferences thus dealt with specific separate themes, although always remaining within the general area of biotechnology in food and agriculture in developing countries. The conferences attracted different audiences, discussed different topics (although they often overlapped) and each had different characteristics. Some general figures from the conferences are provided in Table 1.2.

Table 1.2 Number of people that registered for each conference, number of messages posted and the number of weeks the conference lasted

Conference	Theme	No. members registered	No. messages posted	Duration of conference (wks)
1	Crops	306	138	10
2	Forestry	167	32	9.5
3	Livestock	235	42	11
4	Fishery	149	26	10
5	Hunger/Food security	258	118	6.5
6	IPR	265	50	8

1.6 Limitations of the conferences

a) Language

The six conferences took place in English only. Thus the Background and Summary Documents for each conference, as well as all messages from the Moderator and by participants (with the exception of a couple of messages transmitted in both English and French in the livestock sector conference) were in English. This affects the kind of audience and participants in the different conferences, making it difficult for individuals lacking the English language to contribute to the conferences and to make their opinions/experiences known. For example, in the fisheries sector conference, there were no messages from some of the developing countries that have active programmes in fisheries biotechnology (Brazil, China and Cuba) and language might explain their absence. Nevertheless, messages posted in the Forum conferences came from nearly 50 different countries throughout the world, many of which do not have English as their main language (see Chapter 8).

b) Electronic communication

When people attend a "traditional" conference, the list of participants typically includes those who are invited and those who either pay for themselves or who are paid to attend by their employer. There is often a restriction on the maximum number of attendees. There is thus a certain process of selection where (language considerations apart) a number of people interested in a particular subject may not be present to provide their input. However, with any type of conference, the quality of the discussions and outputs depends on the participants. The aim of the Forum is to allow a wide range of parties to discuss and exchange views and experiences about specific issues concerning biotechnology. The medium for communication is e-mail and, as with a traditional conference, this also involves problems of selectivity.

Even though the Forum is free and open to everyone it requires, however, in the most typical case, electricity, a phone connection and a computer with a modem. There are thus large differences between and within countries regarding access to these new communication technologies. The UNDP Human Development Report 2001 (www.undp.org/hdr2001/) showed there is a large "digital divide" in the world today. Figures from the report indicated that, in the year 2000, nearly seven percent of the world population was using internet but that 79 percent of internet users lived in Organisation for Economic Co-operation and Development (OECD) countries. Furthermore, the percentage of the population with internet use ranged from 28 percent in high-income OECD countries to 0.4 percent in sub-Saharan Africa or South Asia. In addition, the report also provided some information on the "digital divide" *within* countries, pointing out that internet users are mainly:

- urban and located in certain regions (e.g. in China, only four million of 600 million people in 15 poorly connected provinces are internet users while two major cities, Shanghai and Beijing, have five million);

- better educated and wealthier (e.g. in Chile, 89 percent of users have third-level education);
- young (e.g. in China, 84 percent are under 35);
- male (e.g. 86 and 62 percent of users are male in Ethiopia and Latin America, respectively).

These are important limitations that should be kept in mind when reading the summaries from the conferences.

Note

The views expressed by the participants in the different conferences and summarized in Chapters two to seven are those of the participants and do not reflect those of FAO. FAO cannot and does not guarantee the accuracy of any statements made in or materials posted to the Forum’s e-mail conferences by participants.

CHAPTER 2. CROP SECTOR CONFERENCE

HOW APPROPRIATE ARE CURRENTLY AVAILABLE BIOTECHNOLOGIES IN THE CROP SECTOR FOR FOOD PRODUCTION AND AGRICULTURE IN DEVELOPING COUNTRIES?

2.1 BACKGROUND DOCUMENT

2.1.1 Introduction

The biotechnology industry has developed in a very short time period to become a multi-billion dollar industry providing products for the areas of human health care, industrial processing, environmental bioremediation and food and agriculture. It is an industry that has developed, been financed and is firmly based in developed countries (especially North America). Whereas public funding for agricultural research has stagnated or declined, the biotechnology industry has continued to invest heavily in agricultural research due to the large advances made in the area and the strengthening of intellectual property rights for biological materials.

The biotechnologies used and developed by the industry reflect market realities and are used primarily to provide products for developed countries. The biotechnologies used for food and agriculture are no exception in this regard. In this e-mail conference recently-developed biotechnologies that are currently available in the crop sector are discussed, in the context of how appropriate they are for food production and agriculture in developing countries.

2.1.2 Description of currently available biotechnologies in the crop sector

It is probably fair to say that the most significant breakthroughs in recent years in the area of crop biotechnologies have stemmed from research into the genetic mechanisms behind economically important traits. The rapidly progressing discipline of genomics, providing information on the identity, location, impact and function of genes affecting such traits, is producing knowledge that has driven and will increasingly drive the application of biotechnologies in crops. Here, a summary of recently developed biotechnologies for the crop sector that could be used in practice for food production and agriculture in developing countries is provided.

2.1.2.1 Biotechnologies based on molecular markers

All living things are made up of cells that are programmed by genetic material called DNA. This molecule is made up of a long chain of nitrogen-containing bases (A, C, G and T). Only a small fraction of the sequence in plants makes up genes, i.e. that code for proteins, while the remaining and major share of the DNA represents non-coding sequences whose role is not yet clearly understood. The genetic material is organized into sets of chromosomes (e.g. five pairs in the much-studied mustard species *Arabidopsis thaliana*) and the entire set is called the genome.

Molecular markers are identifiable DNA sequences, found at specific locations of the genome. They may differ between individuals of the same population. Different classes of markers exist, such as RFLPs, AFLPs, RAPDs or microsatellites.

Molecular markers can be used for:

- marker-assisted selection, which is the use of markers to increase the response to selection. A quantitative trait (i.e. one such as fruit yield that shows continuous variation and cannot be classified into a few discrete classes) is usually controlled by many genes, called quantitative trait loci (QTLs). By using molecular markers closely linked to, or even located within, one or more QTL, information at the DNA-level is used directly and selection response can be increased;

- marker-assisted introgression, where markers are used to increase the speed or efficiency of introgression (i.e. the introduction of new gene(s) from a population A to a population B by crossing A and B and then repeatedly backcrossing to B). Introgression may be of interest, for example, when wishing to introduce genes from wild relatives into modern plant varieties;
- studies of genetic diversity and of taxonomic/phylogenetic relationships between plant species or between populations (or varieties) within species;
- studies of biological processes, such as mating systems, pollen movement or seed dispersal, and of the genetic mechanisms behind physiological traits.

2.1.2.2 Genetically modified crops

Genetically modified organisms (GMOs) are those that have been modified by the application of recombinant DNA technology (where DNA from one organism is transferred to another organism). The term "transgenic crops" is also used for genetically modified crops, where a foreign gene (a transgene) is incorporated into the plant genome. It may help us to distinguish between three distinctive types of genetically modified crops:

- "Wide Transfer": where genes are transferred from organisms of other kingdoms (e.g. bacteria, animal) into plants;
- "Close Transfer": where genes are transferred from one species of plant to another;
- "Tweaking": where genes already present in the plant's genome are manipulated to change the level or pattern of expression.

Transgenic plants have been the subject of much controversy, although they now cover large areas in certain parts of the world. Estimates for 1999 indicate that 39.9 million hectares of land were planted with transgenic crops (ISAAA, 1999, www.isaaa.org/publications/briefs/Brief_12.htm). Of these, 7.1 (18 percent) were in developing countries, almost all in Argentina (6.7 million hectares) and China (0.3 million hectares), while the United States and Canada accounted for 32.7 million hectares (82 percent). Of the 39.9 million hectares, 28.1 million (i.e. 71 percent) were planted with crops modified for tolerance to a specific herbicide (which could be sprayed on the field, killing weeds while leaving the crop undamaged); 8.9 million hectares (22 percent) were modified to include a toxin-producing gene from a soil bacterium, *Bacillus thuringiensis*, which poisons insects feeding on the plant, while 2.9 million hectares (7 percent) were planted with crops having both herbicide tolerance and insect resistance.

Most of the transgenic crops planted so far have thus incorporated only a very limited number of genes. However, some transgenic crops of greater potential interest for developing countries have been developed in the research laboratories but have not yet been released commercially, such as transgenic rice of high iron content developed by transferring the ferritin gene from soybean to rice, or transgenic rice producing provitamin A.

2.1.2.3 Micropropagation

This is the in-vitro multiplication and/or regeneration of plant material under aseptic and controlled environmental conditions on specially prepared media that contain plant nutrition and growth regulators. The most commonly used materials are excised embryos, shoot-tips or pieces of stems, roots, leaves, etc.

It is the basis of a large commercial plant propagation industry involving hundreds of laboratories around the world. The technique can be used to multiply, in large numbers, clones of a particular variety. Apart from its rapid propagation advantages, micropropagation can also be used to generate disease-free planting material, especially if combined with the use of disease-detection diagnostic kits. Micropropagation techniques have been developed and are applied for a wide range of crops, including woody and fruit plants.

2.1.3 Food and agriculture in developing countries

The emphasis of the e-mail conference is on developing countries. In this context, it should be kept in mind that a tremendous variety of production systems and environmental constraints are found between different developing countries and even within individual countries. Four broad agro-ecological zones (humid and peri-humid lowlands; hill and mountain areas; irrigated and naturally flooded areas; drylands and areas of uncertain rainfall) account for 90 percent of agricultural production in developing countries. Within each of the zones, a range of farming systems are found as well as a mixture of traditional and modern production systems.

The global population size has passed the six billion mark and is increasing by roughly 80 million annually. Almost all population growth is in developing countries. While the number of inhabitants in the developing and developed world, respectively, is estimated at 4.75 and 1.31 billion, respectively, for the year 2000, in 20 years time it is predicted to be 6.15 and 1.36 billion, respectively.

Farm sizes tend to be small, as reflected by a study of 57 developing countries showing that nearly 50 percent of farms were smaller than one hectare. The increase in food production needed to cover the increased population size cannot come from recruiting new land for agricultural purposes. Most land suitable for agriculture is already in use. When comparing the total amount of land of crop-producing potential with the amount of cultivated land, there are however noticeable differences between regions. For example, in South Asia, 191 of the potential 228 million hectares were already under cultivation in 1988-1990, whereas in Latin America and the Caribbean only 190 of the potential 1 059 million hectares were in use. However, parts of these could not be readily converted to crop production as they are already used for other purposes such as forestry, animal grazing or conservation. Degradation of land already in use, due to overgrazing, deforestation and poor farming practices, is also an increasing problem globally. The increases in food production needed to feed the world's growing population must therefore come from increasing the amount of food produced per hectare.

Note, however, that the issue of world hunger may not be simply solved by increasing the world food supply. In the world today enough food is produced to feed all its inhabitants but yet it is estimated that in 1995-1997 there were roughly 790 million undernourished people in developing countries, i.e. whose food intake was insufficient to meet basic energy requirements on a continuing basis (FAO, 1999, www.fao.org/NEWS/1999/991004-e.htm). Hunger and poverty are also influenced and determined by many different demographic, environmental, economic, social and political factors and these factors should also be considered when trying to reduce hunger in the world. Food needs to be available and accessible to the poor, wherever they may be.

2.1.4 Certain factors that should be considered in the discussion

The key question in this e-mail conference is how appropriate each of the different biotechnologies, mentioned previously in this document, may be for the crop sector in developing countries and regions.

The question of appropriateness should consider the following elements:

- the factors determining or influencing the appropriateness of the different biotechnologies e.g. their environmental impact; their impact on human health; the status with respect to intellectual property rights; the status with respect to biosafety regulations and controls; the degree of access to the biotechnologies; the level of capacity-building or resources required to use them; their financial cost; their impact on food production and food security;
- the relative costs (financial, social, political or otherwise) of the biotechnologies versus the relative benefits (productivity, food security or otherwise);

- whether they are more (or less) appropriate than existing conventional methods in the crop sector for food production and agriculture, given the realities of life in developing countries;
- whether some of the biotechnologies are more (or less) appropriate than others;
- whether some biotechnologies are more (or less) suited to certain regions in the developing world than others.

2.2 SUMMARY DOCUMENT

The Background Document described three major kinds of recently developed biotechnologies that could potentially be used for the crop sector in developing countries: a) biotechnologies based on molecular markers; b) genetically modified (GM) crops; and c) micropropagation.

All three kinds of biotechnologies were discussed in the conference. However, the emphasis was overwhelmingly on GM crops. In some topics of discussion, messages representing strongly opposing points of view were posted, reflecting the polarization that exists regarding some elements of the debate on agricultural biotechnology.

In Section 2.2.1, some of the main factors that were discussed in the conference and considered to have direct importance for the appropriateness of the biotechnologies in developing countries are described. In Section 2.2.2, some other main arguments and concerns raised during the conference are described. In this document, references are included to specific messages. The participant's surname and the date posted (day/month of the year 2000) are provided. The messages can be viewed at www.fao.org/biotech/logs/c1logs.htm. In Section 2.2.3, the name and country of the participants that sent the referenced messages are provided.

2.2.1 Factors considered of direct importance for the appropriateness of biotechnologies in developing countries

2.2.1.1 Their status with respect to intellectual property rights (IPR) and the potential power of multinational corporations (MNCs) as a consequence of IPR

The existence and impact of IPR over biotechnological products (e.g. plant varieties) and processes (e.g. techniques used in generating plant varieties) was probably the topic that attracted most discussion throughout the whole two-month long conference. The fact that a small number of powerful MNCs from developed countries had built up extensive patent portfolios meant that there was often a strong socio-political aspect to the discussion. Considerable differences of opinion were expressed about both the need for and consequences of IPR in the crop sector.

Some participants felt that IPR over biological materials were inherently wrong while others felt they were necessary. Berruyer (28/3 and 14/4) suggested it would be better if it was not possible to patent genes. Kumar (18/4) stated that the new seeds patented were developed from existing genetic material, often from developing countries, in a process involving very small (or no) genetic modification and so the patenting process converted something which was the "common heritage of mankind" into private property. She also argued that the process ignored the input over many generations from farmers in building up the base genetic material. Lettington (18/4) argued that enforcing IPR in developing countries created a net loss for humanity due to the lack of access to information.

On the other side, it was argued that farmers always have the choice as to whether or not to buy improved varieties from MNCs and that "those [companies] that invest in developing a product or technology should get paid for their creativity, capital risk-taking and simple hard work" (Laing, 17/4), a view that was also supported by Halos (4/4). Halos (17/5) suggested, in addition, that patenting genes did not mean that the major economic benefit went to the patent holder, but that many diverse groups, including farmers and consumers, also benefited from the GM varieties developed. Roberts (22/5) emphasized that business will only invest where it expects to make a profit and that in order for industry to invest in these technologies they should expect some financial return. Ashton (19/5) disagreed with this argument, maintaining that the nature of capitalism is that the developer bears the risk and nobody owes a return to the risk-taker.

The consequences of IPR were seen as being quite substantial. The point was made that the existence of strong IPR, and the fact that they are often owned by MNCs, would lead to (increased) dependence by developing country farmers on technologies owned by MNCs and developed countries. This was clearly expressed by Hongladarom (3/4) who indicated that "the fear [of biotechnology that has been aired in Thailand] does not so much concern the potential risks of the genetically modified crops as does the possibility that after a while farmers may have to rely exclusively on the technologies owned by these corporations". Berruyer (28/3) also made the same point saying "the problem with biotechnologies is not the tool, but who has the tool". Lettington (18/4) indicated that such dependency relationships were already being built up in East Africa. Salzman (24/3) feared that farmers in developing countries would be at the mercy of MNCs regarding pricing, seed supplies and the types of seeds provided. Reel (6/4) regretted the change by farmers from seed saving towards increased expense and dependence on outside seed resources. Schenkel (4/4), on the other hand, said that he did not see why farmers would become more dependent if the seeds were adapted to their needs.

Another consequence that was much discussed was that patents could be granted to companies from developed countries over genetic material from developing countries. Reel (6/4) provided information on specific examples, such as the yellow bean (Mexico) and basmati rice (India). Carneiro (13/4) pointed out that the recognition of IPR by developing countries opened up the possibility for developing countries to patent biotechnology products or processes either on their own or in joint projects. Munsanje (27/3), however, argued that developing countries lacked the financial resources required to "bioprospect" the large pool of biodiversity in their specific regions and to take economic and social advantage of their resources. Kumar (18/4) gave a concrete example of the problems raised by IPR, writing that each year in her country, Sri Lanka, many new tea and rice varieties are developed by national research institutes but they are never patented because the effective protection of a single variety in the major countries of the world would cost US$75 000-100 000. She noted, however, that there was nothing to prevent a private company patenting these varieties in the West and that government institutes would not be able to find the funds (maybe US$500 000 in the United States) needed to contest a patent. Ashton (19/5) said that measures to prevent "bio-piracy" were needed and that certain developments, such as the sale of some national seed banks in Africa to corporate interests, should be viewed with great concern.

The impact of IPR on plant breeding research in developing countries was also discussed. Carneiro (13/4) wrote that biotechnology research in developing countries was traditionally based on the transfer of technology but, following the adoption of IPR in developing countries, this approach was obsolete and therefore new products and processes specific for agriculture in developing countries had to be generated. Berruyer (14/4) argued that if patenting of genes was not allowed, then technology transfer would still be possible. Berruyer (14/4) also noted the difficulties of this new situation as developing countries now had to discover and develop the use of new genes, which is the most expensive part of the transgenic process and in addition, this had to be done in the context of competition from MNCs.

Some participants maintained that, in the light of this situation, MNCs had to take special consideration of developing countries. Fauquet/Taylor (26/5) proposed that MNCs should offer relevant technologies within their portfolios for use in developing country crops that do not represent a market to them in the near future. Olivares (12/5) proposed that, to encourage such measures, science policy in developed countries should support public science with the idea that the biotechnology products or processes obtained could be transferred free of charge to developing countries.

Others, instead, maintained that a new IPR system was needed. Munsanje (27/3) argued that IPR should be enhanced in developing countries in order to protect their products before they were exploited and patented. Lettington (18/4) argued that the whole current IPR system was developed in the North to serve a series of very particular purposes and that developing countries should develop their own parallel patenting system which would, for example, ensure that the holder of a patent on a traditional variety would compensate and recognize the developers of the variety. Kumar (25/4) supported this view but felt that developed countries would strongly oppose the establishment of such a system.

2.2.1.2 Level of resources or capacity building required for their use in developing countries

It was argued that funds in developing countries are scarce and that often one of the first items in national budgets to be cut is 'research and development', making it very difficult for the countries themselves to develop biotechnology products that are suited to their own national needs (Nwalozie, 23/3; Halos, 23/3; Lettington, 24/3; Kuta, 30/3). Schenkel (22/5) emphasized that today the production of GM crops is still "very, very expensive".

Kiggundu (19/5) noted that third world governments typically do not have the finances to support conventional plant breeding activities and that, in this context, the availability of GM crops would be a breakthrough. However, Schenkel (22/5) argued that when there were insufficient resources to sustain conventional breeding, a country should not spend money on GM activities – a viewpoint strongly supported by Khan (22/5). Wingfield (13/4) noted that using biotechnologies in developing countries can be too expensive, especially when equipment has to be imported, and indicated that there was a definite niche available for people to develop procedures to apply biotechnology using locally available material.

Despite the lack of resources in many developing countries, Rebai (9/5) urged that, given the importance of agricultural biotechnology for food security, all developing countries "should keep trying to stay in the biotechnology train as drivers and not as spectators, as active makers and not passive consumers". Schenkel (22/5) also argued that the lack of resources should not mean that biotechnology would be exploited only by developed countries and that there was an obligation on developed countries to make biotechnology available to developing countries.

2.2.1.3 Their impact on human health

There was much discussion regarding whether GM crops, in particular those producing toxins of the soil bacterium *Bacillus thuringiensis* (Bt), hereafter referred to as Bt-crops, could be harmful or allergenic (i.e. inducing allergies) when eaten by humans. Almost all contributions were from participants in developed countries. Large differences of opinion were expressed on this subject. Some participants maintained that they were at least as safe as non-GM food products while others argued that they were potentially highly allergenic. Some messages went into detail regarding testing procedures for allergenicity and, in some cases, links to websites providing further information were included.

Crystal proteins from Bt are toxins that kill insects feeding on the plant by binding to and creating pores in their midgut membranes. Both Reel (7/4) and Salzman (10/4) argued that there was no evidence that ingestion by humans of plants producing the toxin was safe. Roberts (10/4) stated that, based on the concept of "substantial equivalence", edible GM crops were tested in comparison with their non-modified counterparts and that, in general, no relevant differences in food quality were found and that neither the GM nor the non-GM plants were guaranteed to be "completely safe". Reel (3/4) pointed out that human testing, that might normally be carried out for a new food additive, was not required for GM foods and that testing them on animals (such as mice) was insufficient. Roberts (12/4) counter-argued that the digestive systems of humans were fundamentally different from those of insects and that results of testing with animals could be treated with confidence because of their close relationship to humans.

Berruyer (12/4) and Berruyer and Bucchini (in a joint message of 17/4) then provided more technical details regarding the working of the toxins, describing how most proteins, including Bt toxins, are denatured (i.e. the specific activity is destroyed) by the acidity of the human stomach. Bucchini, in the joint message (17/4), concluded that it is unlikely that the toxin endangers human health but urged caution. He argued (19/4) that there are no direct methods to assess the potential allergenicity of proteins from sources that are not known to produce food allergy. Berruyer, in the joint message (17/4), suggested that the risk of an allergic reaction that endangers human life is low and quite difficult to measure. De Kochko (13/4) argued that Bt had been used for years in organic farming and that "any product, absolutely any product and not only Bt toxin, can be allergenic for someone in particular. Bt toxin has not been shown to be more allergenic (and certainly less) than chocolate or peanut butter!!!"

Some specific concerns were expressed about Cry9C, one of the Bt toxins, which is heat- and digestion-resistant (Bucchini, 17/4; Berruyer/Bucchini, 17/4). The gene producing the toxin has been transferred to GM corn which has been under consideration for use as human food in the United States. Lin (18/4) argued that the fact that it had so far only been approved for animal feed and industrial uses (and not for human consumption) suggested that the regulatory system in the United States works.

Another specific product that was discussed was a transgenic soybean crop, developed as a potential animal feed, containing a gene transferred from the Brazil nut species that expresses a high-methionine protein. A study published in 1996 revealed that the protein was allergenic and Reel (7/4) suggested that this finding was a cause for concern regarding the cultivation of GM crops. Wingfield (10/4), on the other hand, argued that this showed that science works since the results were the consequence of efficient testing of the crop before release and that, from the results of the trials, the crops were found to be unacceptable and were not then used commercially.

2.2.1.4 Their environmental impact

As specified in the Background Document, of the estimated 39.9 million hectares planted with transgenic crops in 1999, 28.1 million (i.e. 71 percent) were modified for tolerance to a specific herbicide, 8.9 million (22 percent) were Bt-crops while 2.9 million (7 percent) were planted with crops having both herbicide tolerance and insect resistance. Most of the messages posted concerning the environmental impact of new biotechnologies dealt with Bt-crops.

a) Pest-resistant GM crops

Some participants expressed the fear that large-scale planting of Bt-crops would accelerate the development of Bt resistance among pests. Geiger (24/3 and 4/4) was one of these, adding that in tropical areas, with several generations of pests per year, this would happen quickly. Reel (29/3) maintained that major companies in the field of agricultural biotechnology were aware that resistance was inevitable and were thus already developing successors to Bt-crops. Geiger (4/4) said that the loss of Bt as an insecticide would be a major loss for farmers and for society. Smith (27/3) counter-argued that the selection pressure on insects to develop resistance would not be any greater than with the use of chemical pesticides.

Another potential concern with Bt-crops (Lettington, 28/3; Srinivasan, 3/4) was raised by a study published in the scientific journal Nature on 2 December 1999 indicating that the Bt toxin exudes from the roots of Bt-corn and that it might therefore have negative consequences on soil ecosystems. Lin (4/4) emphasized that the authors could not indicate how the soil communities might be affected. Halos (17/5) suggested that these results from the laboratory were not supported by field experiments.

The positive impact on the environment of finding alternatives to the current large-scale usage of chemical insecticides was also discussed. Halos (24/3) wrote that corn farmers in the Philippines admit to using a lot of pesticides and that, until the possibility of Bt-corn arose, they saw no alternative. Srinivasan (3/4) reported from an FAO press release that global insecticide sales amounted to about US$12 billion in 1995; that more insecticides were used on cotton than on any other crop and that over two-thirds of the global cotton area treated with insecticides was in India, China and Pakistan. He argued that the introduction of Bt-cotton in these countries would be expected to reduce insecticide applications and their adverse environmental implications. Several other participants also said they expected that Bt-crops would lead to reduced insecticide use (e.g. Halos, 23/3; Açikgöz, 24/3; Smith, 27/3; Berruyer, 28/3; Bartsch, 31/3). However, there seemed to be disagreement about whether the Bt-crops grown so far had in fact resulted in such reductions. Lettington (3/4) cited a study on soybean crops where pesticide use was higher, while Smith (27/3) quoted from an American newspaper article indicating reductions in insecticide sales following use of Bt-corn.

Lettington (28/3) noted that both chemical insecticides and Bt-crops had some problems, such as development of resistance by the insects, and proposed that integrated pest management (IPM), although more time-consuming, might be preferable to GM crops. Halos (27/3) described the situation in the Philippines where corn farms tend to be no bigger than one hectare and, since farmers often have other jobs, she argued that they find IPM too time-consuming.

b) Herbicide-tolerant GM crops

There was much less discussion about herbicide-tolerant crops than Bt-crops. Schestibratov (9/5) argued that GM crops resistant to non-selective herbicides (i.e. that kill almost all plants that are sprayed) meant that fewer and less-expensive herbicides could be used. Srinivasan (3/4) suggested that growing them resulted in an increased use of herbicides. The potential spread of herbicide resistance to other plant species was a cause for concern. Kumar (31/3) said that the development of a fast-growing herbicide-tolerant weed could have very serious implications in a small developing country. Berruyer (28/3) suggested that such GM crops should be forbidden in areas containing related wild species.

c) Impact on biodiversity

It was suggested that biotechnology could have a positive impact on biodiversity in the environment, by increasing the amount of food produced per unit of land area and thus reducing the need to use forest or natural habitats for additional food production in the future (e.g. Paiva, 3/4; Wingfield, 6/4; Roberts, 12/4).

Regarding within crop species diversity, Laing (17/4) indicated that the increasing loss of diverse germplasm was a cause for concern. He said that the availability of improved varieties, often developed using new biotechnologies and producing higher yields, resulted in small-scale farmers neglecting their traditional varieties. Yibrah (25/5) also predicted that the use of GM crops, coming from a narrow genetic base, would lead to genetic erosion.

2.2.1.5 Their status with respect to biosafety regulations and controls

It was suggested that the application and monitoring of biosafety regulations would be more difficult in developing than in developed countries. Thus, Kumar (31/3) wrote that "developing countries possess limited scientific infrastructure and expertise and do not have the wherewithal to monitor such experiments or the products of such experiments. Furthermore, they are ill equipped to deal with any environmental disasters emanating from these products." Sivaramakrishnan (14/4) argued that even in a country with a strong biosafety system in force, such as India, the monitoring process would not be very easy. Yibrah (25/5) maintained that the lack of finances would make it extremely difficult to assess or monitor GM crops. Ashton (19/5) said there had been insufficient consideration given to the ability of developing countries to cope with potential negative consequences and that those promoting the use of GM crops would not accept the risks which, in his country, would instead be borne by the farmers, retailers and consumers of South Africa. Lettington (28/3) emphasized the need for capacity building in developing countries in the area of biosafety.

2.2.1.6 Their role as tools to increase food production, food security and to reduce hunger in developing countries

As indicated in the Background Document, the global population is increasing, the amount of land available is finite and more food per hectare is needed in the future, to avoid growing crops on land currently devoted to functions other than food production. Some participants felt therefore that biotechnology was an important element in this process (e.g. Lin, 30/3 and 31/3; Paiva, 3/4; Fauquet/Taylor, 26/5) and that it would help to maintain or increase food security in developing countries (Schenkel,16/5; Alexandratos, 16/5; Halos, 17/5).

Others argued that social and political factors were of greater importance (e.g. Lohberger, 31/3; Lettington, 3/4; Reel, 3/4), which could be seen by the fact that, even today, when sufficient food is produced globally, there is still hunger and poverty in many developing countries (Yibrah, 25/5). Some messages went a step further and suggested that, in some cases, pro-biotechnology parties argued that biotechnology could reduce world hunger for public relations purposes (Lettington, 3/4; Yibrah, 25/5).

Lin (31/3) and McGuire (31/3) emphasized that biotechnology alone could not solve the problem of world hunger but that it could contribute to solving it. McGuire also pointed out that "it is unrealistic (and unreasonable) to expect Southern agricultural scientists to become political activists as well, especially in charged settings". Reel (6/4) agreed that biotechnology researchers tended to be reluctant about getting involved in the politics and economics of their field, but argued that economic imperatives governed the benefits of their research.

2.2.2 Other main arguments or recurrent themes from the conference

The conference was moderated and every effort was made to ensure that participants kept their contributions strictly to the subject of the conference, although in some cases this was difficult. Here, some of the other main or recurring themes from the conference are summarized.

2.2.2.1 The relative appropriateness of the different biotechnologies

This topic was addressed in several messages. Yibrah (25/5) insisted that developing countries should select the techniques that are most relevant to their own situations and priorities and that, in this context, MAS and micropropagation were more suitable than the development of GM crops. Srinivasan (12/4) maintained that the application of marker-based QTL studies had so far proved unsatisfactory, as it had resulted in few examples of new genetically improved varieties, especially for crops in developing countries. He agreed with comments in a 1996 scientific paper that this was due to the fact that QTL detection analyses and variety development were two different processes and that most QTL studies were directed towards elite genetic material.

Schenkel (12/4), using the example of a QTL analysis project in Indonesia which had limited success, argued that the marker-based approach might be limited because of the extensive field-testing required for QTL analysis and the large amounts of time and money required. This time aspect was also emphasized by Rebai (25/4) who indicated that it would take at least four years to develop improved varieties by MAS, whereas genetic modification could give improved varieties in one or two years. However, he also pointed out that MAS could do some of the same things as genetic modification and even more. Thus, for traits controlled by many genes, such as disease resistance, he suggested that MAS might be more useful than genetic modification.

Ashton (19/5) proposed that micropropagation was a more suitable technology for developing countries than genetic modification from a risk point of view and that many centres in Africa had developed capacity with micropropagation technology. He also argued that technologies involving molecular markers should not be emphasized as they were complex and not well understood. Wingfield (13/4) argued that micropropagation was a low-level technology that had tremendous benefits to offer for developing countries, citing the production of virus-free sweet potatoes in Zimbabwe as a good example. Loebenstein (29/3) also suggested that the combination of efficient virus assay procedures with rapid propagation technologies could have large advantages for sweet potato and the potato in developing countries.

Wingfield (13/4) mentioned that for cloning of eucalyptus trees in South Africa, cuttings were mostly used rather than micropropagation, due to costs. Halos (17/5) also agreed that micropropagation could be very useful in developing countries but added that, in her experience, labour and electricity were the major costs and thus the technology might only be profitable when the product involved is traditionally expensive, such as banana. Halos (17/5) considered that the use of DNA markers was still too expensive at this stage for breeders in developing countries.

Some participants (Guiltinan, 24/3; McGuire, 31/3; Wingfield, 3/4) highlighted the fact that genetic modification is not the only biotechnology available to the crop sector in developing countries. They argued that it represents just one of a suite of available technologies and that the often controversial debate on GM crops should not inhibit the use of other non-GM biotechnologies in developing countries.

Srinivasan (25/5) provided a reminder that there is also a regional or local dimension to the relative appropriateness of different biotechnologies: that more complex biotechnologies might be appropriate in high-producing regions while low-level technologies should be emphasized in areas of low productivity.

2.2.2.2 The appropriateness of different biotechnologies for different parts of the developing world

Lin (30/3) proposed that the appropriateness of different biotechnology products was a complex issue, often depending on factors specific to the country or region. Moscardi (28/3) said that it was useful to distinguish between two regions in Latin America and the Caribbean (LAC). The first, including countries located outside the tropical belt, is a more temperate region where modern technologies are available and well integrated with the agro-industry and where they have put together IPR and biosafety rules. In the second, including countries between the tropics, there is little application of biotechnology and little private or public sector investment in agricultural research.

Srinivasan (25/5) proposed that a division into high and low potential productivity regions would be useful. In the high producing areas, such as South Central China or Northwest India, biotechnologies should be developed both to maintain the existing high levels and to raise the yield ceilings. In the low producing areas, such as Southwest and Northeast China and parts of Africa, the emphasis should be on low-risk/low-cost biotechnologies such as micropropagation.

2.2.2.3 The appropriateness of new biotechnologies compared to conventional methods

Yibrah (25/5) said he was not convinced of the relative advantages of GM crops compared to conventionally improved or even local varieties. He proposed that for poor countries such as Uganda and Ethiopia it “may be better to rationally use the scarce resources available on more conventional, but appropriate technologies than advocating the use of GM crops”. His views corresponded with those of Schenkel (4/4) who stated “I believe the cost effectivity of any technology should be the determining factor in developing countries. If there is an easy and cheap way to achieve a goal, first use this before applying the high tech expensive one !!!”. Schenkel (4/4 and 22/5) argued that if there was a lack of basics – such as seed supply, extension services or breeding – then it was not appropriate to spend scarce resources on biotechnologies, since the best return from these resources would be got from conventional methods of agronomy and breeding.

Schenkel (12/4 and 22/5) also emphasized that molecular techniques should be applied within a sound conventional breeding programme, since strategies such as MAS cannot replace conventional breeding but merely supplement it and they can only be successful if an efficient breeding strategy is already in place. To use QTLs, he therefore proposed (12/4) that an efficient breeding programme be first established, that initial efforts should focus on single gene traits that are difficult to select under normal circumstances (e.g. sex determination in nutmeg, where farmers are unable to determine sex until flowering, which takes about 6-8 years (Srinivasan, 12/4) and that, having found markers for these traits, they should be used in national breeding programmes

2.2.2.4 Traits that are most relevant for improvement in the crop sector in developing countries

This topic was raised indirectly in many different messages, and was occasionally seen in a socio-political dimension. In the context of herbicide-tolerant GM crops, the potential benefits of selecting for labour-saving traits in developing countries were addressed. Lin (30/3) suggested that these crops would eliminate the use of labour for weeding and thus lower earning potential and poverty reduction in many instances, although in other sectors of developing countries where labour was scarce they would be advantageous (he contrasted this with insect resistance which he indicated was a desirable trait for both small and large-scale farmers in developing countries). Salzman (24/3) argued that labour in itself was not a bad thing and that farmers in developing countries would prefer to work on the land than to migrate to urban areas. Halos (27/3) argued that increasing the amount of labour in farms would not reduce poverty in her country, the Philippines. Smith (27/3) suggested that migration of the workforce from rural to urban areas is an inevitable feature of the economic maturation of a nation. Lettington (24/3) maintained that herbicide-tolerance would have little relevance in developing countries because most farmers would not be able to afford the herbicide.

Fauquet/Taylor (26/5) highlighted the fact that in developing the first generation of transgenic crops, scientists had considered traits, such as herbicide tolerance and insect resistance, which would be of interest within the economic realities of industrialized countries and that the products were never intended to address the needs of developing countries. Srinivasan (18/5) supported this view, saying that the current products were not directly relevant to the needs of small farmers in developing countries. The importance of developing biotechnology products that would address specific problems of developing countries (i.e. with improvements in the traits of major interest in these countries), rather than simply using those that are already available from developed countries, was underlined by several participants (e.g. Munsanje, 27/3; Lettington, 3/4; Wingfield, 3/4; Mwangi, 10/4). For example, Archak (22/5) noted that crops with improved salinity tolerance were keenly awaited in countries such as India.

There may be limits, however, to the traits that may be incorporated into the new biotechnology products. Kiggundu (19/5) argued that in his country, Uganda, there were serious agricultural problems due to factors such as land fragmentation, increasing population pressure and soil erosion and that GM crops with appropriate traits could help to alleviate these problems. Both Schenkel (22/5) and Yibrah (25/5), however, counter-argued that these kinds of problems would not be solved using GM crops but through changing detrimental agricultural practices and that investments in improving the extension services would be more worthwhile.

2.2.2.5 Polarization of the biotechnology debate and the need for balanced information

When this FAO Biotechnology Forum was established, it was recognized that in some areas of agricultural biotechnology, the debate was quite polarized and it was hoped that, by providing a neutral forum for different parties to exchange views and experiences, this polarization might in some way be reduced because, in the words of Lettington (27/3), “as soon as the different interest groups refuse to talk and acknowledge each others concerns we are all in trouble”. The large differences between the sides can be seen by comparing some of the messages posted in the conference. For example, both Reel (6/4) and Halos (17/5) consider the impact of GM crops on areas such as the environment, human health and society and come to totally opposing conclusions regarding their impacts and consequences, with numerous references provided from the scientific literature (both refereed and non-refereed) to back up their respective cases.

Some of the factors leading to this polarization were discussed. Salzman (22/5) suggested that polarization was inevitable as GM crops had been grown commercially without sufficient consultation and before there was a thorough investigation of the potential hazards and problems. Srinivasan (18/5) argued that recent developments in "terminator gene" technology, with MNCs claiming numerous patents in the area, had further polarized public opinion.

Archak (9/5) argued that polarization had implications at the farmer level, since government organizations were influenced by the political party in power while NGOs tended to oppose biotechnology. Thus, correct information about biotechnology rarely reached the farmers. The importance of the availability of good balanced information on a controversial topic such as GM crops was also emphasized in other messages. Knausenberger (15/5) said that fora such as this one, would help public understanding of the issues and that a publicly funded agency, such as FAO, should remain objective and not commit itself to any paradigm. Towards the end of the conference, Ashton (19/5) said that although many of the messages posted had reflected the polarity of the debate, it was "refreshing to see some meeting of minds. Dogmatism and polemic do little for the debate from either side but instead we should concentrate on the common ground."

It is obviously difficult to measure whether the conference had some impact on polarization. However, in the current "electronic age", e-mail conferences such as this can also reach audiences beyond the actual participants. We know, for example, that the conference was discussed in an article in the scientific journal Nature (1 June), it was used as the basis of an article in the Spanish national newspaper El País (19 July), referring especially to the message of Yibrah (25/5), and as research material for a series of Finnish television programmes on GMOs.

2.2.2.6 The use of biotechnology in developed countries to feed the developing world

Alexandratos (15/5) argued that consideration of the welfare and food security in developing countries should not ignore the fact that they are net importers of food and that the amount imported, coming mainly from North America, Europe and Australia, had increased in recent years and was predicted to increase even further towards the year 2030. He suggested (16/5) therefore that the application of biotechnology in developed countries, to allow them to meet these expected export requirements, was thus important for food security in developing countries. Yibrah (25/5) rejected this line of argument and suggested that increased food production in countries such as Argentina and the United States and its cheap export could not solve the hunger and poverty problems in developing countries, since it did not address their cause – lack of fair trade and justice. Lettington (24/3), furthermore, suggested that the use of biotechnology in developed countries could have a negative impact on small farmers in developing countries, by increasing oversupply in developed countries and consequently depressing world prices.

2.2.2.7 GM crops and evolution

In transgenic crops, a foreign gene (or genes) is incorporated into the plant's genetic material. The gene may be from the same species, a related plant species or even a species from another kingdom (e.g. from winter flounder fish to the strawberry or from Bt to corn). The evolutionary implications of such across-species transfer of genetic material were discussed in a few messages.

Salzman (30/3 and 31/3) argued that crossing the species barriers is non-adaptive and contradicts the process of natural selection and that the creation of GM crops such as Bt-corn runs counter to the normal tendencies of nature and evolution (which tend to minimize the opportunities for crossing the species barrier) and so there is therefore the risk of a global ecological disaster. Knausenberger (15/5) expressed the same fears because "million of years of co-evolution are being circumvented". Both Schenkel (30/3) and Rebai (28/4 and 9/5) argued instead that crossing the species, genera and, sometimes, family barrier was something that happened naturally in nature (although rarely) or that could be achieved artificially. It was pointed out that some common food crops (such as bread wheat and canola) contained genetic material from more than one species and that some crops created by plant breeders and used already for many years were interspecies hybrids, such as triticale (a hybrid of *Triticum aestivum* and *Secale cereale*).

2.2.2.8 Public versus private sector

Lin (30/3) argued that whereas the "green revolution" was based on the results of scientific research carried out in public institutions, the new age of agricultural biotechnology was driven by tools developed and patented by private and not public, institutions and that a second "green revolution" would depend on a rethinking of the role of public research and on incentives to the private industry to make the tools available. McGuire (31/3) supported these views, emphasizing that the role of public research needed to be both rethought and revitalized. Carneiro (13/4) noted that investment in science and technology was much lower in developing than in developed countries and that the public research sector needed to find new ways of promoting scientific development in developing countries. He argued that there was a need to build up relationships between public and private sectors at both national and international levels, and between the scientific and production sectors. Fauquet/Taylor (26/5) also emphasized the need for collaboration between the public and private sectors in developed countries with policy-makers, scientists, breeders, extension workers and farmers in developing countries. Berruyer (14/4), however, warned that cooperation between public research institutes in developing countries and powerful MNCs might be biased by foreign private interests and would not favour small farmers in developing countries.

2.2.3 Name and country of participants with referenced messages

Açikgöz, Nazimi. Turkey
Alexandratos, Nikos. Italy
Archak, Sunil. India
Ashton, Glenn. South Africa
Bartsch, Detlef. Germany
Berruyer, Romain. France
Bucchini, Luca. United States
Carneiro, Mauro. Brazil
De Kochko, Alexandre. France
Fauquet, C.M./Taylor, Nigel. United States
Geiger, Chris. United States
Guiltinan, Mark. United States
Halos, Saturnina. The Philippines
Hongladarom, Soraj. Thailand
Khan, Iftikhar Ahmad. Pakistan
Kiggundu, Andrew. Uganda
Knausenberger, Walter. Kenya.
Kumar, Vijaya. Sri Lanka
Kuta, Danladi Dada. Nigeria
Laing, Mark. South Africa
Lettington, Robert. Kenya
Lin, Edo. France
Loebenstein, Gad. Israel
Lohberger, Ben. Australia
McGuire, Shawn. Netherlands
Moscardi, Edgardo. Colombia.
Munsanje, Elliot. Zambia
Mwangi, Peter. Kenya
Nwalozie, Marcel. Senegal
Olivares, Jose. Spain
Paiva, Edilson. Brazil

Rebai, Ahmed. Tunisia
Reel, Jeffrey. United States
Roberts, Tim. United Kingdom
Salzman, Lorna. United States
Schenkel, Werner. Germany
Schestibratov, Konstantin. Russia
Sivaramakrishnan, Siva. India
Smith, Jay. United States
Srinivasan, Ancha. Japan
Wingfield, Brenda. South Africa
Yibrah, Haile Selassie. Ethiopia

CHAPTER 3. FORESTRY SECTOR CONFERENCE

HOW APPROPRIATE ARE CURRENTLY AVAILABLE BIOTECHNOLOGIES FOR THE FORESTRY SECTOR IN DEVELOPING COUNTRIES?

3.1 BACKGROUND DOCUMENT

3.1.1 Introduction

Plant biotechnology is a field of scientific research in which rapid advances have been made in recent years and which appears to have much potential for further development. Numerous opportunities for using biotechnology in plant breeding have been identified, some of which might be appropriate for the improvement of crops in developing countries, as discussed in the crop sector conference (Chapter 2). In this conference the focus is on forest trees and currently available biotechnologies and their application in the forestry sector are discussed with reference to their potential use in developing countries today. Please note that for the purposes of this conference, the term “forestry sector” specifically excludes fruit orchards.

Most forest tree species are characterized by inherently high levels of variation and extensive natural ranges. This high level of genetic variation needs to be maintained to ensure present-day and future adaptability to changing environmental conditions. It is also needed to maintain options and potential for improvement to meet changing end-use requirements. Forests provide a wide range of goods and services such as timber, fibre, fuelwood, food, fodder, gum, resins, medicines, pharmaceutical products and environmental stabilization. Similar goods and services are often provided by a wide range of genera and tree species. Despite the availability of a large number of forest tree species, less that 500 have been systematically tested for their present-day utility for human beings and less than 40 species are included in intensive selection and breeding programmes.

Selection in breeding populations with a broad genetic base is the most common approach to forest tree improvement. Although demand for wood is the driving force in the development of large-scale forest plantations, several selection and breeding programmes aim at enhancing other goods and environmental services provided by forest trees and shrubs.

Since most forest tree species are characterized by long generation intervals and a generally long juvenile phase before flowering, much time is needed before assessment of important traits can be carried out. For example, if wood quality is of interest in breeding for timber or fuelwood, selection can only be carried out after trees have reached a certain size which, in some cases, can require decades. The above factors are limitations to rapid improvement and only a maximum of three or four generations of breeding have been completed in a few forest tree species to date (*Eucalyptus grandis* and some pine species).

3.1.2 Description of biotechnologies in the forestry sector

This section provides a summary of recently developed biotechnologies that could be used, or more widely used, for forest trees in developing countries today. Additional technical details may be found at www.fao.org/forestry/FOR/FORM/FOGENRES/genresbu/125/125e/arte11.stm.

3.1.2.1 Biotechnologies based on molecular markers

Reliable information on the distribution of genetic variation is a prerequisite for sound selection, breeding and conservation programmes in forest trees. Genetic variation of a species or population can be assessed by measuring morphological and quantitative characters in the field or by studying molecular markers in the laboratory. A combination of the two methods is required for reliable results.

Molecular markers can be used for:

a) Quantification of genetic diversity

The use of molecular markers for the determination of the extent of variation at the genetic level, within and between populations, is of value in guiding genetic conservation activities, which are aimed at maintaining genetic diversity with respect to traits of both known and unknown importance, and in the development of breeding populations for specific end uses.

It should be noted that studies on genetic diversity based on molecular markers must be interpreted with caution, due to frequently low correlations with patterns of variation for adaptive traits, which are of major importance in forestry.

b) Genotype verification

Molecular markers have been widely used for identification of genotypes and applied in taxonomic studies, biological studies and 'genetic fingerprinting'. Good taxonomy is fundamental to conservation and tree improvement programmes and to programmes involving hybridization between species. The use of molecular markers has revolutionized studies of mating systems, pollen movement and seed dispersal. Results of such biological studies are of considerable practical significance to advanced tree improvement programmes, specifically in population sampling, design and management of seed orchards (i.e. orchards consisting of clones or seedlings from selected trees and cultured for early and abundant production of seeds for reforestation), estimation of pollen contamination and development of controlled pollination methods. Germplasm identification, through 'genetic fingerprinting', has been used in advanced breeding programmes which rely on controlled crosses or in which the correct identification of clones for large-scale propagation programmes is essential.

c) Gene mapping and MAS

Genetic linkage maps can be used to locate genes affecting quantitative traits of economic importance. Quantitative traits, such as wood yield, wood quality or pulp yield, are usually controlled by many genes, termed QTLs. By using molecular markers closely linked to, or located within, one or more QTL, information at the DNA-level can be used for early selection. The potential benefits of MAS are greatest for traits that are difficult, time-consuming or expensive to measure (for example, wood quality traits or pulp yield). Mapping and MAS tend to be used only in species of high economic value and have most potential in clonal breeding programmes, where additional genetic gains can be rapidly multiplied.

3.1.2.2 Biotechnologies based on vegetative propagation

Strategies supporting large-scale utilization of genetic material with a narrow genetic base must be appropriately integrated into tree improvement programmes. Vegetative propagation within such programmes allows for a fast release of new materials and for appropriate matching of clones to different local conditions. It also allows continued cultivation of given clones and to efficiently change the mixture of clones used in a given programme. Vegetative propagation also supports other currently available biotechnologies (*in vitro* storage and cryopreservation; *in vitro* selection).

a) *In vitro* storage and cryopreservation

In vitro storage refers to the storage of germplasm in aseptic culture under laboratory conditions, while cryopreservation refers to the storage of cells, tissues, seeds, etc. at temperatures of liquid nitrogen (-196ºC). The two techniques do not seem to be widely used in genetic conservation activities for forest trees, but they may serve as back-up strategies for species with seed storage problems.

b) *In vitro* selection

In vitro selection refers to the selection of germplasm based on test results using tissue culture under laboratory conditions. Many recent publications for crop plants have reported useful correlations between *in vitro* responses and the expression of desirable field traits, most commonly disease resistance. Positive results are available also for tolerance to herbicides, metals, salt and low temperatures. For the selection criteria of major general importance in forest trees (in particular vigour, stem form and wood quality), poor correlations with field responses will limit the usefulness of *in vitro* selection. However, *in vitro* selection may be of possible interest in forestry programmes for screening disease resistance and tolerance to salt, frost and drought.

c) Micropropagation

For crop and horticultural species, micropropagation (*in vitro* vegetative propagation of plants) is now the basis of a large commercial industry involving hundreds of laboratories around the world. Successful protocols now exist for a large number of forest tree species and the number of species for which successful use of somatic embryogenesis has been reported is increasing (somatic embryogenesis is a step in micropropagation where somatic cells are differentiated into somatic embryos). So, in the future, it is likely that micropropagation in the forestry sector will become commercially more important. Compared to vegetative propagation through cuttings, the higher multiplication rates available through micropropagation seem to offer a quicker capture of genetic gains obtained in clonal forestry strategies.

One major factor impeding early application of micropropagation in many large-scale forest plantation programmes, is that breeding and selection of desired clones are not sufficiently advanced for clonal forestry to be contemplated. Current high costs will also be an impediment to the direct use of micropropagation in many programmes. Technologies resembling those used commercially in horticulture are most likely to be affordable for a limited number of high-value forest tree species, particularly those for which propagation by cuttings is difficult. Micropropagation is unlikely to be used for the production of planting stock of non-industrial forest tree species.

3.1.2.3 Genetic modification of forest trees

GMOs are defined as organisms that have been modified by the application of recombinant DNA technology (where DNA from one organism is transferred to another organism). The term “transgenic trees” is also used for GM trees, where a foreign gene (a transgene) is incorporated into the tree genome.

One of the first reported trials with GM forest trees was initiated in Belgium in 1988 using poplars. A study carried out in 1999 indicated that, since then, there have been more than 100 reported trials, involving at least 24 tree species - most of which are timber-producing species. The majority of the field trials were carried out in the USA and Canada. Whereas it is estimated that roughly 40 million hectares of transgenic agricultural crops were grown commercially in 1999 (ISAAA figures), there is no reported commercial-scale production of transgenic trees. Information on field trials of GM trees has been published by the OECD [www.olis.oecd.org/biotrack.nsf] and the World Wide Fund for Nature (1999) [www.wwf-uk.org/news/n_0000000172.asp].

Traits for which genetic modification can realistically be contemplated in the near future include insect and virus resistance, herbicide tolerance and lignin content. However, insertion of any gene into a tree species with expected functional results will be a substantial undertaking and insertion of enough genes to confer e.g. long-term insect resistance in a perennial species even more so. Virus and insect resistance, in particular, are of major significance for crop plants. By contrast, these traits are not the most important in breeding programmes of forest tree species (poplars being an exception).

Reduction of lignin is a valuable objective for species producing pulp for the paper industry; work on this aspect is underway in aspen.

A major technical factor limiting the application of genetic modification to forest trees, is the current low level of knowledge regarding the molecular control of traits which are of most interest, notably those relating to growth and stem and wood quality. Genetic modification of these traits remains a distant prospect. Investments in genetic modification technologies should be weighed against the possibilities of exploiting the large amounts of genetic variation, which are generally untapped, available within any single species in nature.

Biosafety aspects of GM trees need careful consideration because of the long generation time of trees, their important role in ecosystem functioning and the potential for long distance dispersal of pollen and seed.

3.1.3 Forestry in developing countries

Forests cover approximately 30 percent of the world's total land area [Data from 2000, see www.fao.org/forestry/fo/sofo/sofo-e.stm]. They are the source of vital commodities, including raw materials and food and are essential for maintaining agricultural productivity and the environmental well-being of the planet as a whole. They protect soil and water and buffer the effects of wind and rain, thus helping to decrease soil erosion and they are an important sink for carbon dioxide. Forests are also among the most important repositories of biological diversity.

Roughly 500 million rural people live in, or close to, forests. Most communities use a variety of forest products, particularly those in developing countries. Plant stems, tubers and fruits provide additional food during hungry seasons or when crops fail; wild animals are harvested for meat and hides; and the forests provide fuelwood, fodder for livestock, medicines and other products and services.

The most important trend in forestry in developing countries is the progressive reduction in the area of forests due to changes in land use. Another important trend, evident at a global level, is increasing forest degradation through unmanaged use. When forests are degraded, their productive functions and their capacity as regulators of the environment are reduced, increasing flood and erosion hazards, reducing soil fertility and contributing to the loss of forest products and overall loss of biological diversity.

While forests are being lost, there is growing demand both for environmental services and for wood and wood products which they provide. A forecast by FAO predicts that wood demand is expected to increase by 25 percent from 1996 to 2010. This demand will, increasingly, have to be met by forest plantations, and with decreasing land areas available for forestry, plantation methods will have to be increasingly intensive. This will necessitate better tree improvement programmes in which biotechnology may play a role.

3.1.4 Certain factors that should be considered in the discussion

The key question in this e-mail conference is how appropriate each of the different biotechnologies may be for the forestry sector in developing countries today.

The question of appropriateness should consider the following elements:

- the added value of biotechnologies: what is their impact on the production of goods and services and on food security?
- the existence of good operational and long-term tree improvement programmes, in which biotechnologies can be important tools;
- the availability of financial resources and the ability and commitment to use the biotechnologies over a given time period;

- institutional capacities: existing capacities and the requirements for capacity building;
- the environmental impact of biotechnologies and their impact on human health;
- the relative costs (financial, social, political or environmental) of the biotechnologies versus the relative benefits (productivity, food security or otherwise).

3.2 SUMMARY DOCUMENT

3.2.1 Background

As was the case for the e-mail conference on crops (Chapter 2), this conference asked a similar question, i.e. "how appropriate are currently available biotechnologies for the forestry sector in developing countries?" Again, the three major areas of discussion revolved around biotechnology based on the use and development of a) molecular genetic markers; b) micropropagation; and c) GM trees. However, the technology of genetic modification was by far the primary topic of discussion.

Thirty-two submissions were received during the e-mail conference, compared to 138 in the crop conference, but the 32 messages covered a wide range of ideas related to the three major areas. Comments ranged from general observations to very detailed suppositions. Important points were made several times and these formed the basis for "themes" that emerged.

Section 3.2.2 of this document attempts to summarize these themes. Section 3.2.3 provides additional points that did not fall logically into the general themes, but were important points to consider. Specific references to messages posted, giving the participant's surname and the date posted (day/month of the year 2000), are included. The messages can be viewed at www.fao.org/biotech/logs/c2logs.htm. Section 3.2.4 gives the names and country of the people that sent referenced messages.

3.2.2 Major themes and factors of importance for the application of biotechnology

3.2.2.1 All biotechnologies need to be considered within the framework of a larger genetic resource management programme

This point was made several times, i.e. modern biotechnology should only be realistically developed for species which already have a substantial infrastructure in basic plantation technology, e.g. in seed collection, nursery techniques, silviculture and in tree breeding and related research.

Serrano (9/5) indicated that while research is underway in somatic embryogenesis in pine in Mexico, the largest problem is that of basic forest management practices (e.g. appropriate harvesting systems). This may point out a fundamental dilemma for developing countries with respect to investments in biotechnology. If there are more basic forest management issues to be solved, then should investments be made in technologies that may never be applied? Burdon (20/6) added to this by saying, "in the short- to medium-term, the development of biotechnology is likely to make much increased demands of the breeding infrastructure."

Southerton (19/6) emphasized this point again by saying that there is a danger in rushing to use the latest technologies when more basic approaches, such as provenance testing (i.e. seed source) and selection of appropriate plantation species, would provide a much larger payoff. Ashton (13/6) suggested that the discussion may be premature for forestry at this time (e.g. it is not yet simple to transfer multiple-gene constructs to a recipient genome), so developing countries need to focus more on "recreating the full local diversity of forest ecosystems" rather than "genetically engineering some unstable, unpredictable exotic import."

Several contributors appropriately pointed out that many GM transformed clones would have to be developed for use at any one time, and most would be screened out due to poor performance or poor stability. Smith (15/6) suggested that if there are additional concerns about the use of GM trees (over and above simple clonal forestry), there could be requirements for increasing the rigour and length of time for field testing protocols. This could put the utility of technology in an even more cost prohibitive situation. DiFazio (7/6), Strauss (7/6) and Smith (15/6) all agreed that deployment and monitoring schemes that address appropriate genetic considerations for safety and productivity of GM tree plantations have to be developed and implemented. Furthermore, as suggested by Strauss (7/6), and supported by Hong (8/6), the assessment of risk could be responsibly monitored if there are step by step requirements laid out: "the same requirements that should apply to any good silviculture or breeding programme."

Even in more developed tree breeding programmes, a push to develop advanced techniques such as markers for QTL selection could increase demands on tree breeding programmes (e.g. larger progeny tests required). Burdon (20/6) summarized this theme quite appropriately by saying, "the application of new biotechnology will need to stand as an enhancement of classical breeding, rather than as a substitute for it".

3.2.2.2 Long rotation ages for most forest tree species

Lindgren (4/5) made several observations related to the use of new biotechnology and the long generation time of tree species relative to crop species. He noted that, first, many developing countries are in warmer climates and many of the species used by them may have relatively short rotation ages (rotation age is the age at which trees are harvested). GM trees with short rotation ages would also be more reliable, with respect to expression of the trait (i.e. testing ages may more closely correspond to harvesting ages, so there would be greater confidence in trait expression). For long-rotation species, there would be many doubts, because testing would probably not be able to cover the full rotation (which is particularly important if the trait is required for the full lifetime of the tree). Second, some of the end-product objectives of GM trees, e.g. special pulping attributes, are likely to be more relevant for short rotation species. Third, even for some of the major commercially important pine species (with rotation ages typically over 20 years), investments in new biotechnologies may not be profitable. However, he proposed that it could be appropriate for those species that will be tested and harvested within a roughly 10-year time frame *(Moderators note: we are assuming this approximation would need to be based on some investment calculations).*

Strauss (10/5, message 4) stated that GM trees will be limited to the common short-rotation forest tree species in intensively grown plantations in the developing world (e.g. *Eucalyptus*) and intensively managed species (e.g. poplars and some pines) in the developed world. Later (7/6), he re-iterated the point that GM trees "will only be used commercially after a number of years of testing on many sites. During this process the vast majority of transgenic lines are discarded......only those that are most stable and perform well are considered for commercial use". Lindgren (14/6), supported by Southerton (19/6), pointed out that there would be a tendency to use fewer clones, so it may be best to see how trends develop for clonal forestry programmes (e.g. in *Eucalyptus*) around the world. Again, this stresses the need, as mentioned earlier, for developing genetic diversity and deployment guidelines. Strauss (7/6) stressed the basic fact that there are also substantial physical limitations to establishing large areas of forest tree plantations on a scale and time frame similar to that of crop species.

In summary, lengthy research and developmental periods will be required to develop and deploy GM trees. Therefore, it is likely that there will be a relatively long time period for foresters, relative to crop geneticists and agriculturists, to monitor and correct trends and policies in the use of GM trees, prior to large-scale use across plantation estates.

3.2.2.3 Technology being appropriate or inappropriate for developing countries

There was a clear consensus that many factors need to be considered in deciding whether or not any biotechnology is appropriate in forestry (i.e. biological, economical, and political restraints and opportunities). Therefore, it was not easy to say that modern biotechnology is either appropriate or not appropriate for developing countries.

As mentioned above, Lindgren (4/5) argued that although developing countries may not generally have advanced infrastructure and modern laboratories, they often have better growing conditions for trees (shorter rotations) than temperate/boreal developed countries. Strauss (7/6) noted this is particularly relevant for *Eucalyptus* in some developing countries, in which well-developed plantation forestry systems are already in place.

Keeping local options open was brought up a few times. As pointed out by Strauss (10/5, message 3), “why do we seek some kind of global consensus about use of genetically engineered plants and trees?”. He added, “all practitioners know, the only place [GM trees] will find use, for the foreseeable future, is in intensively managed plantations – whether they be industry or community owned.” Fenning (14/6) further supported this view by stating that people should be left “free to choose the most appropriate solution to local needs in future.”

Another view of the issue was that if the appropriate technology exists for a given situation, it would be negligent not to apply the tools available (Fenning, 9/6). For example, some modern tissue culture techniques may be suitable for special situations; such as the conservation and management of *Prunus africana* (Smith (11/5)), which has been used for medicinal purposes and may require special attention to ensure sustainability of the resource.

This does, however, raise the general concern of whether developing countries have the means and resources to appropriately assess or manage the risks, compared with more developed countries. This was to some degree raised by Johnston (11/5), who stated that the burden of proof for risk assessment should lie with the proponents of the technology. Smith (29/6) also pointed out that technologies might have additional “hidden costs” in the future and not just environmental risks. For instance, products from the early attempts at tissue culture showed that physiological ageing was present that could reduce stem volume growth in trees produced by tissue culture. (This may not be detected in the testing phase). An additional point is that even with the use of conventional technology (e.g. fast growing plantation management), the characteristics of the wood may change and require research and development in processing technology (e.g. special drying/sawing technology). These issues may be risky for developing countries that may not be able to bear the additional costs of research and development for a changed product.

3.2.2.4 Increased public awareness and societal concerns regarding the threats and benefits of biotechnology

Nine of the 32 e-mail submissions touched upon this general concern. A quote from Strauss, Raffa and List (26/5) is quite appropriate to sum up the general concerns of this theme:

“The challenges to ethical uses of GM trees in forestry reside not in the process by which they are created, but rather in how their new characteristics and use will affect the environment and society. Substantial benefits have been documented in laboratory and field experiments. However, there are reasonable ecological and social concerns based on precedents from other kinds of agricultural technology. The key problems are deciding when our knowledge base is adequate, when there has been sufficient public discussion, and when there is adequate social consensus that the net effects for proposed uses are positive. If the process of public evaluation is scientifically sound and democratically rigorous, it should be possible to enjoy a continuing flow of new products from this rapidly maturing technology for the benefit of forestry in coming decades. If it is not, the technology may remain on the shelf in spite of its technical merits.”

Johnston (11/5) agreed that decisions regarding biotechnology should be made on local needs, economics and environmental considerations and that “all the risks and alternatives must be discussed alongside the possible benefits.” Overall, there was a large consensus that there is a much greater need now for public information and awareness of these technologies, before they should or will be used. Although most, if not all, GM trees will be used in high investment plantations, there are complex ecological questions that still must be carefully analysed.

3.2.2.5 Ownership and sharing of germplasm, techniques and financial arrangements with developing countries

Compared to the crop conference, there was rather limited discussion on the problem of moving new technologies (e.g. genetic modification) to developing countries. Perhaps it is not as clear in forestry, with respect to where specific genetic modification technologies would be useful, as no GM trees have yet been commercially released.

In some developing countries, ownership of land, forests and trees is not clear. This was specifically raised by Fenning (19/5) who said that it may not be clear who owns the forests or trees in developing countries where this technology could be applied. This creates a fundamental problem of guarantees on who will actually reap the benefits from any specific investment in these situations.

Fenning later (14/6) suggested (a point also made in the crop conference), that there is a need for innovative ways to provide access to the appropriate biotechnology for local programmes in developing countries. There were, however, no real proposals or examples in the e-mail conference where this was examined. Smith (13/6) pointed out that patent lives of around 20 years could provide substantial protection for certain types of biotechnologies. However, this may not be directly applicable to forestry, as trees planted 20 years from now with the patented technology, or those developed now but which are not harvested till later (after more than 20 years), may not be subject to such patent protection (or financial obligations or previous arrangements to the patent holders). In the short-term, patent or ownership restrictions could have immediate effects on investment incentives, particularly if there are large upfront costs associated with purchasing rights to use various products or techniques of biotechnology.

Burdon (19/5), considering political and institutional aspects of biotechnology, wrote the following that summarizes the issue quite nicely:

"Much may depend on the agencies involved. If large foreign investors are involved, they can in principle put in place a well-balanced technological base, whereby the biotechnology is properly coupled with complementary, field-based programmes in which there is a proper infrastructure of genetic management. However, for such an organization, the operation in a single developing country may be a small part of a global risk spread, in contrast to the risk exposure for the individual country and especially the local community(ies). In this situation there will also be Intellectual Property issues, while the regulatory mechanisms for risk management (which is not straightforward anywhere) are likely to be weak."

3.2.3 Additional points of relevance to the use of biotechnology in forestry

- Substantial concerns were raised about the risks of gene flow from GM plantations to adjacent natural populations (e.g. Serrano, 9/6). This was also a major concern in the crop conference. In the case of GM trees, most of the discussion led to the conclusion that sterility would be preferred or required in situations where GM trees will be established in large plantations close to natural forests composed of the same species.
- Developments in tissue culture research have been geared primarily to improving the advantages of clonal selection, but are now also required and used in the delivery system for GM transformation programmes. Re-juvenation of mature tissues has always been desirable but difficult to obtain. Smith (11/5) pointed out he has had success with this in radiata pine (*Pinus radiata*), and if the technology could be routinely used it would provide new options for clonal programmes (supported by Burdon, 19/5).
- Smith (13/6) raised the issue of variety genetic use restriction technologies and trait-specific genetic use restriction technologies as they may relate to forestry. He discussed the potential impacts of both types and argued that the latter may be far off in the future in GM forest trees. Immonen (5/6) noted that while "terminator technology" has been

considered largely negative for agriculture, it might be appropriate for forestry. This issue, however, is very much related to sterility or reduced flowering GM trees. Tree sterility with transgenic technology has been a major research area for several years now, but the genetic details of how it is created may not be as important as its reliability and use. Strauss (5/6) reiterated that functional redundancy for sterility was possible and this could ensure a high level of stability in the trait, but rigorous field-testing would still be required. Lindgren (14/6) expressed his viewpoint that sterility "seems to be the place to start [with GM trees]." Burdon (6/6) made the point that with genetic modification of forest trees there is a potential risk from a new pathogen strain arising years after the planting of trees with a particular genetic transformation.

- Smith (6/6) presented some potential guidelines for the use of forest biotechnology in the developing world. He considered four situations: 1) MNCs operating in developing countries with exotic or 2) indigenous species, and 3) local/national governments or agencies operating with exotic or 4) indigenous species. These four categories could provide some useful structure once GM technology advances to the level where developing country governments and MNCs might attempt to establish agreements on the use of the technology.
- Hong (8/6) noted that conventional breeding has accomplished astounding achievements in developing countries, such as increases in latex yield in rubber from 300 to 1 500-2 000 kg/ha. This may suggest that GM traits in forest trees might be best focused on introducing genetic characteristics that are not already available in the species.
- "Retroactive transformation" (i.e. only transforming elite and desirable genotypes), which is not currently done in most GM tree programmes, could reduce current costs of genetic transformation by approximately one-half (Smith, 15/6). This is because most GM tree research is still largely at the exploratory stage, and has not yet been incorporated into mainstream elite breeding programmes anywhere in the world.
- A few other interesting points were raised in the crop sector conference that were not specifically emphasized here, but which may be relevant to forestry in the future. This is probably due to the higher level of application of GM technology in the field today in agriculture, relative to forestry. These included, for example, issues of ownership and control of biotechnologies or the implications of Bt toxins on other organisms (e.g. soil fauna).

3.2.4 Name and country of participants with referenced messages

Ashton, Glenn. South Africa
Burdon, Rowland. New Zealand
DiFazio, Steve. United States
Fenning, Trevor. Germany
Hong, L.T. Malaysia
Immonen, Sirkka. Italy
Johnston, Sam. United States
Lindgren, Dag. Sweden
Serrano, Carlos Ramirez. Mexico
Smith, Dale. New Zealand
Southerton, Simon. Australia
Strauss, Steven. United States
Strauss, Steven; Raffa, Kenneth and List, Peter. All from United States

CHAPTER 4. LIVESTOCK SECTOR CONFERENCE

THE APPROPRIATENESS, SIGNIFICANCE AND APPLICATION OF BIOTECHNOLOGY OPTIONS IN THE ANIMAL AGRICULTURE OF DEVELOPING COUNTRIES

4.1 BACKGROUND DOCUMENT

4.1.1 The context: trends in animal agriculture in developing countries

Human population growth, increasing urbanization and rising incomes are fuelling a massive increase in demand for food of animal origin (milk, meat, eggs) in developing countries. Globally, livestock production is growing faster than any other sector and by 2020 the livestock sector is predicted to become the most important agricultural sector in terms of added value. In view of its substantial dynamics, this process has been referred to as the ‘livestock revolution’. Important features of this process are: (1) a rapid and massive increase in consumption of livestock products in developing countries with, e.g. *per caput* meat consumption in the developing world expected to double between 1993 and 2020; (2) a shift of livestock production from temperate and dry areas to warmer and more humid environments; (3) a change in livestock keeping from a family-support activity to market-oriented increasingly integrated production; (4) increasing pressure on grazing resources; (5) more large-scale, industrial production units located close to urban centres, (6) decreasing importance of ruminant vis-à-vis monogastric livestock species; and (7) a rapid rise in the use of cereal-based feeds.

Most food of animal origin consumed in developing countries is currently supplied by small-scale, often mixed crop-livestock family farms or by pastoral livestock keepers. The ongoing major expansion of the demand for livestock products for food is expected to have significant technological and structural impacts on the livestock sector. The productivity of animal agriculture in developing countries will need to be substantially increased in order to satisfy increasing consumer demand, to more efficiently utilize scarce resources and to generate income for a growing agricultural population.

Agricultural biotechnology has long been a source of innovation in production and processing, profoundly impacting the sector. Rapid advances in molecular biology and further developments in reproductive biology provide new powerful tools for further innovation. Increasingly, the advanced molecular biotechnology research and development activities are conducted by large corporations and are designed to meet the requirements of developed country markets rather than the conditions of small-scale farmers in tropical regions of the world. Whilst the developing countries accommodate an increasing majority of the world’s people, farmers and animals, there is a risk that biotechnology research and development may by-pass their requirements.

In this e-mail conference it is suggested to discuss biotechnologies that are either currently applied or are likely to come on stream for use in animal agriculture. The main theme of the conference is the question as to how relevant and appropriate these technologies are to meet the necessary enhancement of animal production and health in developing countries and which factors determine their adoption or lack thereof.

The question needs to be addressed why exactly this potential is so under-utilized in developing countries. To what extent is the technology transfer, in adaptation and adoption, affected by, e.g.:

- lack of clear livestock development policy conducive to the introduction of new proven technology;
- lack of necessary technology adaptation to suit local/regional conditions;
- insufficient information flow from and to decision-makers;
- accessibility of technologies as determined by price, intellectual property rights, the presence or absence of support or backstopping after their introduction;

- insufficient understanding of the decision process of the livestock owner/producer with regard to investment in animal production and health;
- weak expression of technology demand;
- public acceptance or rejection of biotechnology and ethical questions.

4.1.2 Biotechnologies for consideration

4.1.2.1 Reproductive biotechnologies

The main objective of biotechnologies in reproduction is to increase reproductive efficiency and rates of animal genetic improvement, thereby contributing to an increased output from the livestock sector. They also offer potential for greatly extending the multiplication and transport of genetic material and for conserving unique genetic resources in reasonably available forms for possible future use.

a) Artificial insemination (AI)

AI has already had a major impact on cattle, sheep, goat, pig, turkey and chicken improvement programmes of developed countries by accelerating breeding progress primarily through increased intensity of selection of males and through diffusion of breeding progress, initially with fresh and later, with frozen, semen, offering rapid worldwide transport of male genetic material. Globally, more than a 100 million AIs in cattle, 40 million in pigs, 3.3 million in sheep and 0.5 million in goats are performed annually. Only in very few developing countries is AI practised to a level that impacts substantially livestock production. What are the reasons that such a powerful technology has not been more widely adopted in developing countries? What is required to make the technology the same success as in developed countries?

b) Embryo transfer (ET)

ET in the mammalian species, enhanced by multiple ovulation and embryo transfer (MOET), allows acceleration of genetic progress through increased selection intensity of females and freezing of embryos enables low cost transport of genetic material across continents, and also conservation of diploid genomes. MOET may also be used to produce crossbred replacement females whilst only maintaining a small number of the straightbreds. In 1998, worldwide 440 000 ETs were recorded in cattle, 17 000 in sheep, 1 200 in goats and 2 500 in horses. About 80 percent of the bulls used in AI in the developed world are derived from ET. Despite the potential benefits of ET, its application is largely limited to developed countries. What are the required technical and/or policy elements that will enable developing countries to make use of these technologies on a greater scale?

ET is also one of the basic technologies for the application of more advanced reproductive biotechnologies such as ovum pick-up (OPU) and in vitro maturation and fertilization (IVM/IVF), sexing of embryos, cloning and of transgenics.

c) OPU and IVM/IVF

OPU in mammals allows the repeated pick-up of immature ova directly from the ovary without any major impact on the donor female and the use of these ova in IVM/IVF programmes. Making much greater use of genetically valuable females at a very early age may substantially increase genetic progress. What potential uses of these technologies are feasible in developing countries? What are the required technical and/or policy elements that will enable developing countries to make practical use of these technologies?

d) Sexing

Technologies for rapid and reliable sexing of embryos allow the generation of only the desired sex at specific points in a genetic improvement programme, markedly reducing the number of animals required and enabling increased genetic progress. Sexing of semen using flow-cytometric sorting has decisively progressed in recent years but still with limited sorting rates, even for IVF. Sexed semen could markedly increase genetic improvement rates and have major implications for end-product commercial production. What is the scope for the use of these technologies in developing countries?

e) Cloning

IVM/IVF are a source of large numbers of low cost embryos required for biotechnologies such as cloning and transgenesis. Three different types of clones are distinguished, as a result of: (1) limited splitting of an embryo (clones are genetically identical); (2) introducing an embryonic cell into an enucleated zona (clones may differ in their cytoplasmic inheritance); (3) introducing the nucleus of a somatic cell (milk, blood, dermal cells), after having reversed the DNA quiescence, into an enucleated zona (clones may differ in their cytoplasmic inheritance and substantial knowledge of the phenotype of the parent providing the somatic cell probably already exists). Cloning will be used to multiply transgenic founder animals. Cloning technologies offer potential as research tools and in areas of very high potential return. The sampling of somatic tissue may assist collection and transfer of breed samples from remote areas for conservation purposes.

4.1.2.2 Molecular biotechnologies

Various molecular biotechnology applications are available in animal production and health, involving both on-farm production and off-farm product processing applications. In this e-mail conference on-farm use is considered; only technologies based on DNA procedures are suggested for consideration.

a) DNA technologies and animal health

Animal diseases are a major and increasingly important factor reducing livestock productivity in developing countries. Use of DNA biotechnology in animal health may contribute significantly to improved animal disease control, thereby stimulating both food production and livestock trade.

i) Diagnostics and epidemiology

Advanced biotechnology-based diagnostic tests make it possible to identify the disease-causing agent(s) and to monitor the impact of disease control programmes, to a degree of diagnostic precision (sub-species, strain, bio-type level) not previously possible. For example, DNA analysis of bovine viral diarrhoea virus (BVDV) has been shown to be composed of two genotypes, BVDV1 and BVDV2. Only the latter was found to produce haemorrhagic and acute fatal disease, and diagnostic tests to distinguish between the two are under development. Enzyme-immunoassay tests, which have the advantage of being relatively easily automated, have been developed for a wide range of parasites and microbes. Relevance and accessibility of these diagnostic tests to the livestock industry in developing countries are suggested for debate.

Molecular epidemiology is a fast growing discipline that enables characterization of pathogen isolates (virus, bacteria, parasites) by nucleotide sequencing for the tracing of their origin. This is particularly important for epidemic diseases, where the possibility of pinpointing the source of infection can significantly contribute to improved disease control. Furthermore, the development of genetic probes, which allow the detection of pathogen DNA/RNA (rather than antibodies) in livestock, and the advances in accurate, pen-side diagnostic kits, considerably enhance animal health programmes. The conference should establish the status and potential uses of these technologies in developing countries.

ii) Vaccine development

Although vaccines developed using traditional approaches have had a major impact on the control of foot-and-mouth disease, rinderpest and other epidemic and endemic viral, mycoplasmal and bacterial diseases affecting livestock, recombinant vaccines offer various advantages over conventional vaccines. These are safety (no risk of reversion to virulent form, reduced potential for contamination with other pathogens, etc.) and specificity, better stability and importantly, such vaccines, coupled with the appropriate diagnostic test, allow the distinction between vaccinated and naturally infected animals. The latter characteristic is important in disease control programmes as it enables continued vaccination even when the shift from the control to the eradication stage is contemplated. Recombinant DNA technology also provides new opportunities for the development of vaccines against parasites (e.g. ticks, helminths, etc.) where conventional approaches have failed. What is the status and potential for the use of these technologies in developing countries?

b) DNA technologies in animal nutrition and growth

i) Nutritional physiology

Applications are being developed to improve the performance of animals through better nutrition. Enzymes can improve the nutrient availability from feedstuffs, lower feed costs and reduce output of waste into the environment. Prebiotics and probiotics or immune supplements can inhibit pathogenic gut micro-organisms or make the animal more resistant to them. Administration of recombinant somatotropin results in accelerated growth and leaner carcasses in meat animals and increased milk production in dairy cows. Immunomodulation can be used for enhancing the activity of endogenous anabolic hormones.

In poultry nutrition, possibilities include the use of feed enzymes, probiotics, single cell protein and antibiotic feed additives. The production of tailor-made plant products for use as feeds and free from antinutritional factors through recombinant DNA technology is also a possibility.

Plant biotechnology may produce forages with improved nutritional value or incorporate vaccines or antibodies into feeds that may protect the animals against diseases.

ii) Rumen biology

Rumen biotechnology has the potential to improve the nutritive value of ruminant feedstuffs that are fibrous, low in nitrogen and of limited nutritional value for other animal species. Biotechnology can alter the amount and availability of carbohydrate and protein in plants as well as the rate and extent of fermentation and metabolism of these nutrients in the rumen. The potential applications of biotechnology to rumen micro-organisms are many but technical difficulties limit its progress. Current limitations include: isolation and taxonomic identification of strains for inoculation and DNA recombination; isolation and characterization of candidate enzymes; level of production, localization and efficiency of secretion of the recombinant enzyme; stability of the introduced gene; fitness, survival and functional contribution of introduced new strains.

Methods for improving rumen digestion in ruminants include the use of probiotics, supplementation with chelated minerals and the transfer of rumen micro-organisms from other species.

c) DNA technologies in animal genetics and breeding

Most animal characteristics of interest to food and agriculture are determined by the combined interaction of many genes with the environment. The genetic improvement of locally adapted breeds will be important to realizing sustainable production systems.

The DNA technologies provide a major opportunity to advance sustainable animal production systems of higher productivity, through their application in:

- characterizing and better understanding animal genetic variation;
- manipulating the variation within and between breeds to realize more rapid and better-targeted gains in breeding value; and in
- conserving genetic material.

i) Characterizing genetic variation

The use of microsatellites in genetic distancing of breeds is gaining momentum. While most breeds are located in the developing world, this work is confined to developed countries. How is it possible to more effectively involve the developing country breeds? Are the current protocols adequate or what further standardization is required?

ii) Increasing the speed of genetic improvement of locally adapted breeds

There are many links in the chain to realizing rapid genetic progress in the desired goals, with the objective being to rapidly transmit from selected breeding parents to offspring those alleles which contribute to enhanced expression of the traits of interest. In developing countries, generation intervals are generally longer for all animal species of interest than in developing countries. How can DNA technologies be used to reliably realize intense and accurate selection and short generation intervals and to enable genetic improvement of these many locally adapted breeds to contribute to the required livestock development?

There is rapid progress in the preparation of sufficiently dense microsatellite linkage maps to assist in the search for genetic traits of economic importance. Can these linkage maps be used to develop strategies of MAS and marker-assisted introgression to meet developing country breeding goals? How should this be approached? Given the limited financial resources, how might work for the developing country breeding programmes strategically utilize the rapidly accumulating functional genomic information of humans, mice and drosophila?

Transgenic animals have one or more copies of one or various foreign gene(s) incorporated in their genome or, alternatively, selected genes have been 'knocked out'. The fact that it is possible to introduce or to delete genes offers considerable opportunities in the areas of increasing productivity, product quality and perhaps even adaptive fitness. In initial experiments, genes responsible for growth have been inserted. The technology is currently very costly and inefficient and applications in the near future seem to be limited to the production of transgenic animals as bio-reactors. What is the potential significance of these advanced technologies for developing countries and what are the technical, societal, political and ethical determinants of their application?

iii) Conserving genetic diversity

Global surveys indicate that some 30 percent of all remaining livestock breeds are at risk of loss, with little conservation effort currently invested. The majority of domestic animal breeds are in developing countries. Whilst animals cannot be re-formed from DNA alone, the conservation of genomic DNA may be useful. Under what circumstances should DNA genomic material be conserved and how should this be done by developing countries? What other information should be retained and what policy issues need to be taken into account?

4.2 SUMMARY DOCUMENT

In the Background Document to the conference the biotechnology options were classified into two main groups: reproductive and molecular. Application of biotechnologies in three different animal sectors was also considered: a) health (disease diagnosis, epidemiology and vaccine development); b) nutrition and growth (nutritional physiology and rumen biology); and c) genetics and breeding (genetic improvement and characterization/conservation of genetic diversity).

A total of 42 messages were posted during the conference, of which more than half were from developing countries. In contrast to the crop, forestry or fishery sector conferences (Chapters 2, 3 and 5, respectively), where a single biotechnology (genetic modification) dominated discussions, participants in this conference dealt with a wide range of biotechnologies and transgenic animals were not a major topic of discussion. Regarding the different animal sectors referred to previously, all three were covered at different stages throughout the conference although there was greatest discussion concerning the use of biotechnologies for the third sector, genetics and breeding, and least on the second sector, nutrition and growth.

The majority of messages came from participants with extensive experience of development projects and animal agriculture in developing countries. A large number of different topics were covered, ranging from those that were biotechnology-specific, such as participants' experiences or comments regarding individual biotechnologies in their country, to those that dealt with broader issues, such as the impacts of biotechnology on livestock biodiversity in developing countries. In summarizing the discussions, participants' comments are grouped into a number of main topics within two sections. The first section attempts to summarize what participants said about the appropriateness, significance and application of specific biotechnologies. The second section is not biotechnology-specific and deals with their comments on a range of broader issues.

Sections 4.2.1 and 4.2.2 of this document thus attempt to summarize the main elements of the discussions. Specific references to messages posted, giving the participant's surname and the date posted (day/month of the year 2000), are included. The messages can be viewed at www.fao.org/biotech/logs/c3logs.htm. Section 4.2.3 gives the name and country of the people that sent referenced messages.

4.2.1 Discussions related to the appropriateness, significance and application of individual biotechnologies in developing countries

4.2.1.1 AI

The Background Document indicated that AI has already had a major impact on genetic improvement programmes in developed countries and questioned why it had not been more widely adopted in developing countries. Most comments received (which came mainly from participants in developing countries) dealt with the factors explaining the relatively moderate uptake and whether natural service is preferable to AI.

Steane (20/6) argued that low conception rates and dependence on donor funding, which eventually is exhausted (a point also highlighted by Tibary, 4/7), were two major factors behind its low use in developing countries. Steane, in a later message (30/6), elaborated on the first factor, suggesting that low conception rates were due to a) poor heat (oestrus) detection; b) poor communication and infrastructure; and c) the fact that inseminators do not carry out sufficient numbers of inseminations to achieve high success rates. Chandrasiri (24/7), on this subject, stressed the need for farmer education and suggested that significant improvement could be achieved if farmers were educated on proper heat detection and timing of AI.

Traoré (6/7) concluded that, for developing countries, "at the present status, it is out of the question to consider AI as an alternative reproductive method to natural service (as is often the case in developed countries today)". He maintained that there were still many problems with AI, due to a) relatively high costs, where components such as liquid nitrogen continued to increase in price; b) poor heat detection, often making heat synchronization necessary; and c) its use when unlinked to good health care and animal husbandry. This last point was also emphasized by Ramsey (17/8).

Na-Chiangmai (4/8) supported the conclusion of Traoré (6/7), saying that AI at the small farmer level is not practical, especially for swamp buffalo and that natural mating probably gives better results under village conditions. He noted that correct timing of AI can be difficult for small farmers when the buffaloes are kept far from the village, due to problems with heat detection and the short ovulation period. Chandrasiri (24/7) said that although AI could be considered as an alternative to natural service, it was not popular among small-scale dairy farmers in Sri Lanka, a country where 85 percent of cows are naturally bred. Wiwie (11/7) maintained however, that in her country, Indonesia, AI was indeed an alternative to natural service for cattle because heat detection was easy, as farmers had only few cattle and these were kept in pens, and because bulls were both expensive to maintain and to transport within the country, which consists of many islands. Tibary (7/8) argued that although natural service gave good fertility results, the cost and the accident/health risks involved in keeping live males meant that AI should be recommended. He maintained that efficient programmes involving ovulation synchronization and AI, without requiring heat detection, could be developed.

4.2.1.2 ET

ET is a more advanced reproductive biotechnology and is less widely used than AI in both developed and developing countries. Its potential impact and current status in developing countries were considered in the conference.

The potential merits of ET for dissemination of crossbred genetic material, for conservation of endangered local breeds and for genetic improvement in developing countries were mentioned by Traoré (6/7). He also, however, argued that the technology had, since the beginning, been too focused on dissemination of purebred genetic material for commercial production. Steane (20/6) felt that its use in the developing world would be more effective for dissemination of appropriate genetic material (such as crossbred dairy females) than for genetic improvement. However, he highlighted (30/6) that the current conception rates were low, for the same reasons as he gave earlier for AI and that they would need to be improved. Tibary (7/8) suggested that if the parties involved are convinced that technologies such as ET and AI are useful, then technical problems can be solved if there is adequate funding of local research. As an example, he cited the large progress made in ET and AI in camels in the Middle East. Ramsey (17/8) emphasized that both ET and AI can be very useful, provided that other basic inputs (good husbandry, nutrition and management) are in place.

Wiwie (5/7) reported her experiences with a dairy cattle ET project in Indonesia and suggested that such projects could be successful if begun slowly with local pilot projects and then expanded on a step-by-step basis. Chandrasiri (24/7) reported that in Sri Lanka, ET was still only at the experimental stage and that it would take a few more years for it to be established commercially.

4.2.1.3 IVM/IVF and sexing

There was little discussion about these techniques. Chandrasiri (24/7) however, raised the issue of using IVM/IVF in countries like Sri Lanka, where slaughter of female cattle and buffaloes is prohibited and slaughter house ovaries are thus unavailable. He suggested that collaborations with countries allowing their slaughter would solve the problem. Steane (20/6) and Chandrasiri (24/7) both mentioned that in some circumstances it would be advantageous to have sexed genetic material available for dissemination purposes.

4.2.1.4 Cloning

Blair (29/6 and 30/6) suggested that adult cloning could be beneficial in centralized breeding schemes for efficiently disseminating the genetic gains achieved to other levels of the animal population. Cronjé (29/6) proposed that the government could stimulate farmer support (including financial) for centralized breeding schemes by offering free cloning of genetically superior animals and sale of clones back to the farmers at subsidized rates. Gibson (21/7), on the other hand, recommended that one should stick closely to foreseeable realities. He said there was no evidence that the use of cloning for livestock dissemination can be economically viable in developed countries and that “we should exercise extreme caution in predicting future applications of cloning technologies”.

4.2.1.5 Genetic modification

Compared to other conferences of the Forum, discussion of this biotechnology was less emotive and extensive. Muir (10/7) felt that transgenic technology offered tremendous potential for developed and developing countries and said that he strongly supported it. He emphasized, however, that potential negative impacts, as well as the true costs of the technology, should be evaluated. Steane (20/6) was concerned that, due to financial restraints, all the tests required to evaluate the potential adverse effects of GM animals might not be carried out. Martens (3/7) argued that before introducing GM animals, their performance should be tested under local feeding and management conditions. Gibson (21/7) said that it was appropriate that there should be a debate on testing GM livestock but that, in his opinion, “appropriate testing is not a substantive issue or limitation”. He suggested that genetic modification had as much potential for animals as for crops and that production of GM livestock was already economically feasible (although not cheap) due to advances in transgenic technologies. He was, however, concerned that resources would not be directed towards producing GM animals of benefit to developing countries, such as those with improved disease or parasite resistance.

4.2.1.6 Use of molecular markers for MAS

There were some differences of opinion concerning the potential benefits of MAS for developing countries. Steane (20/6) pointed out that some research results suggest that MAS could reduce the overall total genetic progress. Muir (10/7) also urged caution and referred to some of his computer modelling results, which showed that, in certain conditions, MAS had very little positive impact on genetic improvement. He thus questioned whether it would be appropriate for developing countries to use the large financial resources that MAS requires for this purpose. Jeggo (20/7), on the other hand, was more optimistic, arguing that the use of microsatellite marker information to analyse production traits may offer ways to maximize use of the favourable genetic characters of indigenous livestock and to accelerate their genetic improvement. He suggested that support should be given so that developing countries could be provided with this technology.

4.2.1.7 Comparisons of different biotechnologies

In addition to discussions on individual biotechnologies, some participants also tried to compare and contrast them. Gibson (21/7), in the context of their application to livestock agriculture in the developing world, tried to place them in four classes according to the levels of infrastructure they require. In order of increasing complexity, there were:

- biotechnology products that could be applied in virtually any setting, such as recombinant vaccines or genetically improved animals;
- biotechnologies requiring a moderate amount of infrastructure, such as AI in cattle or molecular diagnostic tools;
- more complex biotechnologies, requiring advanced laboratories and infrastructure, such as ET or use of molecular markers;
- biotechnologies requiring very high levels of infrastructure (often available only in the wealthiest developing countries or in international research centres), such as development of recombinant vaccines, detection of quantitative trait loci or development of GM livestock.

Some participants compared the two principal reproductive biotechnologies – AI and ET. Steane (20/6 and 30/6) maintained that timing practicalities favoured the use of ET over AI at the local level, as the latter requires efficient heat detection followed by quick insemination of the female, whereas with ET there is less urgency. The ET technology is nevertheless more specialized and Wiwie (11/7) noted that, unlike AI, ET was only carried out by a few experts in her country, Indonesia. Traoré (6/7) maintained that, except in some high producing zones, AI was more competitive than ET, as farmers were then dealing with crossbred genetic material that was more adapted than the purebred genetic material that tended to be transferred by ET. He thus concluded that "contrary to AI, ET will still belong for a long time to the field of research".

4.2.2 Discussions on broader issues

4.2.2.1 Biotechnology and the dynamics of livestock production in developing countries

Wiwie (28/6) and Ali (29/6) provided a reminder of the current situation for many farmers in developing countries. In Indonesia, farmers usually have one to three cattle and a few head of sheep and goats and the animals are kept as financial security for the future (Wiwie, 28/6). Ali (29/6) noted that due to poverty, "consumption of livestock products is viewed as more of a luxury than a necessity" for many people in developing countries. The people's lack of purchasing power means then that farmers keep livestock as a social insurance rather than for profit (Ali, 29/6). Woodford (4/7) argued that "it is inevitable that agriculture in the less developed countries will undergo enormous change in relation to socio-economics and farming systems", where biotechnology was likely to play an important role and that the same transition from rural-based to urban-based societies, that happened gradually over the last 400 years in developed countries, was occurring now in developing countries, but at a much faster rate.

Ali (29/6) noted that in many countries, "good prices are only available in urban areas where economic growth in other sectors provides a spill over effect to the livestock sector" and that only progressive farmers close to urban areas, where the products can be sold at reasonable prices, may use biotechnologies. Traoré (6/7) supported this by saying that AI could be justified in some breeding systems with crossbreeding of local with exotic breeds, where there was a socio-economic environment to justify the crossbreeding operation, such as in peri-urban milk production systems. He said that this had been the experience in Mali. Regarding industrialization of animal production in peri-urban areas, Steane (20/6) urged that more attention should be paid to its impact on the environment and suggested that biotechnology might be used to address this problem.

4.2.2.2 Why biotechnology is used relatively little in developing countries

Several messages addressed this important question. Many explanations were provided and the factors were often related.

a) Lack of infrastructure

Sedrati (14/8) recognized the large potential that new biotechnologies in animal agriculture have for breeders and consumers, but maintained that "these technologies need an environment that we don't have in developing countries", in terms of educational and basic infrastructural (water, roads, sanitation, etc.) standards. His conclusion was that the role of developed countries should be to raise the levels of social development in developing countries so that it would then be possible for them to develop and use biotechnologies. Gibson (21/7), in a similar vein, wrote that the main difficulty in applying new technologies in developing compared to developed countries was that "the vast majority of new technologies build upon and depend upon a highly developed physical, social and educational infrastructure, which makes transplantation to other settings very difficult". To integrate the need for large infrastructural requirements with the wishes of developing countries for locally-based solutions, he argued that there was an even greater need now for large international centres to carry out biotechnology research and development. Hanotte (11/8) supported this and referred to the successful example of the collaboration shown between individual African countries in a project to genetically characterize indigenous cattle, where the molecular data from each country was analysed in a single international research centre. The importance of cooperation between research centres in both developing and developed countries was also emphasized by Traoré (16/8).

b) Low levels of information/knowledge about science and agricultural biotechnology

The challenges in this area are considerable since, as pointed out by Sedrati (14/8), the levels of illiteracy can be quite high in rural areas of developing countries while only few farmers have technical training. Worku (29/6) nevertheless emphasized the importance of reducing the information and knowledge gap that exists between developing and developed countries regarding agricultural biotechnology (he called this the “biotech divide”). He proposed that several approaches need to be taken to bridging the divide, including enhancement of science education (and integrating applications/principles of biotechnology into the curriculum) at the school and college level, while also targeting extension workers, opinion leaders, small farmers and consumers.

c) Low capacity of developing countries to use biotechnology

Jeggo (20/7) pointed out that there is an increasing gap between the ability of developing and developed countries to utilize biotechnology and that it was critical to bridge this north-south technology gap. Sedrati (14/8) pointed out that the level of investment in scientific and technical research in developing countries was very low and that, even when people in developing countries are trained in high-level technologies, they tend to take jobs in developed countries because of the higher salaries and better working conditions.

Regarding capacity-building in developing countries, Traoré (6/7) was convinced that researchers in developing countries had a lot to gain from cooperating with research institutes in developed countries to get access to useful biotechnologies and adapt them to the needs of developing countries. Jeggo (20/7) suggested that some technologies offered significant advantages to developing countries that did not hold for developed countries, but that they would not be realized unless support for the introduction and use of these technologies was provided.

d) Insufficient economic incentives for farmers to use biotechnology

As pointed out by Worku (29/6), poor profit margins in farming is one of the factors contributing to low rates of adoption of biotechnologies in developing countries. As the general population is poor and cannot typically afford to buy meat, milk or eggs, farmers do not tend to keep livestock for profit and so have no incentive to use biotechnologies (Ali, 29/6). The exception is when farmers produce close to urban areas, where they can expect good prices and their investments in the use of biotechnologies may be rewarded (Ali, 29/6).

e) Reliance on external funding for biotechnology projects

The dependence of many biotechnology projects on external funding was also considered to be a factor behind the low uptake of biotechnologies as often the projects collapsed once the funding finished. In discussing AI and ET, Tibary (4/7) pointed out that in his experience, “the use of these technologies is usually erratic and depends on funds provided by “development projects” and as soon as these funds are gone the activity ceases”. This was also the reaction of Steane (20/6) regarding AI, saying that it was often free and poorly structured with the result that when donor funding ended there were insufficient financial resources to continue.

Wiwie (5/7) agreed that this was a problem, but suggested that if the projects were carried out slowly on a step-by-step basis rather than as one-off, big projects they might be successful. By beginning with a small pilot project, as she had done in Indonesia with ET, there was firstly, a good probability of getting successful results and, secondly, seeing these good results, farmers were then more likely to support (and pay for) expansion of the project. Steane (30/6) emphasized that proper study and planning of the use of biotechnologies was first needed and that, unless planning was done and the extension services properly informed, no sustainable projects would be achieved. Gibson (21/7) expressed similar sentiments, writing that "through experience we have learned that development that is based locally and driven locally will have the greatest chance of being sustainable".

4.2.2.3 Relationship between biotechnology and other components of animal agriculture

Several participants emphasized the fact that biotechnology and genetic improvement in particular, cannot be considered in isolation from the other components of animal agriculture. Tibary (4/7) bemoaned the fact that in many cases "the use of biotechnology has been looked at as a magic solution to the growing demand on animal product". He argued that, since genetic improvement can only be expressed if other aspects of livestock management are improved, any implementation of reproductive biotechnology (his major area of interest) should be part of a larger programme to improve health and forage production. Donkin (21/8) echoed these sentiments, saying that although the temptation is to view new technologies as being able to provide a "quick-fix" solution, this was seldom true as the problems were usually more complex than they initially appear. He also argued that "no genetic improvement should be introduced without making provision for other improvements in aspects such as nutrition, disease control, or simply in the organization and control of breeding".

Ramsey (17/8) expressed similar views, emphasizing that biotechnology needs to be used responsibly and that important issues, such as general animal husbandry, should not be overlooked. Referring specifically to AI, he noted that very often "the fact that stressed and underfed animals do not respond well to synchronization and AI is simply overlooked". Traoré (6/7) was of the same opinion, saying "the application of AI as a lucrative activity remains questionable if it is not linked to some other activities, such as health care and advice on animal husbandry practice".

Given that new biotechnologies are often very expensive and require sophisticated back-up services, facilities and technical staff, Donkin (21/8) suggested it was appropriate to ask whether the resources could be used more effectively for developing countries. Muir (10/7) made a similar point, writing that "high tech does not necessarily equate with good tech. Good tech is that which is cost effective and appropriate for the situation". Referring specifically to MAS, he argued that the economic resources might be better utilized in raising the management skills of farmers or in improving the extension services.

4.2.2.4 Biotechnology and vaccine development or disease diagnosis

According to Steane (30/6) the potential of biotechnology is probably greater than in most other areas of animal production when directed towards new vaccines or the use of disease resistance genes. Halos (13/7) noted that one of the major problems facing the livestock production services was availability of effective vaccines far from major urban areas. As those currently available need refrigeration, she argued that DNA vaccines may help to solve this problem. Jeggo (20/7) was slightly more cautious, saying that although biotechnology offered solutions for animal vaccines, "there is a long way to go". He argued that DNA vaccines, recombinant vaccines and genetically modified marker vaccines are obvious paths to follow, but that there were problems due to a) the intense debate on GMOs currently taking place in Europe; and b) the limited research funds available for work on developing country diseases. Regarding diagnosis of animal diseases, Jeggo (20/7) argued that diagnostic systems based on the polymerase chain reaction had an advantage due to their specificity and sensitivity and that technical developments were making them more attractive. He noted, however, that their use in developing countries was still limited due to problems of assay control and contamination.

4.2.2.5 Biotechnology and nutrition

Cronjé (5/7) suggested that blood metabolite concentrations could be useful measures of nutrient status for free-ranging animals in developing areas. Makkar (17/7) provided some detailed comments on the potential role of biotechnology in animal nutrition. He argued that “the manipulation of plants is likely to improve the utilization of feed resources by livestock with lesser investment of efforts and money compared to the manipulation of rumen microbes”. To illustrate how genetic manipulation of plants might improve feed quality, he gave seven examples where it held great promise such as increasing sulphur amino acids in leguminous forage or increasing the digestibility of existing nutrients, especially fibre, for tropical forage. He questioned, however, whether reduction or elimination of plant secondary metabolites (anti-nutritional factors) by plant breeding and molecular technologies might be advisable in developing countries as the plants are faced with various environmental challenges and the metabolites have a protective role – a viewpoint that was supported by Dundon (18/7). Makkar (17/7) suggested that problems caused by the metabolites could be mitigated in some cases by transferring rumen micro-organisms from resistant to susceptible animals.

4.2.2.6 Traits for genetic improvement in developing countries

A range of biotechnologies can be used to genetically improve livestock in developing countries. There was some discussion in the conference about which traits should be targeted for genetic improvement. Steane (20/6) questioned whether it was sensible in dairy cattle breeding to follow the developed world and to increase body size and maintenance requirements and to reduce fertility as had happened with the Holstein-Friesian population. Cronjé (20/6) maintained that selection for single traits, as practised in developed countries, increased the animals’ adaptation to higher levels of nutrition and that it was important to genetically select the animals so that they could reproduce and carry out other essential functions when nutrient supply was low. The importance and potential of using biotechnology to genetically improve disease resistance was emphasized by Steane (30/6), Worku (1/7) and by Gibson (21/7), who said, regarding genetic modifications of livestock of potential benefit to the developing world, that he would focus on efforts to modify resistance to disease and parasites.

4.2.2.7 Genotype by environment (G × E) interactions

The topic of G × E interactions, where the genetic superiority/ranking of animals is dependent on the environment they are in, was discussed in two different contexts: i) the import of genetic material selected in developed countries to developing countries; and ii) genetic improvement programmes in developing countries

a) Import of exotic breeds

Both Woodford (4/7) and Ramsey (17/8) noted that experts from developed countries often advocated use of foreign breeds for developing countries, a strategy that was often unsuccessful as the animals were not genetically adapted to the new environment. Cronjé (20/6) emphasized the animal nutrition aspect to this problem, arguing that caution should be expressed about using genetic material in developing countries that has been selected under high nutritional levels in developed countries. Cronjé (5/7) however, also insisted that, given the increasing demand for food for the expanding human population, the existence of G × E interactions should not be used to delay the application of biotechnology until all genotypes had been tested in all environments.

b) Genetic improvement programmes in developing countries

To overcome the difficulties associated with on-farm recording and testing in developing countries, Blair (29/6) suggested that genetic improvement programmes should be based in centralized breeding stations, from which the superior genetic material could be then disseminated. Cronjé (29/6) however, argued that this approach was associated with problems because in such stations i) the management/nutrition levels were typically far superior than in normal farm conditions; and ii) genetic selection was usually based on a single trait recorded in the station environment. Because of G × E interactions, he concluded that this could result in animals being selected that were genetically superior in the station but inferior in the farmers' environment. He suggested a compromise, where farmers would cooperate in a group breeding scheme, each contributing their own animals to be recorded under normal nutritional/management conditions in a centralized farm or grazing area. The concept was supported by Muir (1/7) who insisted that when G × E interactions are strong then the way to deal with the problem is to select the animals in the normal environment of production. Blair (3/7) suggested that the solution was to change the ranking process in the centralized station, which would require either assessing new traits on the station animals, recording their relatives under commercial conditions outside the station or modifying the station environment to reflect commercial conditions (as suggested by Muir, 1/7).

4.2.2.8 Impacts of biotechnology on livestock biodiversity in developing countries

There was much discussion throughout the conference about the potential impacts (negative and positive) that biotechnology has (or may have) on animal genetic resources in developing countries. The theme is important as much of the potentially important livestock biodiversity is found in developing rather than developed countries (Steane, 20/6; Hanotte, 11/8) and it was argued that it could be a potential goldmine for developing countries if properly studied and evaluated (Hanotte, 11/8).

a) Negative impacts of biotechnology on livestock biodiversity

Discussions about the negative impacts were, to a large degree, a consequence of the many experiences that developing countries have already had of the use of reproductive biotechnologies (especially AI) to introduce foreign or exotic genetic material from developed countries, either for crossing with the local breeds or as purebreds. The primary negative impacts mentioned were that "the existing adapted genetic material might be diluted or lost" (Donkin, 21/8), seen for example in the Philippines (Halos, 13/7), and that the imported genetic material might not be adapted to the new environment and would require improvements in nutrition/housing, etc. since "if we change the genetics then the chances are that we must also change the environment" (Woodford, 4/7). Ramsey (17/8) expressed similar sentiments, saying that using AI, "adapted indigenous animals have been crossed with breeds that are often totally unsuited to the environments in question - and we are left with a legacy of animals that require additional inputs to perform - and an eroded indigenous gene pool". Cronjé (20/6) also emphasized that once genes are introduced into an indigenous gene pool, it is hard to remove them if they are later discovered to be inappropriate. Traoré (16/8) suggested that a problem for breed conservation is that foreign breeds often have a strong appeal to farmers because they, and their crosses, are believed to be of high performance.

Note that crossbreeding, *per se,* using AI, was not seen as being a negative factor. Steane (20/6) lamented the fact that very few developing countries offered AI of local breeds to allow their sires to be used in crossbreeding systems, but said that this was changing slowly. Ramsey (17/8) argued that in certain conditions (where there was a need for a specific product, such as milk and where the management inputs were sufficiently high), there was a niche for the development of a composite breed using local adapted animals as the dam line. The sire line could be non-local but should be chosen carefully, keeping the developing country environment in mind. He provided two examples of the development of composite breeds in South Africa.

b) Positive impacts of biotechnology on livestock biodiversity

Many participants emphasized the potential positive contribution that biotechnology could make to the conservation and characterization of livestock biodiversity (e.g. Jeggo, 20/7; Ramsey, 17/8).

Ramsey (17/8) maintained that the preservation of endangered breeds was a vitally important niche for biotechnology. Here, he argued that reproductive biotechnologies, such as AI and ET (also promoted in this context by Traoré, 6/7), and DNA technologies, to verify parentage and breed purity, could be very useful.

The importance of using molecular markers for studying livestock biodiversity was underlined by Hanotte (11/8). He noted that they allow us to identify the ancestral origins and to investigate the history of domestication of modern livestock species. Muir (21/8) argued that, having identified the ancestral wild populations from which the modern breeds evolved, biotechnology could play an important role in identifying alleles of production traits present in ancestral populations but absent in modern breeds.

Hanotte (11/8) stressed the importance of international cooperation when using molecular markers to genetically characterize local breeds and gave an example of successful collaboration involving an African cattle project. This point was strongly supported by Tiesnamurti (16/8) and Li (17/8), who, together with Steane (25/8), gave some advice on how such international projects could be successfully operated. Li (17/8) also argued that, apart from molecular markers, basic data on production characters, population size and breed histories were also important for genetic characterization. Traoré (16/8) maintained that although characterization was an important step, it was not enough to ensure conservation of the local genetic resources, as this depended on a true appreciation of their characteristics. Ramsey (17/8) suggested that, wherever possible, conservation should start with on-farm initiatives.

4.2.2.9 The role of animal scientists in the biotechnology debate

Harper (18/7) urged scientists to be more active in public discussions about biotechnology and in providing information to groups looking to learn about biotechnology. He predicted that this information-provider role would grow for scientists in the coming decades. He also observed that it was important for scientists to communicate the role that the different biotechnologies are already playing in the production system, although without over-emphasizing the importance of transgenic solutions, as this may lead to loss of public support. Donkin (21/8) noted that scientists tend to be enthusiastic about technological advances and keen to find ways to apply them. He cautioned, however, that this enthusiasm needs to be directed appropriately and that in development projects, the people to be helped should also be involved. These elements of caution were also expressed by Steane (25/8) who suggested that many scientists in developing countries seemed to emphasize obtaining the technology rather than looking at the possible adaptations, which could be infrastructural, needed to make them serve local needs. For him, this emphasized the need for increased dialogue “between the various interested parties - planners, scientists, extensionists and above all, farmers”.

4.2.3 Name and country of participants with referenced messages

Ali, Kassim Omar. Norway
Blair, Hugh. New Zealand
Chandrasiri, A.D.N. Sri Lanka.
Cronjé, Pierre. South Africa
Donkin, Ned. South Africa
Dundon, Stanislaus. United States
Gibson, John. Kenya
Halos, Saturnina. The Philippines
Hanotte, Olivier. Kenya

Harper, Gregory. Australia
Jeggo, Martyn. Austria
Li, Kui. China
Makkar, Harinder. Austria
Martens, Mary-Howell. United States
Muir, Bill. United States
Na-Chiangmai, Ancharlie. Thailand
Ramsey, Keith. South Africa
Sedrati, M'Hammed. Morocco
Steane, David. Thailand
Tibary, Ahmed. United States
Tiesnamurti, Bess. Indonesia
Traoré, Adama. Mali
Wiwie, Caroline. Indonesia
Woodford, Keith. Australia
Worku, Mulumebet. United States

CHAPTER 5. FISHERY SECTOR CONFERENCE
HOW APPROPRIATE ARE CURRENTLY AVAILABLE BIOTECHNOLOGIES FOR THE FISHERY SECTOR IN DEVELOPING COUNTRIES?

5.1 BACKGROUND DOCUMENT

5.1.1 Introduction

Biotechnology in fisheries and aquaculture represents a range of technologies that present opportunities to increase growth rate in farmed species, improve nutrition of feeds for aquaculture, improve fish health, help restore and protect environments, extend the range of aquatic species and improve management and conservation of wild stocks. In this e-mail conference, the focus is on genetic biotechnologies, with a brief treatment of related reproductive and gene banking technologies, and the appropriateness of their application in the fishery sector in developing countries. It is important to note that developing countries produce more fishery products from aquaculture, inland capture fisheries and marine capture fisheries than developed countries. The coverage of the biotechnologies here is not comprehensive, but should be enough to stimulate discussion in the conference.

The vast majority of aquatic genetic resources are found in wild populations of fishes, invertebrates and aquatic plants. Fishstat, the FAO database on fishery statistics, lists 1 235 taxa of common aquatic species that are harvested by humans in major fisheries; thousands more species are taken by small-scale fishers. It also contains information on 440 species that are farmed, but just 20 of these taxa account for approximately 80 percent of world aquaculture production. Domestication of aquatic species has not proceeded to the same level as it has in the crop and livestock sectors. Genetic biotechnologies must be used both to assist in the further domestication of aquatic species and to help manage and conserve the genetic resources found in wild populations.

5.1.2 Genetic biotechnologies in the fishery sector

This Background Document provides a summary of recently developed biotechnologies that could be used or more widely used, in the fishery sector in developing countries. Genetic biotechnologies that can be used in fisheries and in aquaculture include those that help to manage genetic resources and those for genetic improvement.

For management of genetic resources, markers can be used in the identification of management units and of endangered species to assist fishery management and they can also help broodstock management in stocking programmes. These markers may be genes, proteins (i.e. the products of genes) sequences of DNA or the phenotypic expression of genes (different colours, shapes, etc.). In the 1960's, analysis of proteins revealed a wealth of genetic diversity in wild populations. Protein analysis is now relatively fast and inexpensive, but it requires tissue samples to be stored and transported frozen. DNA analysis is becoming the method of choice because of the small amount of tissue needed, the fact that the tissue can be stored dried or in alcohol and because DNA analysis reveals much more genetic variation than protein analysis.

Several kinds of DNA markers exist, such as RFLPs, AFLPs, RAPDs and microsatellites. These, as well as other kinds of markers, can be used to analyse gene frequencies and genetic variation in and between different groups of fish. Studies carried out using these technologies in fish populations have revealed high levels of genetic variation distributed throughout the fish genome.

Genetic improvement technologies cover a range of techniques requiring different levels of expertise and resources. Chromosome-set manipulation (i.e. polyploidy induction) is an established technique to increase the number of chromosome sets (ploidy number) in an organism. Temperature, chemical and pressure shocks applied to fish eggs can be used to produce triploid (three chromosome sets) individuals that have desirable culture traits. Sex-reversal and the production of single-sex groups of fish is also a simple technology that combines hormone treatment and chromosome-set manipulation.

Hybridization, i.e. the mating of genetically different groups from the same species (intra-specific hybridization) or from different species (inter-specific hybridization), is a simple technique that is now easy to accomplish due to our increased knowledge of reproductive biology. It can be used to combine good traits from two different species into one group of fish or to transfer a characteristic of one group to another. A problem is that breeding hybrids with hybrids results in a non-uniform and unpredictable group of fish that is generally not well suited for culture. Therefore, for hybrid production, the parent-lines must be maintained pure. The above genetic improvement techniques are considered short-term strategies, where the gains are seen in one or two generations.

Selective breeding is a longer-term strategy where gains are accumulated at each generation of selection. Molecular markers may now increase the efficiency of selective breeding by facilitating the identification of quantitative trait loci, i.e. genes that control complex characters such as growth rate and environmental tolerance and secondly, by making it possible to use molecular markers linked to QTLs to identify desirable individuals or families.

Genetic engineering and the production of transgenic organisms is an active area of research and development in aquaculture. This is a medium-long-term strategy in that development and testing of stable transgenic lines requires time. The large size and hardy nature of many fish eggs allows them to be manipulated rather easily and facilitates gene transfer by direct injection of a foreign gene or by electroporation, where an electric field assists gene transfer.

In the next three sections, currently available biotechnologies are briefly discussed in the context of fishery management, aquaculture and conservation respectively.

5.1.3 Biotechnologies in fishery management

The role that the application of genetic principles can play in the sustainable use and conservation of living aquatic resources is being increasingly appreciated by resource managers, policy-makers and the international community. Fishery management requires information on the fishery resources in order to be effective. Primary information needs include:

- an identification of the resource;
- the breeding or stock structure of the resource;
- an estimate of the size of the resource; and
- the identification of key habitat that the resource requires.

Genetic analysis of the resources can address these information needs. Gene and genotype frequencies of different markers can provide information on, *inter alia,* species identification, population stock structure, hybridization and gene flow. Often, data from other sources, e.g. studies of tagged fish or of external characters of fish, cannot provide such information or are extremely difficult to collect in certain areas such as large river systems, floodplains or marine areas.

The use of protein and DNA data in fishery management requires collection of baseline (or background) genetic information. Genetic data were used to determine how sub-groups of Pacific salmon differed from each other in the Pacific Northwest. This required the analysis of hundreds of stocks of salmon but, once completed, endangered stocks were identified, levels of migration were estimated and the contribution of different stocks to a mixed stock ocean fishery was estimated.

Protein and DNA information has been used to identify endangered species that are either inadvertently captured in wild fisheries or are purposefully taken illegally. DNA analysis of legally sold whale meat revealed that many samples came from protected species of whale and dolphin. Species of shark are often difficult to identify because it is only the fins or flesh that are for sale; DNA analysis can be used to identify the species that provided the tissue and has the added advantage that dried tissue or less-than-fresh samples from markets can be studied.

5.1.4 Biotechnologies in aquaculture

Genetic biotechnologies in aquaculture focus primarily on increasing growth rate, but also include disease resistance and increased environmental tolerance. There are several biotechnologies that can be applied to farmed aquatic species.

Selective breeding, i.e. traditional animal breeding, started with the common carp several thousand years ago. However, it has only recently been applied to a handful of other species of food fish such as catfish, trout and tilapia. Therefore, many farmed aquatic species are very similar to their wild relatives. Selective breeding programmes have yielded significant and consistent gains of 5-20 percent per generation in species of, *inter alia*, Atlantic salmon, catfish and tilapia.

Hybridization is a simple genetic technology that has become easier with the development of artificial breeding techniques, such as the use of pituitary gland extract and other hormones to initiate gamete development and induce spawning (i.e. the depositing of eggs), and an increased understanding of environmental cues that influence reproduction, such as day length, temperature or water current. Many of the natural reproductive isolating mechanisms that species develop in the wild can now be overcome by fish farmers.

These improvements in reproductive technologies have also assisted aquaculturists greatly in their efforts to domesticate aquatic species. In addition, by making it possible to remove the natural constraints and timing of breeding, farmers are able to mate many more species at the times that are most beneficial and thus help to ensure a steady and consistent supply of fish to the market.

Chromosome-set manipulation can be used to produce triploid organisms that generally do not channel energy into reproduction because of problems associated with development of reproductive organs. Initially it was thought that this energy saving would result in increased growth rate, but this seems not to be the case. The real advantage of triploids seems to be in their functional sterility. For example, triploid oysters do not produce gonads (i.e. reproductive glands) and are therefore marketable at times of the year when mature oysters have an off-taste because of production of gametes (i.e. sex cells – the ovum, or egg (female), and sperm (male)).

In aquaculture, one sex is often more desirable than the other. For example, female sturgeon produce caviar, male tilapia grow faster than females whereas it is the female trout and salmon that generally grow faster than the males. The production of single-sex groups of fish takes advantage of these differences between the sexes and can be accomplished by manipulation of the developing gametes and embryo. The manipulation can be in the form of denaturing (i.e. destroying) the DNA in gametes followed by chromosome-set manipulation or by hormonal sex-reversal and subsequent breeding. The phenotypic sex of many aquatic species can be changed by administering appropriate hormones. For example, genetically male tilapia can be turned into females through estrogen treatments. These genetic males when mated with normal males produce a group of all-male tilapia that grow faster and have less unwanted matings (that lead to overcrowding and stunting) than a group of mixed-sex tilapia. Some of the all-male offspring would have two male chromosomes and these could be used as broodstock for subsequent generations, thus avoiding the use of hormones in the broodstock. Hybridization can also be used to produce single-sex groups of fish, when the sex-determining mechanisms in the parental lines are different (for example, hybridization of Nile tilapia and the blue tilapia).

Genetic engineering is a vague term that has come to be nearly synonymous with gene transfer, i.e. the production of transgenic fish or GMOs. This technology is progressing rapidly and it is now possible to move genes between distantly related species. Gene transfer in fish has usually involved genes that produce growth hormone and has been shown to dramatically increase growth rate in carp, catfish, salmon, tilapia, mudloach and trout. A gene from the winter flounder that produces an anti-freeze protein was put into salmon in the hope of extending the farming range of the fish. The gene did not produce enough of the protein to extend the salmon's range into colder waters, but it did allow the salmon to continue growing during cold months when non-transgenic salmon would not grow. Transgenic technology is currently in the research and development stage. To our knowledge there are no transgenic aquatic plants or animals available to the consumer.

5.1.4.1 Cryopreservation

The development of cryopreservation or low-temperature technology allows the short- and long-term storage of gametes. Currently, these low-temperature techniques can only be used on male gametes; eggs and embryos can generally not be stored in this way. Freezing gametes can increase the flexibility of a fish breeder, especially when breeding species where the sexes mature or migrate at different times, when the breeding season is very short, when the breeders are far apart or when one sex is exceptionally rare.

5.1.4.2 Fish health

Genetic biotechnologies are being used to improve fish health through conventional selection for disease resistance and through the use of molecular investigation of pathogens for characterization and diagnosis. DNA-based technologies are being used now to characterize different species and strains of pathogens. Genetic characterization of the pathogen may also reveal information about its origin, e.g. DNA analysis revealed two strains of crayfish plague fungus in Sweden: one from the local species and one originating in Turkey. Once the pathogen is characterized, DNA probes can be developed to screen for specific pathogens in tissue, whole animals and even in water and soil samples. These techniques are being used to detect viral diseases of marine shrimp throughout the world and for bacterial and fungal pathogens in fishes in many areas.

Genetically engineered vaccines are also being developed to protect fish against pathogens. Genetic immunization of rainbow trout with a glycoprotein gene from the virus causing viral haemorrhagic septicaemia has recently been shown to induce high levels of protection against the virus. Work is also underway on immunizing carp, salmon and other fishes with genetically engineered vaccines for other diseases.

The new molecular techniques are extremely sensitive and can identify pathogens in fish long before there are any clinical signs of the disease. This has implications for quarantine and the trade of aquatic species, which is currently governed by the World Trade Organization and the Office International des Epizooties. Trade can be restricted based on the disease status of a product or a region; identification of minute quantities of a pathogen or of a new strain of an existing pathogen could change or influence existing trade patterns.

5.1.4.3 Farming system

Farming systems for aquatic species are diverse and include industrial-scale farms, family ponds and culture based fisheries (stocking), in both developed and developing countries. Often, there is a division of the production process where fingerlings (i.e. small fish, especially up to one year of age) or eggs are produced by the seed-supplier, but the grow-out to market size is done elsewhere. In the case of sea going salmon, there is often a seed supplier operating a hatchery near a river, a fingerling producer in a freshwater lake, and another group that grows the fish to market size in the sea. Marine shrimp hatcheries in Asia are usually small family-owned ventures, whereas in Latin America they are more industrial in scale. Appropriateness of genetic biotechnologies must take these different systems into consideration.

5.1.5 Biotechnologies in conservation

Genetic biotechnologies can be used to reduce the impacts of farmed fish on wild populations, to identify and manage endangered species and to manage captive populations in aquaria or in species recovery programmes. In several areas, farmed fish must be made triploid, i.e. sterile, in order to reduce their impact on wild populations should they escape from the fish farm. Generally, the planned use of transgenic fish also includes the provision that they are sterile, to reduce the chance of mixing with other fishes. Genetic manipulation and polyploidization can be combined to regenerate endangered species. This can be done from frozen sperm by denaturing the DNA in an egg of a related species, fertilizing with frozen sperm from the endangered species and then duplicating the chromosome set of the fertilized egg.

5.1.6 Certain factors that should be considered in the discussion

The key question in this e-mail conference is how appropriate the different biotechnologies may be for the fishery and aquaculture sectors in developing countries today.

The question of appropriateness should consider the following elements:

- how does the farming system influence the use of genetic biotechnologies in developing countries?
- what are the factors that determine or influence the appropriateness of the different biotechnologies in developing countries e.g. their environmental impact; their impact on human health; the status with respect to intellectual property rights; the status with respect to biosafety regulations and controls; the degree of access to the biotechnologies; the level of capacity-building or resources required to use them; their financial cost; their impact on food production and food security;
- the relative costs (financial, social, political or otherwise) of the biotechnologies versus the relative benefits (productivity, food security or otherwise);
- whether they are more (or less) appropriate than existing conventional methods in the fishery sector in developing countries;
- whether some of the biotechnologies are more (or less) appropriate than others;
- whether some biotechnologies are more (or less) suited to certain regions in the developing world than others.

5.2 SUMMARY DOCUMENT

In the Background Document prepared for this conference, a brief coverage of some main biotechnologies was provided. These included the use of protein or DNA markers, triploidization, sex-reversal, hybridization, selective breeding, freezing of male gametes, genetic modification of fish and finally, DNA-based technologies to diagnose and characterize fish pathogens and to develop vaccines. They were discussed in the context of three main areas: fishery management, aquaculture and conservation.

However, participants in the conference focused to a large degree on a single biotechnology, the use of genetic modification, in a single main area, aquaculture. Of the 26 messages posted during the conference, 19 dealt only with this theme. Apart from genetic modification, the technology of triploidization was also much discussed, but only in the context of its application to GM fish.

A range of factors (such as the impact on human health, the status with respect to intellectual property rights, the costs or capacity-building required) that might influence the appropriateness of the different biotechnologies were also mentioned in the Background Document. But again, one factor dominated the discussions: the potential ecological risk or environmental impact of GM fish.

Section 5.2.1 of this document attempts to summarize the main elements of the discussions. Specific references to messages posted, giving the participant's surname and the date posted (day/month of the year 2000), are included. The messages can be viewed at www.fao.org/biotech/logs/c4logs.htm. Section 5.2.2 gives the name and country of the people that sent referenced messages. No messages came from some of the developing countries (Brazil, China and Cuba) that have active programmes in fisheries biotechnology.

5.2.1 Topics discussed in the conference

5.2.1.1 The nature of GM fish

There was some basic disagreement about how different GM fish were from non-GM fish. Muir (1/9) maintained that GM fish were very different as they could retain all the benefits of the wild species, while the transferred gene (the transgene) could potentially confer major advantages on the individual fish, such as being able to spawn at different times or invade new habitats. Conversely, the transgene could also make individuals less fit than wild types by affecting traits such as juvenile survival (Muir, 30/8). Moav (4/9 and 28/9) maintained that GM fish lines were similar to the domesticated parental lines which created them and that their genetic superiority for traits such as growth rate or disease resistance would be similar to that achievable through many years of conventional selective breeding.

5.2.1.2 Production of GM fish in developing countries

Currently, there is no commercial growth of GM fish, either in the developed or developing world. Norris (23/8), however, predicted that within the next five years or so, production of GM fish for human consumption would be a reality. She argued that there were two reasons why it might happen in a developing country such as Chile. The first is that Chile is an important producer of farmed fish, thus representing a major potential market for the technology. Secondly, consumer opposition to GMOs in general is far tamer than in developed countries, a point also made by Mair (15/9). Halos (12/9) emphasized that in densely populated developing countries with rising population numbers the priority is providing people with food as "poor people do not care to save for tomorrow since they fear tomorrow may not come for them, anyway". Mair (15/9) concluded that concerns about human health and environmental aspects of GM fish would inevitably be weighted lower when food security was a major issue, which could result in GM fish in aquaculture being adopted first in developing rather than developed countries.

5.2.1.3 Potential environmental impact of GM fish

As mentioned earlier, this was the major topic taken up by the participants during the conference. Discussions touched on four main areas:

- the potential impact when GM fish are introduced into ecosystems where the wild species already exists;
- the potential impact when GM fish are introduced into ecosystems where the wild species does not exist;
- whether triploidization (and thus sterilization) of the GM fish would reduce the ecological risk;
- biosafety in developing countries.

a) Growing GM fish where wild relatives exist

Muir (30/8) pointed out that, unlike the situation of domesticated animals, domesticated GM fish might escape into an ecosystem where the wild non-GM members of the same species are found (e.g. a hypothetical case might be production of transgenic Atlantic salmon in the Atlantic Ocean). He argued that this was a major concern because a) the wild relatives are likely to be an integral part of the ecosystem and disruption of the species could affect the entire ecosystem; and b) the escaped individuals can establish themselves by interbreeding with the wild relatives.

For this situation, Muir (30/8 and 1/9) summarized results from a paper he co-authored in 1999 which, using a theoretical model, considered the potential consequences of a small number of GM fish escaping and mating with their wild relatives. His results showed that if the transgene increased mating success but reduced the viability of transgenic offspring, then the local fish population could be driven to extinction. Halos (31/8) pointed out that the introduction of a new fish strain or of a superior conventionally bred strain might have the same consequences on a wild fish population and that this phenomenon was thus not unique to GM fish. She reported that this had already happened with the native catfish strain in the Philippines.

Regarding fish escapes, Halos (12/9) and Mair (15/9) both described the problems, especially due to large environmental extremes, of enforcing risk management strategies in developing countries. Mair (15/9) concluded, based on his practical experiences, "I would never like to guarantee that any domesticated fish cannot escape from an aquaculture facility".

Halos (31/8) argued that if GM fish mated with wild relatives, this might increase genetic diversity in the wild population. Muir (1/9), however, refuted this, concluding that GM fish (or exotic non-GM fish species) might in the short-term add diversity but, in the long-term, they decrease it because they eliminate competitors.

b) Growing GM fish where wild relatives do not exist

Moav (4/9) pointed out that in his country, Israel, carp had been imported from Europe and that the transgenic carp (with increased growth rates) that they had developed in Israel would not present such potential problems as there was no native carp population. Muir (5/9) suggested that the issue of the production of GM fish in regions where the wild species does not exist was of great importance and that there was a range of other potential examples, such as the production of transgenic tilapia in Cuba or transgenic Atlantic salmon in the Pacific. He had two major concerns about such potential initiatives:

- he argued that the introduction of exotic non-native species usually resulted in ecosystem disruption and so should be treated with extreme caution – an argument that would be valid for both GM and non-GM introduced species. A much-quoted example of the potential hazards was the introduction of the (non-GM) grass carp, *Ctenopharyngodon* *idella*, species from Asia to the United States to control aquatic weeds (Kapuscinski, 22/9). The species caused much ecological damage and its escape into new ecosystems in the country has exacerbated the problem (Muir, 7/9). In this context, Ashton (25/9) also noted that the movement of African fish species between regions had caused serious environmental disruption to aquatic systems in Africa. Halos (12/9) underlined that the increasing need for food in developing countries has been a driving force behind the practice of introducing exotic fast-growing aquatic species. She argued that if GM fish gave higher yields per unit area and at a lower cost, then they might be a better alternative;

- Muir's (5/9) second concern was that such initiatives might give a false sense of security, as there was nevertheless a danger of the GM fish being later transported and introduced to other regions of the world where wild relatives are found – something which might be driven by economical imperatives. Mair (15/9) supported this point saying that "you can be fairly sure that if a fish is considered superior for aquaculture, its movement will be impossible to control completely". Muir (5/9) wondered who would be liable for any environmental damage in these situations.

c) Triploidization

With such concerns expressed about the potential ecological risk of GM fish mating with non-GM wild relatives, the potential application of triploidization to GM fish to ensure their sterility was raised (Ibarra, 6/9). Benfey (6/9) pointed out that reliable technologies for making GM fish triploid exist for salmonids and that this was a simple way to ensure they would not breed if they escaped into the wild. He also suggested that companies producing transgenic fish might want to only sell sterile fish, in order to protect their investment.

In theory, each individual GM fish could be tested to ensure it was triploid before being released, a procedure already established in some situations with the grass carp in the United States (Benfey, 7/9; Kapuscinski, 22/9). Chevassus (11/9), however, pointed out that it is possible to test for triploidy but not for sterility and that in some species, although not in salmonids, a few or large number of triploid individuals may in fact be fertile. Muir (6/9) also argued that it is actually hard to quantify how successful a sterilization technique such as triploidization may be if the true probability of failure is very low (e.g. one in a million), because, to reliably quantify it, an extremely large number of fish, more than normally tested, may be required.

Muir (11/9) also pointed out that even though triploid males might be sterile they may still mate with fertile females of the wild species, thus interfering with reproduction and breeding of the wild population. To avoid this potential problem, he thus proposed that GM fish, in addition to being made triploid, should also be sex-reversed so that only females be grown. Mork (11/9) reported that a Working Group on the Application of Genetics in Fisheries and Mariculture, belonging to the Mariculture Committee of the International Council for the Exploration of the Sea, had considered the issue of triploidization at various times throughout the 1990s. An impetus for this work was the finding that some previously triploid Pacific oysters (*Crassostrea gigas*) introduced to the east coast of the United States reverted back to the diploid state. Their conclusion in a 1995 report was that "no current mass triploidization/sterilization technique is guaranteed 100 percent effective".

Mair (15/9) pointed out that there was an additional reservation about the application of triploidization in aquaculture of GM fish in developing countries, i.e. that "the application of triploidy in commercial stocks (mainly salmonids and grass carp) has been limited to species that are habitually bred using artificial fertilization and incubation. For most of the important species in developing country aquaculture (namely tilapias and carp) artificial fertilization is rarely used and therefore application of triploidy on a commercial scale would be very unlikely to be viable".

d) Biosafety

Such discussions on the potential impact of GM fish escaping into the wild and the use of technologies such as triploidization to minimize potential risks, brought up the main issue of biosafety which, broadly defined in relation to GMOs, involves assessing and monitoring the effects of possible gene flow, competitiveness and the effects on other organisms, as well as possible deleterious effects of the products on health of animals and humans. Ibarra (6/9) noted that in developing countries there was a substantial lack of human resources in the fishery sector trained in genetics and that this could lead to the situation where "potentially high-risk biotechnologies will become implemented without a careful evaluation". Norris (23/8) also expressed the fear that GM fish might be introduced in developing countries "without even considering risk assessment for such introductions". Ashton (25/9) insisted that, prior to release of any fish, GM or not, in developing countries, there was a need for adequate biosafety protocols, legal instruments, liability procedures and a clear thread of responsibility for any damage that might be caused to the countries by their release. Del Valle Pignataro (27/9) lamented the fact that, in relation to introducing non-native species (GM or not) to developing countries, it was not possible in most cases to establish strict regulatory/monitoring systems, due to factors such as low economic priority or the lack of qualified human resources.

Gjoen (5/9) argued that it was difficult to foresee all the risks involved with GM fish and that the precautionary principle should be given priority, a view that was shared by Ashton (25/9). The need for carrying out risk assessment in a scientifically sound manner was emphasized in a few messages (Moav, 4/9; Muir, 5/9; Gjoen, 5/9; Moav, 28/9).

5.2.1.4 Use of genetic modification versus other alternatives

Genetic modification dominated discussions in the conference. Nevertheless, some participants did consider other biotechnologies and other aspects of aquaculture in developing countries. Doering's (25/9) perspective was that, with few exceptions, the fish species cultured today are wild and that enormous gains for traits such as productivity, growth rate or survival can be achieved by selective breeding, assisted by molecular methods. He argued that, apart from concerns about the potential environmental impact, "transgenic aquatic animals are not sensible or cost-effective in the genetic background of a wild animal and the enormous productivity gains to be made by intensive selective breeding". Norris (23/8) also emphasized that many developing countries were "in need of practical help and advice in developing good aquaculture breeding and husbandry practices which would benefit their programmes greatly".

Ibarra (6/9) suggested that most of the currently available genetic biotechnologies are very appropriate for developing countries and that the main reason for their under-use was the "lack of human resources within the fishery and aquaculture sector trained in the adequate use of those genetic biotechnologies".

Doering (25/9) emphasized that many of the current problems in aquaculture in developing countries have low-technology solutions and that "the species appropriate for culture in developing countries generally do not have the production economics to justify many high cost inputs such as vaccines and artificial larval feeds". He argued that policy-makers and scientists can become over-enthusiastic for molecular techniques, ignoring the large capacity-building needs that these technologies require. His conclusion was that "investments in developing countries on farmer education, reducing culture stress and improving water quality as well as domestication will yield higher returns than investments in high technologies".

Ashton (25/9) argued for the prioritization of local solutions in developing countries and that management systems which secure the protection, husbandry and sustainability of native species should first be put in place before any fish, GM or not, are introduced. Del Valle Pignataro (27/9) supported this viewpoint. She suggested that prioritization should be given to domestication, culture and (eventual) genetic improvement of native fish species that are already exploited and that have good consumer acceptance in developing countries. She gave a summary of their ongoing marine fish efforts in this direction in Mexico, which will eventually involve the use of selective breeding with medium-level biotechnologies

5.2.2 Name and country of participants with referenced messages

Ashton, Glenn. South Africa
Benfey, Tillmann. Canada
Chevassus, Bernard. France
Del Valle Pignataro, Gabriela. Mexico.
Doering, Don. United States
Gjoen, Hans Magnus. Norway
Halos, Saturnina. The Philippines
Ibarra, Ana. Mexico
Kapuscinski, Anne. United States
Mair, Graham. Thailand
Moav, Boaz. Israel
Mork, Jarle. Norway
Muir, Bill. United States
Norris, Ashie. Ireland

CHAPTER 6. IPR CONFERENCE

THE IMPACT OF INTELLECTUAL PROPERTY RIGHTS (IPR) ON FOOD AND AGRICULTURE IN DEVELOPING COUNTRIES

6.1 BACKGROUND DOCUMENT

This conference was dedicated to the theme of the impact of IPR on food and agriculture in developing countries, to allow more detailed and comprehensive discussion of a topic that has clearly shown to be of major interest to Forum members, especially in the conferences on the crop sector and on hunger/food security. Note that discussion in this conference may cover the animal, fishery and forestry sectors as well as the crop sector.

6.1.1 The concept of IPR

Firstly, a few words about the concept of IPR in general. IPR are intangible rights which grant an exclusive right to impede others to freely exploit an invention or creation. Different forms of IPR exist such as patents, trademarks, industrial designs or copyrights. Each form of IPR has different requirements and grants different rights.

For example, patents are granted on inventions which are novel, inventive, with a useful application and sufficiently described to allow verification. Some things may not be patented, such as discoveries. Patents are granted for a limited time period, usually 20 years and are only valid in the country where they have been granted. Registered trademarks also have national coverage and the time limit of the rights may be extended. Plant variety protection (PVP) provides protection to new plant varieties that have previously not been commercialized, are distinct from existing varieties, are uniform in their main characteristics and stable over the years for those characteristics. Unlike patented material, protected varieties can be used for the development of new varieties without the authorization of the rights holder.

IPR in general, and the patent system in particular, were established originally as a way to reward creativity and promote innovation. They allow the holder of the rights to recoup the investment in research required to develop the new invention, which can be quite substantial for high technology inventions and, in exchange, society receives the benefit of the disclosure of the new invention.

6.1.2 IPR in the field of biotechnology for food and agriculture

Before the whole range of possibilities offered by modern technologies in the agricultural sector was available, inventions based on living organisms were considered natural phenomena, i.e. discoveries, and were thus not patentable. However, developments in modern biotechnology require substantial levels of investment in research and development, and its processes and products can be easily copied. The IPR system provides a way of ensuring the financial revenues required to make the technology profitable.

In 1980, the United States Supreme Court made a landmark decision in the Diamond versus Chakrabarty case. The ruling stated that a live, human-made, genetically engineered bacterium (of the genus *Pseudomonas*, that was modified to break down components of crude oil) could be patented, thus initiating an era of massive private investment in biotechnology and of rapid expansion in the patenting of new biotechnological innovations and products. Many biotechnology companies and universities have since applied for and been granted patents on a wide range of biotechnology processes and products, involving genes, viruses, bacteria and even living higher organisms.

While the positive impact of the IPR system on investments in research is not in question, concerns have been raised regarding the following issues:

a) The limits of patentability

The difference between invention and discovery becomes a matter of interpretation when it refers to living material. The isolation of a gene from its natural environment and the identification of its function render the gene and its sequence an invention for patenting purposes in some countries. The impact of patenting of genes in the agricultural sector cannot be minimized and should be discussed in this conference.

b) Patenting of “enabling technologies” (i.e. technologies that are essential for the practical implementation of a wide range of other biotechnological processes and products)

This issue is of great importance as it has an impact on access to these technologies, not only by developing countries but also by the agricultural research system in general.

c) The multiplicity of patents required to develop an agricultural product

This complicates management of the research agenda. Developments in modern agricultural biotechnology require the use of several processes and products, which in most cases will be subject to patent protection. As an example, let us consider development of GM crops. Firstly, individual genes, affecting characters of interest such as disease resistance or herbicide tolerance, are patentable. Secondly, DNA sequences controlling the expression of these genes, such as promoters, may also be patented. The two methods most widely used for transferring foreign DNA, as well as methods for identifying plant cells that have successfully incorporated the foreign genes, are also patented. Thus, many steps of patented technologies are required for the development of a product in the field of agricultural biotechnology.

An example illustrating the complexity of IPR is “golden rice”, a rice plant into which three foreign genes (two from the daffodil and one from a bacteria) have been introduced so that it produces provitamin A. The plant variant was produced by researchers collaborating in Switzerland and Germany and there is large interest in making it available to farmers in developing countries. However, the number of concurrent patents has complicated this possibility. Seventy techniques and materials used in developing the variant are patented and are owned by 32 different parties.

d) Patents on specific genes usually extend to the GMOs into which the genes are inserted, thus bringing the entire organism under patent protection.

This question has raised considerable debate in the crop sector. Eventual financial revenues are granted to the patent holder, without compensating the developers of the original plant variety. In some cases, however, particularly when the original plant variety is protected through PVP, sharing of benefits is achieved on a contractual basis with the patent holder.

e) Concentration of the agricultural industry

Another important element in this discussion is that a small number of MNCs dominates the field of agricultural biotechnology. Companies from developed countries therefore own many of the important IPR in this area and the power that this provides is concentrated in very few hands. For example, it is reported that of the roughly 270 patents related to genes of the soil bacterium *Bacillus thuringiensis* granted from 1986 to 1997 in countries of the OECD, about 60 percent was owned by only six MNCs. As the development of biotechnology products requires the use of many protected technologies, the private sector usually overcomes this problem by cross-licensing their patents, involving the mutual exchange of access to patented products or processes without financial compensation. For small organizations that do not have IPR to trade, licensing negotiations may be difficult and costly.

From discussions in the crop sector conference, it was apparent that many participants were convinced that the impact of IPR on agricultural biotechnology in developing countries was quite substantial. Some of the potential consequences mentioned by participants were:

- increased dependency of developing countries on developed countries: the point was made that the existence of strong IPR, and the fact that the rights over the technologies and products are often owned by MNCs, might lead to (increased) dependence by developing country farmers on MNCs and developed countries;
- patenting of genetic resources native to developing countries: patents can and have been issued to companies from developed countries over genetic material from developing countries, particularly for pharmaceutical and cosmetic purposes. In some cases, the lack of appropriate mechanisms for sharing of benefits has generated considerable controversy. A much-cited example is that of the neem tree (*Azadirachta indica*), which is a member of the mahogany family and which is indigenous to the Indian subcontinent where it has traditionally been used for agriculture, medicine and cosmetics. Around 90 patents exploiting the tree have been granted worldwide. In some cases, patents have been granted for particular uses, which are already known by traditional indigenous communities, not fulfilling the novelty requirement. Following a legal challenge, the European Patent Office in May 2000, revoked one of the patents (number EP0436257), granted to an American MNC and the United States Department of Agriculture, on a neem seed extract with insecticide and fungicide properties on the basis of its lack of novelty. Patent litigation costs are high and are an important factor in deciding whether to challenge such patents.

6.1.3 Factors that should be discussed in this conference

The main topic of this e-mail conference is the impact of IPR (over biotechnological products and processes) on food and agriculture in developing countries.

The following areas should be considered during the conference:

- what are the impacts of IPR (positive or negative) for food and agriculture in developing countries?
- compare the relative impacts in the animal, crop, fishery or forestry sectors;
- are the impacts different for different countries or regions of the developing world?
- are the impacts more substantial for some biotechnologies than for others?
- if some of the impacts or consequences are negative for developing countries, how can they be avoided or alleviated?
- whether the lack of an appropriate or harmonized IPR system in a developing country can have an impact on biotechnology transfer.

6.2 SUMMARY DOCUMENT

The importance of the theme of the conference was evident from other conferences, in particular those on the crop sector (Chapter 2) and to a lesser degree, on hunger and food security (Chapter 7). Participants in these conferences highlighted the negative impacts IPR might have for developing countries, such as their increased dependency on developed countries, increased "bioprospecting" in developing countries, reduced technology transfer and reduced ability of developing countries to produce their own biotechnology products. This conference made it possible, therefore, for a deeper discussion of these issues to take place.

A relatively large number (265) of Forum members registered for the conference and 50 messages were posted over the eight-week period, covering a wide range of themes concerning IPR and their impacts on developing countries. The majority of participants considered the impacts of IPR to be primarily negative for the developing world. They seemed then to have two approaches to deal with the situation. The first was to reject the current IPR system that they consider to be wrong and unjust and to propose how it should be changed. The second approach was to accept that the current system is here to stay and to propose strategies to overcome or alleviate the problems associated with it.

Throughout the conference, the crop sector received far more attention than the other agricultural sectors while the kinds of IPR specifically discussed were patents and to a lesser degree, PVP. In addition, genetic modification was the biotechnology that participants singled out for particular attention. This is probably because, as Srinivasan (7/5) pointed out, impacts of IPR are more substantial for modern biotechnologies and products with multiple patents (such as GM plants) than for products that are derived from traditional biotechnologies, such as micropropagation or tissue culture.

In Section 6.2.1 of this document, the main elements of the discussions are summarized under a number of main themes. Specific references to messages posted, giving the participant's surname and the date posted (day/month of the year 2001), are included. The messages can be viewed at www.fao.org/biotech/logs/c6logs.htm. One participant, Glenn Ashton, posted two messages on a single day and they can be differentiated by the order in which they were posted (i.e. Ashton 12/4(1) indicates the first message he posted on 12 April). Section 6.2.2 gives the name and country of the people that sent referenced messages.

6.2.1 Main themes discussed in the conference

6.2.1.1 Background information on IPR and patents

A few participants gave some background information on IPR and patents that reinforced or supplemented information previously provided in the Background Document to the conference.

Roger (9/5) emphasized that IPR are, firstly, scientific disclosures that can contribute to human knowledge. As Lettington (20/3) said, they "are a limited monopoly granted by individual states as a privilege in return for making an invention, or some other useful information, public. The policy reasoning is that, even though society as a whole loses a little through the monopoly, it gains more from the information". Roger (9/5) also reminded participants that IPR have a temporal and geographical limit and that perpetual and worldwide patents, trademarks or plant breeders' rights do not exist. He also noted that a patent was not an authorization for commercialization, although Steane (11/5) pointed out that the aim with many biotechnology patents was often not commercialization but to stop others using the technology. Saunders (10/4), on the same subject, wrote that ownership of a patent in a particular country is "a negative right. It permits the owner to exclude others from practising the invention. A patent does not act to permit the patent owner to do anything".

Saunders (10/4) also gave good insights into some of the commercial considerations behind patenting, including:

- there are two reasons why someone would apply for a patent in a developing country: i) to make a profit – which requires two elements seldom present together in developing countries, i.e. a good market for the invention and the means (financial resources and a functional legal system) to enforce the patent; and ii) to prevent the developing country making infringing products (only the largest international corporations would patent for this reason);
- making a profit from a patent requires the applicant having funds to i) obtain or license the patent; and ii) enforce it;
- licensing of patents is less attractive in developing countries as the market may be small and patent enforcement may be expensive, slow or uncertain.

6.2.1.2 Companies from developed countries patenting genetic material from developing countries

One of the most controversial impacts or consequences of the current IPR system, which was also raised in the crop sector conference, is that "there are many instances where genetic resources from developing countries were granted patents in developed countries, often without the knowledge and consent of the owners of such resources in developing countries" (Srinivasan, 22/3). The term "biopiracy" is often used to describe this phenomenon. The frustration and anger the issue raises come from the perceived appropriation (or "sack" as Ferry (23/3) called it) of the resources in developing countries by parties in developed countries; the apparent lack of adequate mechanisms to prevent it happening (Vasquez, 3/5) and the failure to both acknowledge the contribution that farmers in developing countries have made to the resources and to share the benefits with them.

Ageeb (21/3) provided some examples where biotechnology companies had reputedly patented genetic material of commercial value in developing countries and made use of existing indigenous knowledge of native peoples in these countries. One particular case discussed in some detail (e.g. Srinivasan, 26/3) was that of the United States patent 6,040,503 awarded in March 2000 for beans that expand (pop) upon heating, involving crosses of Nuna beans, from the Andean region of South America, with the common bean (the patent can be seen on the web by searching on the patent number at 164.195.100.11/netahtml/srchnum.htm). Srinivasan (22/3) expressed reservations about the patent and argued that stricter rules on awarding IPR should be devised. He reported a range of concerns, including the use of genetic material (from a public gene bank) freely provided by Andean farming communities for conservation purposes and the fact that the indigenous people had prior knowledge of the popping characteristics of the Nuna bean (Srinivasan, 22/3 and 26/3). Lin (23/3) argued instead that the variety was novel and the patent was defensible. He emphasized that the patent claims did not directly concern the Nuna bean but only the results of crossing them with the common bean, producing a novel variety adapted to the more temperate climate in the United States.

Gallego-Beltran (30/4) claimed that biotechnology companies used universities as a "middleman" to gain easier access to valuable biological material. He argued that some research collaborations between institutions in developed and developing countries resulted in researchers "sometimes voluntarily sometimes not, acting just as sample collectors and couriers from the south to the north" and that the "capturing" of the biological material was often one of the main motives for the collaboration. Although from Latin America, a couple of participants in Africa (Olutogun, 4/5; Wingfield, 4/5) identified with these experiences and argued that they also reflected events in their continent. Ndegwa (2/5) emphasized that the situation described by Gallego-Beltran (30/4) occurred frequently in developing countries and was getting worse over time.

Both Ndegwa (2/5) and Ageeb (21/3) emphasized the need for action by developing countries, as "countries of the biologically-rich regions should protect their natural genetic resources and the indigenous knowledge of their native peoples" (Ageeb, 21/3). Ndegwa (2/5) argued that the starting point should be investments by governments and institutions in building the necessary intellectual property and legal capacity, to "ensure that they are not ignorantly short-changed by developed countries or institutions. It is futile to fight a system that one does not understand". She noted that, in the current situation, most universities in developing countries will sign a collaborative research agreement without understanding the IPR provisions it contains, whereas those in developed countries will have a legal/IPR unit to look at any agreements before they sign.

Participants seemed to agree that, until now, there had been little or no sharing of the economic benefits from biotechnology developments derived from genetic resources of developing countries (Ageeb, 21/3; Ferry, 23/3; Srinivasan, 27/3; Vasquez, 3/5). Ferry (23/3) argued that big companies had earned a lot of money from these genetic resources and that they should return part of it to the poor farmers in these countries. Ageeb (23/3) pointed out that in the current biotechnology era, the working unit is the gene rather than the organism and that if rare, valuable genes (which he termed "green gold") from developing countries were used then the countries should ask for compensation. Srinivasan (27/3) proposed that, to secure some of the benefits, an assessment be carried out of the value of genetic resources from different countries so that, based on factors such as the amount of germplasm contributed by developing countries, a percentage of the value of a crop in a developed country could be shared with and used to establish strong IPR systems in, developing countries.

Srinivasan (7/5) pointed out the economic damage this issue may cause since "if patents are given in developed countries to products from certain regions in developing countries, those regions could experience substantial negative impacts in terms of reduced exports". To illustrate the point, he raised the specific case of the United States patent 5,663,484 granted in 1997 on Basmati rice lines and grains to a company based in Texas. Since the owner of the patent could call the rice "Basmati", both within the United States and when exporting, he argued that this could damage the traditional and economically important export of Basmati rice from India and Pakistan throughout the world (including to the United States).

It might be expected that the Convention on Biological Diversity could contribute to solving problems regarding the protection and use of biodiversity (Vasquez, 3/5), as it provides "a legally binding framework for conservation and sustainable use of biodiversity while seeking to establish benefit sharing mechanisms" (Ndegwa, 2/5). In addition, Article 16 (5) of the Convention states that parties to the CBD shall cooperate to ensure that patents and other IPR "are supportive of and do not run counter to its [CBD] objectives" (Van Overwalle, 4/5). However, Wollny (21/3) argued that, with respect to their plant genetic resources, the CBD had failed to ensure that local and indigenous communities had been protected and provided with benefits. Participants also argued that it favoured developed rather than developing countries (Lettington, 20/3; Ndegwa, 2/5). Steane (11/5) also pointed out that one of the major biotechnology patenting countries (the United States) had not yet ratified the CBD and so was not bound by it. The potential contribution of another international agreement, the International Undertaking on Plant Genetic Resources for Food and Agriculture, to this question was also mentioned (Lettington, 20/3; Wendt, 11/4).

Central to this whole issue is the question of what can be patented and the problem of distinguishing between discovery and invention. As Lettington (20/3) pointed out, this is a huge problem, particularly in developed countries and, in relation to biological material, clarification is needed on to what extent something that previously existed can be "invented". In this context, some participants found it hard to accept that genetic resources of developing countries could be treated as inventions rather than discoveries (Ageeb, 21/3; Fakir, 21/3; Srinivasan, 22/3). Graff (12/4) argued that one of the failures of IPR systems was, indeed to define what is patentable, i.e. "to clearly demarcate between what should be placed in the country's public pool of human knowledge (or genetic resources) and what can be rightfully defended within the borders of the country as a private piece of knowledge or technology (or genetic resource)". He pointed out that policies on the definition of what is patentable in the field of agricultural biotechnology differ from country to country and within each country, they vary over time. He suggested, using the United States as an example, that it might be difficult to make specific changes to the definition of what is patentable.

6.2.1.3 Impact on agricultural research

This issue was raised frequently throughout the conference. Participants suggested that IPR had influenced the quality of agricultural research carried out, as well as the nature of research collaborations between public and private institutions, between developing and developed countries and even between private companies.

a) Quality of research

Most comments on this subject argued that IPR slowed down research collaborations and the flow of knowledge between interested research parties and that they therefore had a negative impact on the quality of research carried out. Wollny (21/3) reported that restrictive national policies on international research and exchange of animal genetic resources, introduced because of IPR issues, had in some cases prevented genuine research being carried out. Glover (28/3) referred to a paper by Professor Barton published in Science (2000, volume 287, pages 1933-1934) which argued that one of the three problems caused by applying current United States patent law was “the tendency for patents to complicate and deter useful and desirable follow-on research, which can occur when patents are granted on ‘broadly useful information and technology’ or ‘fundamental research processes’”.

Fakir (29/3) agreed with the arguments in an article in Science (1998, volume 280, pages 698-701) that, unlike the “tragedy of the commons” (where having too many owners can result in overuse of a resource), the complex proliferation of patents in research was leading to the “anticommons”, where many owners have the right to exclude others and the resource then becomes underused, i.e. that research and innovation are stifled rather than stimulated by the multitude of patent holders. This point was supported by comments of Lin (27/3), who noted that patenting hindered the flow of knowledge and genetic material in private industry, often leading to biotechnology companies abandoning promising lines of agricultural research as they lacked sufficient “freedom to operate” because of patents held by a competitor. Ndegwa (2/5) and Tripathi (2/5) also concluded that IPR did not encourage innovation.

Roger (9/5), however, argued that “a patent provides transparent information about scientific knowledge and by limiting patentability I fear that transparency will be lost”. De Lange (11/5) disputed this, suggesting that “scientists working on something that may be patentable, will share less knowledge with colleagues in order to prevent someone else stealing the idea and patenting it”. Roberts (14/5) disagreed with De Lange’s proposition, arguing that many scientists work in the private sector and once a patent application is filed or published, companies will allow research results to be published whereas, in the absence of patenting, they would be more cautious and try to keep everything secret.

b) Private-public sector research collaborations

Roberts (14/5) pointed out that money for public research is scarce whereas research in the private sector is increasingly important and that IPR are an important incentive for private sector research. However, the effect of IPR on crop improvement is to restrict the flow of both knowledge and improved germplasm between the private and public sectors, which is a particular disadvantage for poor farmers who previously benefited from this flow in the “green revolution” (Glover, 26/3). Apart from the desire to cut public expenditure (Cummings, 9/4), public-private partnerships are therefore often encouraged in order to tap, for the benefit of public goods research, “the knowledge and technologies developed in the private sector” and that this was the trend with international agricultural research centres (Immonen, 2/5). She, however, expressed concerns about such partnerships, as the collaboration agreements may require confidentiality and may restrict sharing of ideas with the greater research community – something which might ultimately damage the public sector research effort (Immonen, 2/5). Ferry (11/4) urged that public laboratories, working on questions of interest to developing countries, should negotiate contracts with the private sector that fit with their public obligations or else they should refuse them. Immonen (2/5), in a similar vein, argued that where they had bargaining power, public organizations should avoid exclusive collaboration agreements with the private sector and retain their rights to information sharing.

c) Developed-developing country research collaborations

Participants also discussed the impact of IPR on the nature of research collaborations between developed and developing countries. Lettington (20/3) argued that patenting in the agricultural sector broke the traditional access and benefit sharing (ABS) system previously implicit in agricultural research (i.e. that developing countries provide free access to their genetic resources and receive the benefits of the research in developed countries for free) and replaced it with an asymmetrical system where access to genetic resources was still free but the benefits of research were not, i.e. “all A and no BS”. He noted that the CBD, which recognizes the sovereign rights of states over their natural resources, was a reaction to this situation since parties should now also pay for access to genetic resources.

Gallego-Beltran (30/4) expressed concerns about some unbalanced developed-developing country research collaborations which result in developed countries gaining access to valuable genetic resources in developing countries but where the main, if not all, research activities are carried out in developed countries, so the scientific return for developing countries is minimal. Ndegwa (2/5) emphasized that because of IPR and the increasingly dominant role of the private sector, free exchange of information was becoming a thing of the past and that the universities in developing countries (unlike their counterparts in developed countries) had not yet adapted to the new reality. She summarized the current situation as follows, “you have the private sector who look at scientific information in terms of dollar value, the northern universities who are maximizing the moment by tending towards the 'private' in IPR dealing....and the southern universities who are doing (or willing to do) science in the philosophy-of-science way but who are resource poor”.

6.2.1.4 Whether IPR favour the interests of developed countries and the biotechnology industry over those of developing countries

Some participants argued that the very nature of the current IPR system discriminated against developing countries because it unfairly places a greater value on biotechnology outputs, generally produced in developed countries, than on genetic resources (often used to create the biotechnology products) and contributions from communities, usually in developing countries (Lettington, 20/3; Srinivasan, 22/3 and 27/3; Granda, 28/3; Ferry, 10/4; Vasquez, 3/5).

Some participants went further and argued that IPR were really used by developed countries to dominate and to continue their exploitation of developing countries (Ashton, 12/4(2), Olutogun, 4/5). For example, Ashton, 12/4(1) suggested that the playing field was strongly biased in favour of developed countries and that IPR were merely instruments of economic policies that “entrenched colonialism in a more modern economic idiom”. Others emphasized the specific role that MNCs from developed countries played, arguing that they used IPR to entrench corporate power and to create market monopolies (Lettington, 20/3; Ageeb, 21/3; Fakir, 21/3). Lettington (20/3) suggested that, in addition to IPR, they also used other mechanisms, such as legal contracts with farmers, for the same purposes, or genetic use restriction technologies “that essentially constitute a regulatory system that bypasses IPR and government authority”.

To illustrate the enormous gap between developed and developing countries regarding IPR, as well as the concentration of power among a handful of biotechnology companies, Granda (28/3) referred to statistics from the 1999 UNDP Human Development Report which showed that developed countries hold 97 percent of all patents worldwide; that over 80 percent of patents granted in developing countries are owned by residents in the developed world and that the top five biotechnology companies control over 95 percent of gene transfer patents. Given that the vast majority of patents granted in developing countries are owned by parties in developed countries, some participants argued that the main aim of the pressure exerted on developing countries to harmonize or introduce national IPR legislation, as well as to build up their capacity in this area, was to ensure that MNCs and developed countries would be able to enforce their patents granted in developing countries (Ndegwa, 2/5; Vasquez, 4/5).

Roger (9/5) emphasized however that, for economic reasons, only a minority of biotechnology patents were granted in developing countries compared to the developed world. As Saunders (10/4) pointed out, when a company considers where to apply for a patent it will first assess the markets for the invention, weighing up the costs against the prospective return and the likelihood and timing of the return. He suggested, as an example, that for an invention related to forestry/paper, a company might therefore only apply in “Canada, Scandinavia, Japan, United States, Brazil and perhaps Myanmar and Thailand” or, depending on the financial resources available, in a subset of these countries. Roger (9/5) underlined that the scientific content of a patent is nevertheless available worldwide and it can be used freely in all countries where the patent has not been granted. As Ndegwa (3/5) explained, “a patent owner can ONLY enforce his rights in countries where that protection has been sought and granted. This means that if a USA inventor seeks and obtains a patent in the USA, but fails to do so in Venezuela, he cannot enforce his rights in Venezuela, even though the latter is a member of the WTO as the USA is. In fact, anyone can exploit the invention in Venezuela without infringing on the rights of the patent holder”.

6.2.1.5 Avoiding or alleviating the negative impacts of the current IPR system

From the preceding part of this summary (Sections 6.2.1.2-6.2.1.4), it is clear that most comments in the conference highlighted the negative impacts of the current IPR system on developing countries, on issues such as agricultural research or ownership of genetic resources and knowledge. In Section 6.1.3 of the Background Document, it was suggested that participants should discuss how the negative impacts or consequences of IPR for food and agriculture in developing countries could be avoided or alleviated. Participants seemed to have two different approaches to this question. The first was to call for a reassessment of the current IPR system and to propose a better one. The second approach was to accept the current system and, instead, to seek strategies to minimize its negative impacts.

a) Reconsider the current IPR system and propose a better one

Lettington (20/3) probably provided a good summary of this reasoning, i.e. “there must be a serious reassessment of the IPR system as applied to the agricultural sector - it is not meant to be applied to this and it is creating asymmetries that impact negatively on the most vulnerable”. Participants proposed different kinds of “reassessments” of the system. Ferry (23/3) emphasized the ethical dimension to the question and argued that the system should be changed so that, instead of giving similar rights to the North and South, it should give more to the South, to compensate them for previous wrongs regarding genetic resources and because of their poverty. Srinivasan (22/3) highlighted the need for the system to address the incompatibility between IPR and farmers’ rights (i.e. rights arising from the past, present and future contribution of farmers in conserving, improving and making available the agricultural genetic resources). He proposed that, as a pre-requisite, the concept of ownership of genetic resources should be eliminated. He also called for “flexible IPR”, which would guarantee the right of farmers in developing countries to continue with traditional practices such as on-farm seed saving or swapping grain for seed.

Ashton, 12/4 (1 and 2), supported by Gallego-Beltran (30/4), argued that claims to legal ownership over life forms were inherently flawed. He therefore proposed that “the entire intellectual property regime needs to be rethought and renegotiated” and that a range of possible alternatives existed (Ashton, 12/4(2)). Currently, as explained in the Background Document, patents on specific genes usually extend to the plant into which the genes are inserted. He described one alternative, based on the “principle of proportional ownership”, where the value of any added genetic component would only be a proportion of the whole and where a significant proportion of ownership would remain with the traditional seed holders and developers. The concept was supported by Steane (11/5) who, however, warned that many developed countries would not welcome a re-evaluation of the current IPR system.

b) Accept the current IPR system and pursue strategies to minimize its negative impacts

Even though they might consider the current system to be unjust, some people felt that the best approach was to accept it, while looking for ways to alleviate its negative impacts. The dilemma can be reflected in the words of Ndegwa (2/5): “the stage has been set; the possessive adjective 'my' is replacing ‘our’ day by day. Even if a reverse of the current state was thinkable, we cannot stand by and wait for an IPR-free world. We have to make the best out of the current situation. Governments and institutions in developing countries have to invest in building the necessary IPR and legal capacity”.

Patenting of the developing world’s indigenous knowledge and resources by companies in the developed world was one of the negative impacts commonly raised in the conference (see Section 6.2.1.2). Documentation of the indigenous resources to protect them was one concrete defence action proposed by participants. Srinivasan (22/3) suggested that international organizations should help people in developing countries to patent indigenous technologies in developing countries. Wendt (11/4) also maintained that official registration of already existing (traditional) resources was one of the main features behind the creation and implementation of efficient and just IPR systems.

Another strategy proposed to reduce the negative impacts was to fine tune the way current patent legislation is applied. Glover (28/3) described three modifications proposed by Professor Barton in an article in Science (2000) for the United States patent system, i.e. to raise the standards of patentability of an invention; to ensure that patents do not restrict useful follow-on research and finally, to make it easier to legally challenge invalid patents. Glover (28/3) suggested that if such reforms were applied internationally they might help to improve the patent system by providing a better balance between private and public interests and by addressing some of the concerns raised in the Background Document and throughout the conference. Srinivasan (2/4) proposed that the adverse effects of IPR on innovation could be reduced by “establishing smooth, easy, and less expensive means for licensing”, a point also made at a workshop held recently in this area (Lin, 9/4).

Roger (9/5) also provided a reminder that countries had a choice of protection mechanisms available and that some were stricter than others. He emphasized, for example, that the breeders’ exemption clause in the PVP system based on the UPOV Convention ensures that protected varieties remain freely available for further breeding, whereas with other systems this might not be the case.

In the conference, participants also argued that IPR favour the interests of developed countries and a handful of biotechnology MNCs over those of developing countries (see Section 6.2.1.4). One of the reasons for the extensive merging of biotechnology companies has been their need to accumulate IPR portfolios large enough to allow them to produce crop varieties that can be commercialized. At a meeting in February 2001, Dr Toenniessen of the Rockefeller Foundation pointed out that the international agricultural research system has no such IPR portfolio, so the traditional flow of improved plant materials through the system is breaking down (Glover, 26/3). He therefore proposed that, to rectify this, the agricultural research institutions in the public sector should begin to pool their IPR into a professionally managed IPR portfolio designated to serve poor farmers. Graff (12/4) reported that, similarly, one of the recommendations of a recent workshop was that agricultural research and development for developing countries needs a “multilateral office of technology transfer” to gain and manage access to IPR as well as to manage the internal exchange and pooling of their own IPR. Lin (27/3) felt that private industry might also support the suggestion of a “clearing house for essential technologies”, to enable a freer flow of knowledge and materials.

Van Overwalle (4/5) emphasized the important role that governments in developed countries could play in redressing some negative impacts of the dominating IPR position of developed countries.

He argued that governments should stimulate their universities, research institutes and private companies to provide access to and transfer of, genetic technology and transgenic seeds subject to patents, to developing countries free of charge if the technology or seeds are only going to be used for local, small scale commercialization and marketing. Similarly, Granda (7/5) argued that GM technology should be made available to the public domain for crops that do not generate an economic return.

If private industry developed biotechnology products that were both important for hunger in developing countries and protected by IPR, Ferry (11/4) argued that a media campaign could lead to the companies providing the products at a reasonable price, as had been done in South Africa for medicines to fight AIDS. He argued that the campaign could be justified on the basis that world hunger and food security are a question of life and death. On the same subject, Srinivasan (22/3) suggested that deals between private companies and international organizations to supply the products at a reasonable price should be encouraged.

6.2.1.6 National IPR legislation in developing countries

During the conference, participants raised some specific issues about IPR legislation in developing countries, i.e. the trend towards harmonization of national IPR legislation, as well as infringement and enforcement of IPR legislation.

a) Harmonization of national IPR legislation

IPR regimes in developing countries have tended to be weaker than in developed countries. In recent years, however, steps have been made towards increased harmonization of national IPR legislation. In this context, a key element is the WTO agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) (Ndegwa, 2/5 and 3/5). This international agreement is binding on all WTO members and sets certain minimum standards for the implementation of IPR at national level and in this way promotes harmonization of national IPR regimes (Ndegwa, 3/5; Vasquez, 4/5).

As the agreement has many important implications for developing countries and has been the source of much controversy, it was not surprising that there were some specific comments about it. Some participants suggested that the TRIPS Agreement was promoted by the United States in order to globalize patent laws (Glover, 28/3; Vasquez, 3/5 and 4/5). Ndegwa (2/5) argued that agreements such as TRIPS favoured developed rather than developing countries and the private rather than the public sector. Vasquez (3/5) maintained that it would exacerbate inequities in the world and that it should be reviewed or dropped. Lin (3/5), however, highlighted that national governments had some flexibility when applying provisions of the TRIPS Agreement, i.e. that

- plants and animals and biological processes for the production of plants and animals could be excluded for patentability;
- inventions which threaten public order or morality could be excluded for patentability (although Roger (9/5) thought it would be difficult to determine which patents these might be); and
- although plant varieties have to be protected, this may be done by patents and/or effective *sui generis* systems (such as PVP).

Tripathi (14/5) felt that the introduction of IPR systems (such as PVP) for plant varieties, due to the TRIPS Agreement, would harm farmers in developing countries because of the associated financial costs and the potential risk of reducing plant diversity. She also suggested, based on studies in countries such as the United Kingdom and Brazil, that the introduction of PVP would lead to consolidation of the seed industry (Tripathi, 2/5).

b) Infringement and enforcement of IPR legislation in developing countries

Saunders (10/4) provided some economic insights into this topic, explaining that “a patent holder demanding “too high” a price creates a market for infringers. An infringer succeeding too well at infringement invites the patent holder to enforce. However, infringement is favoured in a developing country by the increased cost of enforcement by a distant patent holder seeking to limit price erosion in a small market”.

The recent much-publicized case in Canada where Monsanto successfully sued a farmer, Percy Schmeiser, for illegally planting the company's patented GM canola seeds, despite the farmer’s insistence that the seeds ended up on his farm by accident (e.g. Srinivasan, 2/4; Cummings, 9/4), led to some comments about enforcement of IPR legislation in developing countries. Hollis (9/4) suggested that, if it had sufficient political and economic weight, a seed company pursuing a similar strategy in a developing country could increase its monopoly on the market and that the dependency created could put farmers at a disadvantage. Srinivasan (2/4) argued that a similar judgement involving farmers in developing countries could lead to a backlash against biotechnology and could “have a dampening effect on the development of indigenous biotechnologies appropriate to a particular crop/region/country”. He suggested therefore that there was a need for differential standards of IPR enforcement and protection in various countries, especially in the food and agricultural sector, which was shown by findings that patents in developing countries (India) have a much lower value than in developed countries and that the value of patents in agriculture was lower than in various other industries.

Wendt (5/4), however, highlighted the problems that seed companies face in Latin America, suggesting that a lot of farmers exploit exemptions in the PVP laws to cultivate and commercialize protected varieties. He therefore argued that if the companies “don’t pursue violations of their IPR they are soon going to lose control of what is happening with their new varieties and won't be able to sell them”.

Wendt (11/4) also noted that, in their national legislation, several Latin American countries explicitly addressed topics such as farmers’ rights and access to and sharing benefits from genetic resources and traditional knowledge. He suggested, however, that there were still difficulties in implementing them and that international organizations, such as WIPO or FAO, could help by creating broader awareness about the importance and problems of protecting IPR and traditional resources.

6.2.1.7 Multiplicity of patents

As pointed out in the Background Document, there are some special concerns about the consequences of the current situation where many steps of patented technologies may be required for the development of a biotechnology product. For example, development of a GM insect-resistant crop may involve using a protected plant variety as well as patents related to the selected marker gene and the insecticidal gene, the transformation technology, the promoter and other regulatory elements needed for adequate gene expression in the plant cells (Srinivasan, 7/5). The multiplicity of patents embedded in a biotechnology product can make the product expensive (Srinivasan, 22/3) and means that even a single IPR holder can block commercialization of a product (Srinivasan, 7/5). In addition, it may give private companies considerable power because of the strategy of building up “defensive patent portfolios”, often involving trivial “inventions” (Glover, 28/3). The costs associated with transacting IPR can be quite substantial “as a result of broadly or poorly defined property rights in individual patents and single products involving technologies claimed by multiple IPR holders” (Lin, 9/4), and can be a major constraint to innovation (Fakir, 29/3).

6.2.1.8 Plant variety protection

When considering particular IPR, most discussion in the conference focused on patents. However, some specific points were also made about PVP (also known as plant breeders’ rights). PVP laws are generally based on the UPOV Convention, signed in 1961 and revised in 1972, 1978 and 1991 (Roger, 9/5). To be granted protection, a variety must fulfil criteria governing novelty, distinctiveness, uniformity and stability (Archak, 7/5; Roger, 9/5), although Archak (7/5) pointed out that it was not easy to define distinctiveness.

Wendt (11/4) noted that, in Latin America, PVP was more important than patents. He pointed out that “there are two very important points in which PVP differs from patents: first, the “farmers’ privilege”, which allows farmers to save seeds for their own use and, second, the “breeders’ exemption” which allows any plant breeder to use the protected variety as a basis to develop a new one without previous consent of the owner of the original protected variety”. He concluded therefore that PVP provided greater access to genetic material, a point supported by Roger (9/5) and Steane (11/5).

6.2.1.9 Livestock sector

As pointed out by Steane (11/5), the majority of messages in the conference dealt with plants, where there is already considerable experience of IPR. He noted that the role of IPR for animals is currently limited but the implications are dramatic. Ageeb (23/3) argued that biotechnology advancements were slower in livestock research than in crops or medicine, but predicted that, “in the near future, the genetic materials of tropical livestock will effectively contribute to the biotechnology revolution”. Wollny (21/3) questioned whether a policy claiming IPR to protect animal genetic resources would have any practical benefits now for farmers in developing countries as most of the genetic material is “of no known use or function and has no present market value”. He suggested therefore that standards for maintaining the resources should be applied and, in the future, when biotechnology discoveries are made, that policy-makers could develop adequate access and genetic material transfer agreements. Finally, Steane (11/5) pointed out that whereas plant sector policy-makers have patent or PVP options available, there is currently no equivalent of PVP for livestock so the problems associated with the definition of what is patentable may have even greater importance for the livestock sector.

6.2.2 Name and country of participants with referenced messages

Ageeb, Abdelgadir. Canada
Archak, Sunil. India
Ashton, Glenn. South Africa
Cummings, Claire. United States
De Lange, Wytze. Netherlands
Fakir, Saliem. South Africa
Ferry, Michel. Spain
Gallego-Beltran, Juan. Colombia
Glover, Dominic. United Kingdom
Graff, Gregory. United States
Granda, Willy Valdivia. United States
Hollis, Kevin. United States
Immonen, Sirkka. Italy
Lettington, Robert. Kenya
Lin, Edo. France
Ndegwa, Rose. Kenya
Olutogun, Olusanya. Nigeria
Roberts, Tim. United Kingdom
Roger, Pierre. France
Saunders, Thomas. United States
Srinivasan, Ancha. Japan
Steane, David. Thailand
Tripathi, Ruchi. United Kingdom
Van Overwalle, Geertrui. Belgium

Vasquez, Chela. United States
Wendt, Jan. Chile
Wingfield, Brenda. South Africa
Wollny, Clemens. Botswana

CHAPTER 7. HUNGER AND FOOD SECURITY CONFERENCE

CAN AGRICULTURAL BIOTECHNOLOGY HELP TO REDUCE HUNGER AND INCREASE FOOD SECURITY IN DEVELOPING COUNTRIES?

7.1 BACKGROUND DOCUMENT

In the public debate about biotechnology in general (and genetically modified food in particular), it has been argued by different parties that biotechnology either will or will not help to reduce hunger and increase food security in developing countries. The aim of this conference is to allow a more detailed and comprehensive discussion of this topic. The aim of this document is to provide some brief background to the subject as well as to mention some of the factors that should be considered in the conference.

The first edition of the State of Food Insecurity in the World, published by FAO in October 1999, provided a recent update on the status regarding hunger in the world (for those with access to the Web, the report can be found at www.fao.org/NEWS/1999/991004-e.htm). It estimated that in 1995-1997 there were roughly 790 million undernourished people in developing countries (and 34 million in developed countries), i.e. whose food intake was insufficient to meet basic energy requirements on a continuing basis. The majority (524 million) was in Asia, including 204 and 164 million in India and China, respectively, while there were 180 million undernourished in sub-Saharan Africa.

The report also examined changes from 1980 to 1996 in the proportion of undernourished people in a selection of countries, to try and understand the factors determining such changes. The analysis highlighted, as other reports have previously done, that many different demographic (e.g. changes in population size or the degree of urbanization), environmental (e.g. degradation of land), economic (e.g. changes in Gross Domestic Product), social (e.g. road infrastructure, literacy) and political (e.g. war, economic boycotts) factors may affect the degree to which particular population groups are vulnerable to poverty and hunger.

The global population size is currently six billion, and it is rising rapidly. By the year 2020, it is expected to reach 7.5 to eight billion. Where will the food come from to feed these additional mouths? Can it be provided by "conventional" methods of plant, animal or fish production alone? An important factor to be considered is that much of the land currently used to produce food is being degraded - largely due to overgrazing, poor farming practices and deforestation. To counterbalance this, one might ask whether there is much additional land that can be brought into use for food production. There is some scope for extending the land area used for production in Africa and South America, although this may be at the expense of forestry and wildlife. For Asia there is little scope for extension of the land base. Under these conditions, will it be possible to provide enough food for the additional billions, *without* using biotechnology in plant, animal and fish production? Is biotechnology indispensable if we are to successfully meet the challenge of an increasing world population?

However, the problem of hunger is complex and does not just depend on the amount of food produced. Currently, enough food is produced globally to feed all its inhabitants. Nevertheless, around 15 percent of them are undernourished. Is the unequal distribution of resources and food a greater threat to world hunger than the sheer quantity of food produced? Biotechnology may increase the amount of food produced but will it affect the key problems of unequal access to food? Is it possible that we may end up in the situation where the amount of food produced globally increases, with the help of biotechnology, but so also does the number and proportion of hungry people?

Comments from Professor Mazoyer in a recent FAO publication, The State of Food and Agriculture 2000, might be of relevance in this context. He wrote “After 50 years of modernization, world agricultural production today is more than sufficient to feed six billion human beings adequately. Cereal production alone, at about two billion tonnes or 330 kg of grain per caput/year and representing 3 600 calories per caput/day, could to a large extent cover the energy needs of the whole population if it were well distributed. However, cereal availability varies greatly from one country to another: more than 600 kg per caput/year in the developed countries, where most is in fact used as animal feed, but fewer than 200 kg per caput/year in the poorer countries. Moreover, within each country, access to food or the means to produce food is very uneven among households. Consequently, in many countries, large segments of the population do not have enough food. And the large majority of the 830 million chronically undernourished are in the poor peasant farming community. World food security, therefore, is not an essentially technical, environmental or demographic issue in the short-term: it is first and foremost a matter of grossly inadequate means of production of the world's poorest peasant farmers who cannot meet their food needs. It is also a matter of insufficient purchasing power of other poor rural and urban consumers, insofar as the poverty of non-farmers is also a product of rural poverty and migration from the land."

Another factor that might be considered for discussion during the conference is that agricultural biotechnology has primarily been driven by private industry for farmers in developed countries. The products developed so far have, with few exceptions, not been targeted towards poor farmers in developing countries. Will biotechnology, which can potentially increase the efficiency and quality of food production, provide tools to aggravate inequalities in the world? If trade barriers are progressively reduced, through organizations such as the WTO and export of food from developed to developing countries becomes easier and more commonplace, is it possible that biotechnology will make this trade more profitable, thus creating or increasing the dependency of developing countries on developed countries for food?

Discussion in this conference should also address whether particular biotechnologies have especially high (or low) potential to reduce hunger and increase food security in developing countries, or whether the application of biotechnology within specific agricultural and food-related sectors (crop, forestry, animal or fisheries) or within specific regions of the developing world can have greater (or lower) impact on hunger and food security in developing countries.

For those wishing to be reminded of the types of biotechnologies currently available in the four sectors, the Background Documents of the first four conferences may be useful. For the crop sector, brief descriptions of genetic modification, micropropagation and biotechnologies based on molecular markers were provided. For the forestry sector, brief descriptions of genetic modification and biotechnologies based on vegetative reproduction or molecular markers were provided. For the livestock sector, reproductive biotechnologies (embryo transfer, cloning, etc.) and DNA-based technologies in animal health, animal nutrition and growth and animal genetics and breeding were described. For the fisheries sector, brief descriptions of molecular marker biotechnologies, induction of polyploidy, sex-reversal and creation of single sex fish groups, hybridization, selective breeding, freezing of male gametes, genetic modification and DNA-based technologies for fish health were provided.

7.2 SUMMARY DOCUMENT

Coming after the first four conferences, dealing with crops, forestry, animals and fisheries respectively, this was the first conference not dedicated to a single agricultural or food sector. Interest in the theme of the conference was high, based on the number of people registered and of messages posted. The level of participation was the highest of the six conferences, with 18 percent of those registered submitting at least one message.

The main impetus behind choice of this theme for the conference was to allow more in-depth discussion of one of the factors considered in previous conferences (especially on the crop sector) to have an impact on the appropriateness of agricultural biotechnologies, i.e. their potential role in increasing food security and reducing hunger in developing countries. Certain aspects of discussions concerning biotechnology have been quite polarized. One of the most hard-fought debating issues regarding biotechnology and especially GM crops, is whether they can be of potential value for food security and hunger in developing countries. Taking two divergent viewpoints, at one end it is argued that biotechnology has great potential, the world’s population is increasing steadily (and almost all growth is in developing countries) and that biotechnology will enable mankind to increase food supplies to feed the world’s new inhabitants. At the other extreme, it is argued that biotechnology is primarily in the hands of private industry, that the private industry has to make profits and lacks real interest in the world’s poor, but will use any marketing opportunities to promote the use of biotechnology.

In the conference, when discussing specific applications of agricultural biotechnology, participants tended to focus on the crop sector. This even led to some individuals (e.g. Steane, 5/12; Jeggo, 12/12; Donkin 13/12) suggesting that the livestock sector had been wrongfully neglected. Impacts of biotechnologies in the fisheries or forestry sectors were unfortunately not discussed. Although the range of available biotechnologies is quite wide, there tended to be most emphasis on a single biotechnology - genetic modification. In particular, there was considerable discussion of one GM variety, the so-called “golden rice”, into which three foreign genes have been introduced so that it produces provitamin A.

On many specific points of debate, considerable differences of opinion were expressed by various parties and there was often a social-political dimension to such differences. For example, Fenning (15/12(1)) referred to messages posted with “dogmatic and strident tones” and wrote that the conference was affected by “unhelpful political rhetoric”. Given the theme of the conference, however, it was probably impossible to expect political and ethical concerns to be ignored and as Ashton (12/12) argued “this debate cannot be separated into scientific and political aspects. The two are inseparable”.

People’s perception of the role or impact of biotechnology on food security and hunger, often depends on their vision of how food security may be achieved and how hunger may be best alleviated. For example, Robert (22/11) argued that there were two main viewpoints concerning the route to food security in developing countries. The first solution involves community access to land, preservation of agricultural diversity and ecologically based land management while the second involves increasing the levels of exports from developing countries so they have the purchasing power to ensure their food security. He suggested that people who believed in the first viewpoint would rank biotechnology as a very low priority while those who believed in the second viewpoint would support the use of biotechnology to increase exports and the efficiency of agricultural production.

A large number of topics were covered in the six and a half weeks that the conference lasted. In addition, some participants provided references in their messages to material published on the World Wide Web so that others (with access to the web) could pursue these topics further. A considerable amount of information directly or indirectly relevant to this debate is freely available on the web.

In Section 7.2.1 of this document, we have attempted to summarize the main elements of the discussions under a number of main themes. Specific references to messages posted, giving the participant's surname and the date posted (day/month of the year 2000), are included. The messages can be viewed at www.fao.org/biotech/logs/c5logs.htm. In a few cases, where individuals posted more than one message on a single day, they can be differentiated by the order in which they were posted (e.g. Rosset, 10/11(1) indicates the first message posted by Peter Rosset on 10 November). Section 7.2.2 gives the name and country of the people that sent referenced messages.

7.2.1 Discussions in the conference

As befitting the theme of the conference, participants paid a lot of attention throughout the conference to the causes of hunger and food insecurity in developing countries and the potential impact and relative importance of using biotechnology against these problems.

7.2.1.1 The causes of hunger and food insecurity in developing countries

There was wide agreement among participants that hunger and food security are complex issues and that their causes (and potential solutions) were economic, social and political, as well as technical (e.g. Fenning, 6/11; Greyling, 20/11; Glover, 21/11). There seemed, however, to be some differences in the relative importance participants attributed to the various causal factors.

Rusch (8/11) provided a clear description of food security, saying that "food security (in peace time) is about a community's ability to provide its food requirements. This can be done by producing food within the community, or by being able to buy food from outside the community's area". He then argued that the ability to produce food within the community "depends on the level of skills and the natural resources. If either or both of these are not adequate, food security may be low, if food cannot be bought by the community".

Rosset (9/11) suggested that the underlying causes of lagging productivity, hunger and poverty in developing countries were, first and foremost, structural and policy-related in nature rather than due to genetic constraints that could be alleviated by biotechnology. Koudandé (9/11) supported this viewpoint, emphasizing the importance of soil and water management. Immonen (23/11) reminded us, however, that in the coming decades there will be a serious need to produce more food, probably through higher productivity per land area unit.

Hongladarom (13/11) emphasized the fact that hunger is linked to other problems, especially poverty, and consequently, to reduce hunger, poverty has to be reduced too. This point was also made by Madalena (5/12), i.e. that "hunger is due to the fact that people do not have the money to buy food". Carvalho (3/11) evoked this very well with his description of the hungry urban dweller, faced with the wide range of foods available in the supermarkets but lacking the money to buy them.

The socio-political context was emphasized by Fakir (11/12) who said that food insecurity was least about good technology and achieving higher yields but instead was "fundamentally, a reflection and symbolism of the inequities that exist in our societies" and that the real issues facing food security were those such as democracy, structures of national economies and land rights (Fakir, 21/11). The potential impact of unequal distribution of resources/food on hunger was also discussed in the Background Document to the conference and this aspect was highlighted by Napier (18/12), who insisted that world hunger was due to problems of food distribution rather than of food production.

Muir (14/12 and 15/12) suggested that a wider view should be taken of the debate and that food security was determined by the population carrying capacity of the environment, i.e. that there are biological and physical limitations to the number of people that the environment can support, which ultimately limits expansion of the human population. Growth of the human population is thus central – if it continues to grow then, even if natural resources are shared equally, the limit will eventually be reached. Fenning, 15/12(1) supported this view and suggested that some people may already be suffering from this limit.

7.2.1.2 How biotechnology can contribute to reducing hunger and increasing food security in developing countries

In general, when people in the conference proposed that biotechnology could contribute to reducing food insecurity and hunger in developing countries, they tended to be quite cautious and measured in their statements, without ignoring the many challenges that need to be overcome. For example, Frey (6/12) listed some plant biotechnologies that could improve crop yields and disease diagnosis in developing countries but added "obviously, biotechnology will not solve all the problems in the developing world - it's just one more tool in modern agriculture". Johanson (11/12), while urging that biotechnologists should address the serious technical problems facing agriculture in developing countries, assured that she knows of no responsible scientist naïve or egotistical enough to claim that biotechnology alone can solve hunger and poverty problems.

Participants described the many potential advantages that biotechnology could confer across a wide range of agricultural applications in developing countries, such as in the livestock sector (Donkin, 13/12), for storage of agricultural products (Olutogun, 11/12), for sustaining current crop yields while reducing inputs of fertilizers, herbicides and pesticides (Fenning, 6/12) or for crop protection (Giga, 29/11). Steane (5/12) emphasized the potential of biotechnology and made a plea for concerted action against hunger and poverty, saying that "it is incumbent on us all to try to assist in any way possible within the bounds of sustainability to ensure that food shortage and poverty are eliminated - the challenge is not whether biotechnology can contribute but whether we are smart enough to harness it to do so".

At a wider, national economic level, Robert (22/11) indicated that many politicians, in both developed and developing countries, believed that biotechnology could contribute to food security in developing countries by increasing agricultural output for export from developing countries and thus allowing them to earn more foreign currency.

Again at the wider level, there was a small discussion about how the use of biotechnology in developed countries could be used to reduce hunger in the developing world (note that, this topic apart, discussions in the conference focused (appropriately) on the potential impact of applying biotechnology in developing, and not developed, countries). The argument outlined in the message of Bharathan (13/11) was that increased population growth in the future would be in developing countries and that it would be necessary to use biotechnology in developed countries to increase exports to developing countries in order to keep pace with their rising population numbers and to feed the "new hungry" in the developing world. However, she maintained that the argument was flawed as such a situation, which would enable and consolidate increased import of food from the developed to the developing world, could not lead to food security, a point that was also made by Hongladarom (13/11).

As pointed out by Benbrook (20/11), an equally important, but different question is whether biotechnology "will" (rather than "can") increase food security. He described a relatively simple method that he suggested could be used to identify policy and institutional factors (e.g. trade, intellectual property rights) that could be changed to narrow the gap between "will" and "can".

7.2.1.3 Biotechnology is just one of the possible solutions to hunger and food insecurity in developing countries

During the conference, when confronted with arguments against the potential merits or value of agricultural biotechnology, it was common for some participants to respond that biotechnology was not a panacea for food insecurity and hunger problems but was just one of the possible solutions that could be used (e.g. Gibson, 10/11; Hruska, 11/11; Fenning, 20/11; Kambikambi, 23/11; Frey, 6/12). As Fenning (10/11) expressed it, "many approaches need to be available for dealing with any particular food supply problem (the tool box approach), and those that work best are kept in use. I would never be prescriptive as what will be most appropriate in what circumstances, but the more options on offer the better surely?".

Hongladarom (23/11) underlined that one solution cannot fit all situations and that, as an example, flood-resistant crop varieties, developed using biotechnology, might be crucial in Thailand but inappropriate in sub-Saharan Africa. Madalena (5/12) also pointed out that, of the many biotechnologies available, some might be appropriate and useful and others not.

However, the "tool box" approach and the exploration of all possible avenues to increasing food quantity/quality, was criticized by some participants on the grounds that efforts and funds to fight hunger are being steadily reduced and that there is an obligation therefore to make choices and to use the little money available in the best possible way (Ferry, 21/11 and 12/12). Rosset (14/11) highlighted, in particular, cutbacks in public sector agricultural research and the fact that since research into GM crops was so expensive it drew scarce resources away from other promising lines of research (such as agroecology or integrated pest management). Boesen (13/12) considered it thus highly relevant that one should look at whether the world's poor can acquire enough food through alternative strategies (e.g. institutional, distributional) to biotechnology and whether investments in research into these alternatives may provide results that are as good and less risky.

7.2.1.4 Biotechnology may increase hunger, food insecurity and social inequalities in developing countries

Some participants expressed concerns that increasing production, e.g. using biotechnology, might actually exacerbate hunger and food insecurity issues and deepen social problems in developing countries. This was a topic flavoured with strong social-political elements, which also included the role/evolution that people saw for the rural population in developing countries in the future.

Fakir (5/12) suggested that the economic and trade implications of increasing the amount of food produced, e.g. using biotechnology, could be quite complex. Firstly, food supply exceeds demand so prices fall and access to food by the poor is increased as the food is cheaper. Secondly, however, as prices are lower and farmers in developing countries are not subsidized, they are forced to absorb costs that are higher than the prices they can get for their commodities on the international market, which leads to them producing only for their limited domestic markets or for subsistence use. Governments in developing countries may then find it cheaper to import grain and other staple foods from developed countries than to buy them from their own farmers (Fakir, 5/12). Rosset, 23/11(3) pointed out that in many parts of the developing world today (especially Africa), farmers already produce less than they can because they have no economic incentives to produce more – prices are low and there are few buyers. Ferry (27/11), however, did not believe that this was the case for the poorest farmers as they "do not need any external or market incentives to increase their production: reducing hunger and increasing food security are quite enough". For developing countries that traditionally export food commodities, any drop in world prices and in subsequent foreign exchange income can create further food insecurity as the countries may lack the money required to import the food requirements (Kirk, 13/12).

Rosset, 5/12(2) argued that such drops in world prices can have two negative effects; a) poor, indebted farmers may give up farming; b) as prices remain low, the minimum farm size needed to maintain a family rises. The end result is that small and poor farmers leave the land while farms become bigger and concentrated in the hands of fewer individuals. Fenning (6/12) argued however that, although it was by no means painless, "it is a classic part of the process of development that people leave small scale agriculture and move to more technologically orientated activities (usually in cities) which are perceived to be better paid, while agriculture is simultaneously mechanized and scaled up". Both Ferry (7/12) and Rosset (8/12), however, highlighted the negative social consequences of poor farmers migrating to cities and to a life of potential urban instability and poverty. Robert (22/11) also questioned whether, with the present system and the rate of consumption in developed countries, all countries could become "developed". Rosset (8/12) emphasized instead the need to create economically sustainable and fulfilling livelihoods in rural areas.

In the context of the potential socio-political consequences of applying biotechnology, Fenning (11/12) argued, however, that biotechnology itself is neutral but that it "will tend to play into any already ongoing political or economic developments". Fakir (12/12) however, from another angle, suggested that because biotechnology was being promoted in a solution-oriented, rather than a needs-oriented approach to the problems in developing countries, it might increase the vulnerability and risk that poor people will have to bear.

7.2.1.5 Impact of GM crops on hunger and food security in developing countries

Among the many potential biotechnologies available and the many different ways in which they could be applied, participants paid most attention to the use of genetic modification in the crop sector. Some of the discussion was general, regarding the potential environmental impact of GM crops and the effect it might have on hunger and food security. Much was, however, specifically focused on a single GM variety, the so-called "golden rice".

a) Golden rice

Between 100 and 140 million children are affected by vitamin A deficiency (VAD) in the world. It is a public health problem in 118 countries, especially in Africa and South-East Asia, which affects young children and pregnant women in low-income countries hardest. An estimated 250 000 to 500 000 vitamin A deficient children become blind each year, half of them dying within 12 months of losing their sight (these figures are taken from the World Health Organization website www.who.int/nut/vad.htm, visited on 18/5/01).

Rice grain is the world's most important source of food. However, it is a poor source of many essential micronutrients and vitamins. The endosperm, the starchy portion of the grain left after milling, does not contain provitamin A (also known as beta-carotene), from which humans can make vitamin A. The Golden Rice variety, however, contains three new genes (two from the daffodil and one from a bacteria) so that the rice plants produce provitamin A. The plant variety was produced by researchers collaborating in Germany and Switzerland and their work was reported in the journal Science on 14 January 2000. There is large interest in making the variety available to farmers in developing countries but it is currently in the testing phase and so may not be released publicly until a few years time.

As mentioned earlier, discussions on the potential value of biotechnology for food security and hunger in developing countries can be quite polarized. Golden Rice, which has also been the subject of much public and media interest, has allowed this polarization of viewpoints to become far more specific, as it is a specific biotechnology product directed towards a specific nutritional problem in developing countries.

The issue of how Golden Rice was presented to the public was raised by participants. Ferry, 8/11(1) complained that to get financial and/or political support, biotechnology projects were often presented incorrectly, badly or superficially and that Golden Rice was a good example of this (Ferry, 6/11). He maintained that exaggerated claims for Golden Rice came often not from journalists but from public biotechnology laboratories and institutions, using the publicity to promote their work at a time that is difficult for public research (Ferry, 10/11). Regarding private industry, Fakir (20/11) argued that the focus on saving people from malnutrition and blindness was a marketing strategy, a view shared by Ferry (21/11) who maintained that “propaganda is an essential part of the strategy of the companies and the Golden Rice has constituted a golden opportunity”. Fenning (20/11), however, insisted that if Golden Rice is at least available as a potential option, it is in part due to biotechnology companies waiving their patent rights over the techniques used to create the plants.

Polarization on this issue was, to a certain degree, also reflected in the different approaches people took to discussing Golden Rice and its impact on hunger/nutrition. For some, the approach was that the variety exists and so why not try it (e.g. Fenning, 10/11). For others instead, the approach was that hunger and nutrition problems exist and why should Golden Rice be used compared to other potential solutions to the problems (e.g. Carvalho, 7/11; Ferry, 10/11 and 15/11). Benbrook (13/11) expressed the latter clearly, saying that if one imagined a hypothetical situation where a “well balanced team of scientists, policy leaders and agriculture and nutrition practitioners came together, heavily weighted toward people with on-the-ground experience in the countries with vitamin A problems. They are given US$300 million to invest over 10 years in solving the problem and can pick any paths or partners.”, then it would be difficult to imagine that they would invest all the money in Golden Rice.

Rosset, 10/11(1) argued that VAD was not best characterized as a problem, but rather as a symptom of broader dietary inadequacies associated with both poverty and agricultural transition from diverse cropping systems to rice monoculture. He thus stressed the importance of having a more varied diet and concluded that “a magic-bullet solution which places beta-carotene into rice...while leaving poverty, poor diets and extensive monoculture intact, is unlikely to make any durable contribution to well-being”. Carvalho (10/11) suggested that if looking for a “magic bullet” solution, then a nutritional supplement could be used. Howell (10/11) reported that studies with vitamin A supplementation in children had successfully reduced mortality rates. Ferry (10/11) suggested that Golden Rice could have counter-productive impacts on nutritional problems, by curtailing the progress made in educating people to diversify their diet and/or increase the diversification of agriculture production. Fenning (10/11) agreed that the points made about the importance of a good diet to combat VAD were totally valid but emphasized that other options need also to be considered, since the possibility of improving the diet in developing countries has been available for a long time, but without resolving the VAD problems.

Ferry, 8/11(1) raised concerns about two additional aspects of Golden Rice. The first concern was that if only a limited number of varieties were genetically modified and they were widely cultivated, then this would have a negative impact on crop biodiversity. Frey (9/11) suggested that it was unsure whether a range of varieties would be genetically modified but that it was more likely that the Golden Rice variety would be simply crossed with the local adapted varieties and that, by backcrossing, the unique genes of Golden Rice would be retained while eliminating most of the foreign genome. Ferry (10/11) questioned this solution, since crossing with the local varieties would diminish one of the main advantages of developing GM varieties, the time saved compared to traditional breeding techniques.

The second concern Ferry, 8/11(1) raised was the price of seeds of the new varieties, which might lead to them being accessible to only the richest farmers. Frey (9/11), however, replied that the seeds would be given free to farmers in developing countries and that they would be able to earn up to US$10 000 profits per year without having to pay any royalties.

For Ferry (10/11), the Golden Rice issue highlighted the importance of having a research team approach, with scientists of various disciplines, including not just biotechnologists but also dieticians, horticulturists and socio-economists, working together on the question of food security and poverty eradication. Both Rosset, 23/11(2) and Greenberg (8/12) stressed that the farmers themselves should also be included in this process.

b) Effect of environmental impacts of GM crops on hunger and food security

The potential environmental impact of transgenic crops is an important subject in its own right. In this conference, however, it was considered only in respect of its potential effect on hunger and food security. Rosset, 23/11(1) outlined some potential environmental risks that could be relevant to food security in developing countries. These include i) potential failures of GM crops; ii) potential negative impacts of Bt-crops (i.e. GM crops producing toxins of the soil bacterium *Bacillus thuringiensis*), such as increased resistance to Bt toxins by the pests; crop losses due to killing non-target biocontrol organisms and reductions in soil fertility due to Bt toxins remaining in the soil; and iii) potential transfer of insecticidal properties or virus resistance to wild relatives of the crop species. Fakir, 23/11(2) highlighted the fact that the risk for small farmers in developing countries is far higher than for commercial farmers in developed countries, who may be able to afford insurance or who may be assisted by their governments if an environmental crisis occurs.

There seemed to be agreement that developing countries should not be used as inappropriate testing grounds by scientists and companies promoting GM organisms (e.g. Koudandé, 11/11) and that the environmental risks of GM crops should be studied, understood and minimized (Fenning, 10/11; Hruska, 11/11; Rosset, 14/11). Glover, 15/12(1), however, doubted whether detailed field trials or risk assessment studies would be carried out in poor countries as they are both time-consuming and expensive and because private companies would prefer to simplify risk assessment procedures.

7.2.1.6 Biotechnology is more than GM crops

As there was a lot of discussion about GM crops (especially Golden Rice) during the conference, some participants (e.g. Koudandé, 9/11) felt it important to reiterate that biotechnology includes a wide range of tools and not just genetic modification, that may be used to address problems of food security and hunger. These include detection of genes affecting traits of importance for developing countries, such as drought resistance in Africa and introgressing them into crops using marker-assisted breeding (Koudandé, 9/11) or the use of disease diagnostic tools or tissue culture to produce healthy planting material (Frey, 6/12), while Ferry (11/12) described one particular project to introduce date palm tissue culture plants in the Sahel.

Donkin (13/12) also underlined the multiple roles and values that livestock represent in developing countries, while complementing crop production and like Jeggo (12/12), argued that biotechnology could be used in various ways to increase these values. Steane (5/12) suggested, in particular, that reproductive biotechnologies, involving in-vitro maturation and fertilization of ova and embryo transfer, could assist poverty alleviation and food security.

7.2.1.7 The relationship between the biotechnology industry and the issue of hunger and food security in developing countries

In general, participants emphasized the potential negative aspects of the role and impact of private industry on food security and hunger in developing countries. Some participants reacted strongly to what they saw as the cynical manipulation of the plight of the poor by the private industry in a marketing operation to promote development of transgenic crops (Ferry 6/11 and 30/11; Rosset, 14/11; Fakir, 20/11). Ferry (5/12) also suggested that biotechnology groups were lobbying strongly for the development and acceptance of GM products in developing countries.

Fenning (15/11) argued that at least some companies were guilty of over-hyping the value of biotechnology for developing countries but that, even though the research and development strategies of big companies and wealthier countries were not really aimed at easing the problems of poorer countries, “blaming biotechnology isn’t going to change anything”. He suggested that over-hyping of the benefits of biotechnology (including to the developing world) had led to some public hostility and distrust of private companies (Fenning, 4/12). He called, however, for a flexible stance on biotechnology, saying that “I get the impression from much of the debate on this issue (and not just here) that anything that has been touched by big corporations or biotechnology is anathema in certain quarters and will be rejected outright on principle, which seems to be in danger of becoming part of the problem" (Fenning, 22/11(1)).

Glover (21/11) tried to explain, *inter alia*, why the industry was actively engaged in a public relations exercise to gain acceptance of biotechnology and why most of the crops being developed and marketed by the biotechnology industry have little to do with enhancing food security for the poor in developing countries. He said this was because "the companies must make profits in order to satisfy their shareholders, beat the competition and stay in business. The biotech firms have invested huge amounts of their investors' and shareholders' money in research and development of biotech crops. By and large, the investors and shareholders themselves are also large institutions with their own shareholders. They are impatient for a handsome return on their stake". Fenning, 27/11(2) also highlighted the expensive nature of crop development and distribution and insisted that if there was not enough profit to be made, then the companies would simply leave the business, which would limit the choice of varieties available. The positive impact of the private sector was emphasized by Freed (23/11) who underlined that it focuses on economic issues and tends to be more efficient than the public sector and that the key to rural development was both a strong private and public sector.

The private industry was also seen to have an impact on food security and hunger by its influence on the biotechnology research agenda. Ferry (6/11) emphasized the importance of decisions regarding which biotechnology research is to be carried out, for whom and with what priority. In his opinion, the private companies had too much power and weight in determining the research agenda. Fakir (22/11) considered a quotation regarding international agricultural research, from a widely-publicized report by scientists from seven science academies published in 2000, to be relevant in this context i.e. "if such research were wholly private, even in a perfectly functioning market, the demands of rich consumers for innovation in their own interests would overwhelm both the needs of and the price signals from poor consumers and small-scale farmers".

Adams (7/12) argued that the poor can generally be reached quickest through public funding of agricultural research and development, compared to the private sector where the main goal is making profits. He thus concluded that "the fruits of biotechnology can only reach the hungry and the poorest through the continuation of public funded projects in a judicious mix with private capital". Immonen (23/11) also highlighted some important differences between the research carried out by the public and private sectors. She pointed out that the public sector deals with genetic improvement of several crop and animal species that the private sector does not consider and that the public sector also invests in research on traits which "are particularly relevant in difficult production conditions (such as resistance to the parasitic weed Striga) or relevant to poor farmers (such as apomixis). These would seem to be research topics where success would benefit poor producers and consumers". Ferry (11/12) emphasized that if public research institutions choose to prioritize the fight against hunger then their research programmes should be re-oriented and re-evaluated with this objective in mind.

7.2.1.8 IPR and the ability of developing countries to use biotechnology for their hunger and food security problems

Hongladarom (13/11) emphasized the importance of developing countries being able to develop their own biotechnology to suit their own particular environments and that "help from the developed countries should not come in the form of giving away of ready made, ready-to-be-consumed products, but in the form of education and technology transfer". Greenberg (8/12) made a similar point, saying that "biotechnology will never be the answer as long as it is imposed from outside. The agenda has to be driven by the farmers themselves". Some participants (e.g. Fenning, 27/11(2)), however, highlighted the potential negative impacts that IPR over biotechnological products, or the processes used to make them, might have on the ability of developing countries to do this.

Fenning, 27/11(2) noted that IPR were held not only by private companies but also by some public organizations and that "it will soon reach the point where it is nearly impossible to use any aspect of biotechnology for improving any major crop species without infringing a patent somewhere in the process". On this point, Glover (21/11) wrote that today, in contrast to the situation of the "Green Revolution", "the technology (knowledge) is owned and controlled by large, private transnational corporations. Their property rights in the technology are protected by international treaties and enforced by states on their behalf". Greyling (20/11) suggested that the debate on biotechnology would be very different if developing countries developed, managed and applied their own biotechnology rather than having to depend on it being given to them. Fenning (1/12) also suggested that because of IPR issues it was not always possible to separate the biotechnology prospects from the business interests involved.

Traoré (6/12) expressed concern about patents and IPR as he argued that they will determine, to a large degree, access by the poor to GM products. Fenning, 27/11(2) pointed out that a major consequence of IPR in agricultural biotechnology was that countries that had not yet invested in biotechnology, such as most developing countries, would probably never be able to make up the lost ground in the future. Mulvany (18/12) instead emphasized the importance for food security of the International Undertaking on Plant Genetic Resources, which seeks to ensure the free flow of plant genetic resources for food production, as it would safeguard these important resources for humanity and guarantee that they remain as a backup to possible breakdown of GM crop varieties in the future.

7.2.1.9 Role of biotechnology scientists in the debate on hunger and food security

The debate on solving food security and hunger problems is very important. Gibson (10/11) provided a reminder of the responsibilities involved when considering potential biotechnology applications for the developing world, saying "sound decisions need to be based on good information. Ill informed claims, whether for or against biotechnologies, get in the way of decision taking that will benefit the world's poor. Whether working directly in the field or simply prognosticating, anything we put into the domain of public debate might influence a decision somewhere that impacts people's lives. We all have a duty to seek out the truth and work to correct the misinformation that the popular press all to often promulgates". Ferry (6/11) urged, however, that the debate should not be dominated by biotechnology scientists and private companies. He argued that biotechnology scientists, due to the nature of their work, are often highly specialized and technique-focused and thus are not competent on the complex question of hunger in developing countries. Fenning (6/11) agreed that it was important to have problem-based rather than solution-based thinking and said it was a classical human error, made also by many scientists, to be dazzled into using the latest technology when sometimes a simpler approach might be more successful.

7.2.2 Name and country of participants with referenced messages

Adams, Herman. Barbados
Ashton, Glenn. South Africa
Benbrook, Charles. United States
Bharathan, Geeta. United States
Boesen, Jannik. Denmark
Carvalho, Luiz. Brazil
Donkin, Ned. South Africa
Fakir, Saliem. South Africa
Fenning, Trevor. Germany
Ferry, Michel. Spain
Freed, Russ. United States.
Frey, Petra. United States
Gibson, John. Kenya
Giga, Danash. Zimbabwe
Glover, Dominic. United Kingdom
Greenberg, Stephen. South Africa

Greyling, Ben. South Africa
Hongladarom, Soraj. Thailand
Howell, Bruce. Canada
Hruska, Allan. Nicaragua
Immonen, Sirkka. Italy
Jeggo, Martyn. Austria
Johanson, Andrea. United States
Kambikambi, Tamala. Zambia
Kirk, Jeffrey. United States
Koudandé, Delphin. Netherlands
Madalena, Fernando. Brazil
Muir, Bill. United States
Mulvany, Patrick. United Kingdom
Napier, James. Canada
Olutogun, Sanya. Nigeria
Robert, Stanley. Australia
Rosset, Peter. Mexico
Rusch, Peter. South Africa
Steane, David. Thailand
Traoré, Adama. Mali

CHAPTER 8. PARTICIPATION IN THE CONFERENCES

As mentioned in the Introduction, the quality and value of the conferences depends on the participants. In this chapter, some figures and an analysis of participation in the Forum's conferences are therefore presented. Most analyses are based on the information provided by people that sent messages (rather than those that simply joined the conferences without participating actively) as more information was readily available on them. People submitting messages were requested to introduce themselves briefly (when sending their first message) and, as a minimum, to give their country of residence. Usually they provided a full work address.

8.1 Overview of participation in the six conferences

An overview of the number of people, messages and countries involved in the six conferences is given in Table 8.1. It shows that the numbers of people that registered and submitted messages to the different conferences varied considerably. Of the four food and agricultural sectors considered – crops, fisheries, forestry and livestock - the crop sector seemed to be of greatest interest to Forum members while fewer people registered for the fishery and forestry sector conferences. The conferences on specific themes - IPR and hunger/food security - were well supported. The degree of participation also varied between conferences, with nine to 18 percent of people that joined sending e-mail messages.

The six conferences covered different subjects, although the topics discussed often overlapped. An analysis was carried out to investigate whether the same people registered for and posted messages to the different conferences. From figures in Table 8.1 it can be seen that a total of 1 380 individuals registered for the six conferences. By looking at their e-mail addresses, however, it was possible to identify those who joined more than one conference. The analysis revealed that a total of 795 *different* people were involved. Of these, there were seven (i.e. one percent) that joined all six conferences; 17 (two percent) that joined five conferences; 49 (six percent) that joined four conferences; 81 (10 percent) that joined three conferences; 173 (22 percent) that joined two conferences and, finally, 468 (59 percent) that joined just one. When Conference 6 ended there were 1 282 Forum members. This means that 795 (i.e. 62 percent) of them had participated in at least one conference whereas 487 (38 percent) had not, simply receiving instead the Background and Summary Documents from the Forum Administrator without joining up for any of the conferences.

The majority of people thus registered for a single conference. The conferences dealt with themes that were often very divergent (e.g. biotechnology in the fisheries sector; biotechnology and IPR) and the analysis suggests that most people have specific ranges of interests and will only invest their time in them. For example, when the sixth conference (on IPR) began, 104 Forum members joined that had not previously registered for any of the five previous conferences.

What about the people that sent messages? Table 8.1 shows that, summing over the six conferences, 184 people sent messages. However, analysis showed that these were 151 *different* people. Of these, one (i.e. one percent) sent messages to five conferences; five (three percent) sent messages to three conferences; 19 (13 percent) sent messages to two conferences while 126 (83 percent) sent messages to just one conference. Nobody sent messages to all six conferences or to four conferences.

These two analyses show that the six conferences, although with some overlap, tended to have different audiences and different groups of active participants.

8.2 Participation from the developing versus developed world

The numbers and proportions of messages from the developing and developed world are given in Table 8.2. Obviously, the results presented here are only an approximation of the relative contribution of the developing versus developed world to the conferences. People from developing countries may currently live in developed countries and thus have their e-mail address in developed countries (and vice versa). Furthermore, some people with addresses in developed countries (e.g. in FAO Headquarters, Italy) may be actively working for projects in developing countries.

A total of 406 messages was posted during the six conferences. Despite the fact that the vast majority of internet users are in OECD countries (see Introduction), participation of individuals from developing countries was substantial, representing 42 percent of all messages. The proportions varied somewhat between the conferences, ranging from 12 percent in the forestry conference to 52 percent in the livestock conference.

Note that the large gap between e-mail and web access for participants in developing countries is highlighted very clearly by comparing the figures in Table 8.2 with those from an analysis of web traffic carried out for the Forum website for the month of October 2000. On an average day during the month, there were 116 visitors and 553 hits on the website. The vast majority of visitors came from developed countries, especially the United States. Of the 3 624 visitors throughout the month, the geographic location of 2 248 could be identified. A total of 1 376 (i.e. 61 percent) of these were from North America and when combined with Western Europe and Australia they accounted for 1 946 (87 percent) visitors. There were far fewer from Asia, South America and Sub-Saharan Africa - representing only six, two and 0.5 percent respectively of visitors. Looking at individual countries, the top 10 were all from the developed world, with 55 percent of visitors of known country coming from the United States.

8.3 Participation by geographical area

The numbers and proportions of messages from individuals in the different main geographical areas are given in Table 8.3. All of the different geographical zones were represented. The highest proportion of messages (30 percent) came from participants in Europe, 22 percent were from North America and 20 percent from Africa. The remaining messages came from Asia (15 percent), LAC (nine percent) and Oceania (four percent). The contributions of different continents varied from conference to conference. For example, those from Africa accounted for 20-25 percent of messages, except for the forestry (three percent) and fishery (four percent) conferences, while those from Asia ranged from 18-31 percent per conference, apart from the forestry and hunger/food security conferences (three percent each).

8.4 Participation from different countries

The number of messages coming from different countries is given in Table 8.4. A total of 47 countries were represented, with the greatest number of messages, 83 (i.e. 20 percent), coming from the United States, followed by South Africa (10 percent) and Germany (seven percent). The five countries of France, Kenya, Mexico, Spain and United Kingdom contributed 101 messages (25 percent).

8.5 Workplace of the participants

Table 8.5 gives information on the kind of people participating in the conferences, by considering where they work. The analysis of participants' workplace was dependent on the information they provided and was, in a few cases, insufficient to pinpoint accurately – in these cases, they were classified under the "general public". Note, again, that these results are only an approximation – people may have several roles at any one time (e.g. a participant with a university work address could also be on a governmental advisory board and/or a member of a NGO) and they may change over time.

The people who submitted messages came from a wide range of walks of life. However, there were three work areas which dominated - 29, 28 and 19 percent of messages, respectively came from individuals in research organizations/institutes, universities and NGOs. The remaining 25 percent came from people working in development agencies, FAO, government agencies or ministries, IARCs, private industry or were independent consultants or patent lawyers. Given the large importance of the private sector in agricultural biotechnology, it was surprising that there were relatively few messages from people in private companies.

8.6 Participation in the individual conferences

Here, the six conferences are considered separately, referring to the figures provided in Tables 8.1-8.5.

a) Crop sector conference

As this was the first conference of the Forum, a more detailed analysis of participation was carried out than for the other conferences. Within a week of launching the conference, 200 people had registered and after a further three weeks the numbers had stabilized at around 300. Very few people unsubscribed themselves once it had started (the same was also true for the other conferences).

At the end of the conference, there were 306 people registered and a rough analysis of their e-mail addresses was carried out. There were 103 of unknown country - these were from MNCs, from companies (i.e. with ".com" addresses), from unidentified CGIAR centres or from personal e-mail accounts (yahoo, hotmail, etc.). Of the 203 people with addresses that could be attributed to a country, 43 percent were in Europe; 14 percent each were in North America, Africa and LAC; nine percent from Asia and six percent from Oceania. Fifty-eight percent were from developed countries while 42 percent were from developing countries

Regarding the 138 messages posted during the conference, roughly 25 percent each were from Africa, Europe and North America, while Asia, LAC and Oceania contributed 19, six and one percent respectively (Table 8.3). Thus, Africa and North America provided only 28 percent of participants, but they contributed roughly half of all messages. Asia had only nine percent of participants, but 19 percent of messages. Forty-two percent of participants were from developing countries and they were responsible for 46 percent of messages posted (Table 8.2).

Messages were posted from 29 different countries. Countries with the greatest number of messages posted were the United States (34), France (14) and Kenya (12). Fifty-one different people sent messages (17 percent of all registered) while the greatest number from any one participant was 12. Participants came from a wide range of occupations (Table 8.5). Over half the messages came from people working in research organizations/institutes or universities; nearly a quarter were from people in NGOs while the remaining messages came from individuals in diverse workplaces such as IARCs, government bodies, the ministry of agriculture or private industry.

b) Forestry sector conference

For this second conference, there were 167 participants who submitted a total of 32 messages. In contrast to all other conferences, the vast majority of messages (88 percent) were from participants living in developed countries. They came from 15 individuals (nine percent of all registered) in 10 different countries. Nearly 70 percent of messages came from individuals working in research organizations/institutes and universities, with the remainder from the private sector, NGOs, IARCs and FAO. The countries contributing most messages were New Zealand (nine), the United States (eight) and Germany (five). Participants in Europe, Oceania and North America accounted for nearly 90 percent of all messages, while those in Africa, Asia and LAC contributed just four of the 32 messages.

c) Livestock sector conference

A total of 235 Forum members registered for the conference and 42 messages were posted. These were submitted by 26 people (11 percent of all registered) living in 14 different countries. Almost 40 percent of messages came from people working in universities while nearly 30 percent were from research organizations or institutes. The remaining 33 percent were from individuals in a wide range of different occupations. The countries from which the greatest number of messages were posted were the United States (11 messages), South Africa (five), Indonesia (four) and Thailand (four). Looking at the wider geographical picture, the greatest number of messages came from Asia (29 percent), North America (26 percent) and Africa (24 percent), with the remaining 22 percent coming roughly equally from Europe and Oceania. Fifty-two percent of messages were posted by participants living in developing countries.

d) Fishery sector conference

For this conference, there were 149 participants who submitted a total of 26 messages. These numbers were the lowest of all six conferences. Messages came from 16 individuals (11 percent of all registered) living in 12 different countries. Fourteen of the messages came from people working in universities, four from research centres and two each from development agencies, a government ministry, NGOs and the private industry. The countries contributing most messages were the United States (eight) and Norway (three). Participants in North America, Asia and Europe accounted for roughly 40, 30 and 20 percent respectively of all messages posted. Forty-two percent of messages were posted by participants living in developing countries.

e) IPR conference

A total of 265 people registered and 30 of them (11 percent) submitted at least one of the 50 messages posted. The greatest proportion of messages was from Europe (36 percent), with 20 percent each from Africa and North America, and 18 and six percent from Asia and LAC, respectively. Roughly two thirds were from participants in developed countries and one third from the developing world. Messages were posted from 18 different countries. Countries with the greatest number of messages posted were the United States (eight messages), United Kingdom (six) and France, Japan and South Africa (five each).

Messages came from a very heterogeneous group of participants. The most highly represented were individuals from research organizations/institutes, universities, independent consultants and NGOs - providing 24, 22, 16 and 16 percent respectively of messages. The remainder was from IARCs, patent lawyers, a reporter, FAO, private industry and a government ministry.

f) Hunger and Food Security Conference

A total of 258 Forum members registered, of whom 46 (i.e. 18 percent - the highest proportion of the six conferences) submitted a total of 118 messages. Contributions came from 22 different countries, with 43 percent of messages from developing and 57 percent from developed countries. Participants in Germany (18 messages), Mexico (17), South Africa (17) and the United States (14) were the most active.

Participants in Europe provided the highest proportion (42 percent) of messages, followed by Africa (21 percent), LAC (19 percent), North America (14 percent), Asia (three percent) and Oceania (one percent). The proportion of messages from individuals in NGOs (28 percent) was higher here than in other conferences. Significant proportions also came from people in research organizations and centres (35 percent) and universities (22 percent). The remaining 15 percent were from a wide range of occupations.

Table 8.1 Number of people that registered for each conference, number of messages posted, number of countries and people providing the messages and percent of people registered for each conference that posted messages

Conference theme	No. members registered	No. messages	No. countries	No. people	% members registered that sent messages
Crops	306	138	29	51	17
Forestry	167	32	10	15	9
Livestock	235	42	14	26	11
Fishery	149	26	12	16	11
IPR	265	50	18	30	11
Hunger/Food Security	258	118	22	46	18
Total	**1 380**	**406**	**105**	**184**	

Table 8.2 Number (and percentage) of messages posted from individuals in developing or developed countries[1]

Conference	No. (%) of messages from developing countries	No. (%) of messages from developed countries
Crops	64 (46)	74 (54)
Forestry	4 (12)	28 (88)
Livestock	22 (52)	20 (48)
Fishery	11 (42)	15 (58)
IPR	17 (34)	33 (66)
Hunger/Food Security	51 (43)	67 (57)
Total	**169 (42)**	**237 (58)**

[1]Classification of countries into developed or developing follows the Development Assistance Committee of the OECD (see www.oecd.org/dac/htm/daclst2000.htm).

Table 8.3 Number (and percentage) of messages coming from individuals in different geographical areas

Conference theme	Africa	Asia	Europe	LAC	North America	Oceania	Total
Crops	34 (25)	26 (19)	35 (25)	8 (6)	34 (25)	1 (1)	138
Forestry	1 (3)	1 (3)	10 (31)	2 (6)	8 (25)	10 (31)	32
Livestock	10 (24)	12 (29)	4 (10)	-	11 (26)	5 (12)	42
Fishery	1 (4)	8 (31)	5 (19)	2 (8)	10 (38)	-	26
IPR	10 (20)	9 (18)	18 (36)	3 (6)	10 (20)	-	50
Hunger/Food Security	25 (21)	3 (3)	50 (42)	23 (19)	16 (14)	1 (1)	118
Total	**81 (20)**	**59 (15)**	**122 (30)**	**38 (9)**	**89 (22)**	**17 (4)**	**406**

Table 8.4 Number of messages coming from individuals in different countries

COUNTRY	C O N F E R E N C E T H E M E						
	Crops	Forestry	Livestock	Fishery	IPR	Hunger	Total
United States	34	8	11	8	8	14	83
South Africa	11	1	5	1	5	17	40
Germany	7	5	-	-	-	18	30
Mexico	1	2	-	2	-	17	22
France	14	-	-	1	5	-	20
Spain	1	-	-	-	3	16	20

United Kingdom	7	-	-	-	6	7	20
Kenya	12	-	2	-	3	2	19
Philippines	9	-	1	2	-	-	12
Netherlands	2	-	3	-	2	3	10
Thailand	1	-	4	1	1	3	10
Brazil	5	-	-	-	-	4	9
Japan	4	-	-	-	5	-	9
New Zealand	-	9	-	-	-	-	9
India	6	-	-	-	2	-	8
Sri Lanka	3	-	2	2	-	-	7
Austria	1	1	2	-	-	2	6
Canada	-	-	-	2	2	2	6
Italy	2	2	-	-	1	1	6
Australia	1	1	2	-	-	1	5
Norway	-	-	2	3	-	-	5
Indonesia	-	-	4	-	-	-	4
Mali	-	-	2	-	-	2	4
Nigeria	1	-	-	-	1	2	4
Uganda	4	-	-	-	-	-	4
Colombia	2	-	-	-	1	-	3
Ireland	-	-	-	1	-	2	3
Israel	1	-	-	2	-	-	3
Tunisia	3	-	-	-	-	-	3
Chile	-	-	-	-	2	-	2
Pakistan	1	-	-	-	1	-	2
Sweden	-	2	-	-	-	-	2
Zambia	1	-	-	-	-	1	2
Barbados	-	-	-	-	-	1	1
Belgium	-	-	-	-	1	-	1
Botswana	-	-	-	-	1	-	1
China	-	-	1	-	-	-	1
Denmark	-	-	-	-	-	1	1
Ethiopia	1	-	-	-	-	-	1
Malaysia	-	1	-	-	-	-	1
Morocco	-	-	1	-	-	-	1
Nicaragua	-	-	-	-	-	1	1
Russia	1	-	-	-	-	-	1
Senegal	1	-	-	-	-	-	1
Turkey	1	-	-	-	-	-	1
Viet Nam	-	-	-	1	-	-	1
Zimbabwe	-	-	-	-	-	1	1
Total	**138**	**32**	**42**	**26**	**50**	**118**	**406**

Table 8.5 Number (and percentage) of messages coming from participants in different occupations

WORKPLACE	CONFERENCE THEME						
	Crops	Forestry	Livestock	Fishery	IPR	Hunger/ Food Security	Total
Development agency	4 (3)	-	-	2 (8)	-	2 (2)	8 (2)
FAO[1]	2 (1)	1 (3)	2 (5)	-	2 (4)	2 (2)	9 (2)
General public	-	-	1 (2)	-	1 (2)	3 (3)	5 (1)
Government // Ministry of agriculture[2]	9 (7)	-	3 (7)	2 (8)	1 (2)	-	15 (4)
IARC[3]	10 (7)	2 (6)	2 (5)	-	4 (8)	6 (5)	24 (6)
Independent consultant	-	-	3 (7)	-	8 (16)	3 (3)	14 (3)
NGO	30 (22)	2 (6)	1 (2)	2 (8)	8 (16)	33 (28)	76 (19)
Patent lawyer	4 (3)	-	-	-	2 (4)	1 (1)	7 (2)
Private company	7 (5)	5 (16)	2 (5)	2 (8)	1 (2)	1 (1)	18 (4)
Research organization or institute[2]	36 (26)	11 (34)	12 (29)	4 (15)	12 (24)	41 (35)	116 (29)
University	36 (26)	11 (34)	16 (38)	14 (54)	11 (22)	26 (22)	114 (28)
Total	**138**	**32**	**42**	**26**	**50**	**118**	**406**

[1]Includes the joint FAO/IAEA Division in Austria
[2] "Research organization or institute" includes governmental research institutes
[3]International Agricultural Research Centre: Mainly includes individuals from CGIAR centres

CHAPTER 9. GENERAL CONCLUSIONS

In this chapter a brief overview of the six conferences is provided, considering both the general operation of the conferences as well as highlighting some of the major concerns and themes raised by participants.

Before launching the Forum, only the themes of the first four conferences were decided in advance, i.e. the appropriateness of currently available biotechnologies for the crop, fishery, forestry and livestock sectors of developing countries. By running these sector-specific conferences first, it was possible to compare and contrast the current interest, reactions and experiences of Forum members towards biotechnology in each sector, as well as to identify subjects that particularly interested them for future conferences. The two subsequent conferences, on IPR and the impact of biotechnology on hunger, were well supported (about 260 people per conference), indicating that the strategy was successful.

From the six conferences, it is clear that there is large interest in receiving and sharing information about biotechnology in food and agriculture in developing countries. What is most encouraging is that, despite relying on e-mail (a medium used primarily in the developed world), over 40 percent of messages were from people living in developing countries.

The conferences provided a democratic forum to capture what people had to say, allowing their voices to be heard. Their views and experiences were shared with the other people that registered for the conferences, put up on the Forum website and included in the Summary Documents. In addition, in the current era of electronic communication, their comments can easily be further disseminated, although it is impossible to quantify this or its impact. What is known is that some e-mail messages and Summary Documents were circulated among other e-mail lists and posted on other websites (many with an educational purpose) and that the conferences were discussed by some scientific journals and daily newspapers.

At various times during the six conferences, participants exchanged sharply contrasting views and arguments concerning the appropriateness, importance and implications of biotechnology for food and agriculture in developing countries. The polarization concerning certain aspects of biotechnology (involving GM crops/food in particular, or the importance of biotechnology for hunger in developing countries) was also evident in this Forum. The most important achievement of the Forum is probably that it provided an opportunity for people to exchange information and views about agricultural biotechnology and that it may thus have contributed in some way to a reduction in polarization and to an increased understanding of other viewpoints. As one participant said in the crop sector conference, "as soon as the different interest groups refuse to talk and acknowledge each others concerns we are all in trouble".

When considering the application of biotechnology to the four different agricultural and food-related sectors, the Forum members showed greatest interest in the crop sector. This is clear from looking at the levels of participation in the first four conferences, as well as the fact that in the other two conferences, on IPR and hunger, the crop sector also received greatest attention. After the crop sector, Forum members seemed to show greatest interest in biotechnologies in the animal sector (especially reproductive technologies and the use of molecular markers) and slightly lower interest in their application to the forestry or fishery sectors.

For each sector, a range of biotechnologies can potentially be used. Most of them (e.g. genetic modification, use of molecular markers) are not sector-specific and can be used for animals, crops, fish and forest trees alike. Genetic modification was the single biotechnology which, by far, attracted the greatest interest and discussion and which dominated the crop, fishery and forestry sector conferences. It was also the biotechnology that featured most prominently in the two non-sectoral conferences. This emphasis seems to be a reflection of the fact that, at many levels of society and in many countries, there is currently tremendous awareness, interest and concern about the topic of GMOs. By comparison, participants did not seem to consider any of the other biotechnologies particularly controversial.

The most likely reason for the focus on genetic modification *in the crop sector* is that plant biotechnology products (GM crops and seeds) are already available to consumers and farmers. An estimated 44 million hectares were planted in the year 2000 in four countries responsible for 99 percent of the world's transgenic crops, namely: Argentina, Canada, China and the United States (ISAAA, 2000, www.isaaa.org/publications/briefs/Brief_21.htm). In contrast, there is still no commercial-scale planting of GM trees and no GM animals or fish are currently produced for human consumption.

The analysis of participation (Chapter 8) showed that, in general, there were different groups of participants in the different conferences. Here, an attempt is made to highlight, in no particular order, some of the main issues that came up repeatedly in the different conferences.

9.1 Potential of biotechnology

On several occasions throughout the conferences, participants emphasized the enormous potential of biotechnology and that it could be used successfully to address specific issues and problems facing food and agriculture in developing countries. However, there were concerns that biotechnology was currently only catering for farmers in developed countries and that there was therefore a need to re-direct it to also consider the specific requirements and problems of small holders in developing countries.

9.2 The environmental impact of GMOs and biosafety in developing countries

In all sector-specific conferences, concerns were expressed about the potential impact of releasing GMOs into the environment. The topic dominated the fishery sector conference while it received least attention in the animal sector conference. It is clear that the degree and type of concerns currently differ between the sectors. In the crop sector, Bt-crops seem to cause greatest environmental concern and over 11 million hectares of crops containing Bt genes were estimated to be grown in 2000 (ISAAA, 2000). In the forestry sector, no GM trees have been planted commercially but transgene flow to adjacent natural populations was considered a major potential concern, needing careful consideration because of the long generation time of trees and the potential for long distance dispersal of pollen and seed. In the fishery sector, GM fish may escape from aquaculture facilities and mate with wild relatives, if they are present in the ecosystem. In the animal sector, mating with wild relatives is rarely possible.

In four conferences, fears were expressed that the risks were greater in developing than in developed countries. Participants were concerned that the application of biosafety regulations would be less strict than in developed countries as risk assessment studies or field trials can be expensive and time-consuming and developing countries have also limited scientific infrastructure and expertise. For similar reasons, some participants felt that, if GMOs were approved for release, monitoring of biosafety aspects could also be less efficient and rigorous. Finally, there were concerns that if GMOs eventually had a negative impact on the environment in developing countries, they had fewer resources to remedy the situation.

9.3 Impact of intellectual property rights

Discussions in the conference suggested that there were major concerns about the impact that IPR (on the products and processes of agricultural biotechnology) are currently having and will have in the future. The large interest expressed led to a separate conference being held on the subject.

Many of the "nuts and bolts" of biotechnology research are protected by IPR, so to develop a single biotechnology product (e.g. a GM plant) might involve nearly 100 protected elements or processes. Private companies in developed countries are the dominant players in this new industry because of the large amount of financial and human resources needed to carry out the research and also because they have built up extensive IPR portfolios enabling them to bring developed products to market.

Participants maintained that IPR had a negative effect on agricultural biotechnology research in developing countries, because they interfered with the traditional system whereby potentially useful technologies could be simply transferred from developed to developing countries. In addition, whereas the so-called "green revolution" was made possible by publicly-funded agricultural research, especially in the CGIAR institutes, there were concerns that public sector institutes were currently hindered from playing a leading role in this new "biotechnology revolution" because of IPR (or, to be more precise, their lack of a comprehensive IPR portfolio to serve their needs).

A frequently cited concern was that, as part of this new revolution, genetic resources of local communities in developing countries were being patented by biotechnology companies in developed countries to provide them with the raw materials needed to develop new products in areas such as human health care, industrial processing or food and agriculture. Much anger was expressed about this issue as it was felt that the IPR system favoured developed countries and MNCs and that developing country communities were not protected; that their contribution to the genetic resources was not acknowledged and that the benefits arising from technical exploitation of the resources were not shared with them.

Although many concerns were raised about these IPR issues, there was also much fruitful discussion on strategies to avoid or alleviate the negative impacts of IPR on food and agriculture in developing countries.

9.4 Domination of agricultural biotechnology by developed countries and by the private sector

Participants pointed out that developing countries currently have low capacity to develop and use biotechnology. In general, the technologies are expensive and may be protected by IPR; governments have limited resources for research and development and there may be a lack of sufficiently qualified people trained to use them.

Agricultural biotechnology is dominated by developed countries and, in particular, by the private sector and a small number of MNCs in developed countries. This reality was highlighted as having a negative impact on developing countries in many conferences (especially the crop sector and the two non-sectoral conferences) and was the background to many heated exchanges concerning the socio-political nature and consequences of biotechnology. There were two major areas of contention.

Firstly, participants were concerned that this situation would make developing countries dependent (or more dependent) on developed countries (or on private companies in developed countries). This is because, as explained in the previous section, IPR play a central role in agricultural biotechnology. Since IPR determine access to the products (e.g. new plant varieties) and to the processes needed to develop the products, this potentially gives the IPR holders (primarily in developed countries) a considerable amount of power (especially given the importance of the final end product, i.e. food).

Secondly, as it is dominated by the private sector, participants pointed out that the application of agricultural biotechnology is determined by the laws of the market and it is therefore directed primarily towards the needs of the clients of these companies i.e. farmers in developed countries. The products developed by the companies do not, in general, include traits (such as drought resistance or salt tolerance) that might be important for small, food-insecure farmers in developing countries as these farmers do not represent an important market for the companies. The implications of this situation for hunger and food security in developing countries are quite substantial and were much discussed in the conference dedicated to this theme. Participants emphasized the importance of ensuring sufficient support for public sector agricultural research initiatives directed to the needs of small farmers.

9.5 Biotechnology as a “magic bullet”

There seemed to be general recognition that biotechnology could be a valuable tool for addressing specific problems facing farmers in developing countries. However, in each of the sector-specific conferences, people also argued that biotechnology should only be used in developing countries when basic management or infrastructural requirements were in place or well established. More specifically, they argued that scarce resources in the crop sector should be used to prioritize basics such as seed supply, extension services or conventional breeding rather than biotechnology; that basic forest management practices should be prioritized over development of GM trees; that biotechnologies should only be employed to genetically improve livestock if animal health and husbandry aspects were also considered and that low-technology solutions should be emphasized in aquaculture in developing countries.

Although there might be a temptation to view new technologies as a “magic bullet” or as a “quick-fix” solution, participants seemed to suggest from experience that this seldom worked out in practice. It was also pointed out that some scientists tend to be dazzled by technological advances and that there was a need to emphasize needs-driven rather than tools-driven solutions for the problems in developing countries.

CHAPTER 10. ADDITIONAL REFERENCE MATERIAL

In this chapter, a selection of references to documents and websites is included that may be useful for people interested in getting additional information on agricultural biotechnology, in general, or on the specific themes of the six conferences.

10.1 General biotechnology references (many of these are useful for more than one conference)

a) Documents

Center for International Development. Links to an extensive list of background papers on biotechnology in developing countries.
www.cid.harvard.edu/cidbiotech/links/biotech_dev-rp.htm

FAO. 1999. Biotechnology. www.fao.org/unfao/bodies/COAG/COAG15/X0074E.htm.
(A paper presented to COAG covering main biotechnology applications, previous major work on biotechnology in FAO, issues and concerns of developing countries and areas for FAO action).

FAO. 1999. Biosafety issues related to biotechnologies for sustainable agriculture and food security. ftp://ext-ftp.fao.org/waicent/pub/cgrfa8/8-i11-e.pdf (Presented at the 8th Regular Session of the CGRFA)

FAO. 1999. Glossary of biotechnology and genetic engineering. FAO Research and Technology Paper 7. www.fao.org/DOCREP/003/X3910E/X3910E00.htm

FAO. 2001. Genetically modified organisms, consumers, food safety and the environment. Ethics Series, no. 2. www.fao.org/Ethics/ser_en.htm

UNDP. 2001. Human Development Report 2001. Making new technologies work for human development. www.undp.org/hdr2001/

b) Websites

Biotechnology and Development Monitor. www.biotech-monitor.nl/
(A quarterly journal published by the University of Amsterdam, Holland, with short, easily-understandable articles on research, development, regulation and applications related to biotechnology relevant to developing countries).

Center for International Development. Links to an extensive list of websites on biotechnology in developing countries. www.cid.harvard.edu/cidbiotech/links/biotech_dev.htm

Electronic Journal of Biotechnology www.ejb.org

FAO Biotechnology Website www.fao.org/biotech/index.asp

OECD's Database of Field Trials. www.olis.oecd.org/biotrack.nsf
(This database includes records of field trials of genetically modified organisms (crops, forest trees, animals, fungi, bacteria and viruses) which have taken place in OECD member countries. It also includes data from other countries, provided by the United Nations Industrial Development Organization).

10.2 Crop sector conference

a) Documents

Anonymous. 2000. Transgenic Plants and World Agriculture. National Academy Press. www.nap.edu/html/transgenic/index.html (A report prepared under the auspices of the Royal Society of London, the U.S. National Academy of Sciences, the Brazilian Academy of Sciences, the Chinese Academy of Sciences, the Indian National Science Academy, the Mexican Academy of Sciences and the Third World Academy of Sciences).

Brink J.A., Woodward, B.R. and E.J. DaSilva. 1998. Plant biotechnology: a tool for development in Africa. Electronic Journal of Biotechnology. 1 (3). ejb.org/content/vol1/issue3/full/6/index.html

Drew, R.A. 1997. The application of biotechnology to the conservation and improvement of tropical and subtropical fruit species. www.fao.org/ag/agp/agps/pgr/drew1.htm

James, C. 2000. Global status of commercialized transgenic crops: 2000. ISAAA Briefs No. 21: Preview. ISAAA, Ithaca, United States. (Key parts of the document can be viewed at www.isaaa.org/publications/briefs/Brief_21.htm).

Mann, C.C. 1999. Crop scientists seek a new revolution. Science, 283, 310-314.

Paarlberg, R. 2000. Governing the GM crop revolution: Policy choices for developing countries. Food, Agriculture, and the Environment Discussion Paper 33. IFPRI (can be found by searching on the IFPRI website at www.ifpri.org/)

Saxena, D., Flores, S. and G. Stotzky. 1999. Transgenic plants: Insecticidal toxin in root exudates from Bt corn. Nature, 402, 480.

Somerville, C. and S. Somerville. 1999. Plant functional genomics. Science, 285, 380-383. www.biotech-info.net/plant_functional.html

Spillane, C. 1999. Recent developments in biotechnology as they relate to plant genetic resources for food and agriculture. ftp://ext-ftp.fao.org/waicent/pub/cgrfa8/BSP/bsp9E.pdf. (A paper prepared for the CGRFA).

b) Websites

Crop Biotech Net. Run by the International Service for the Acquisition of Agri-Biotech Applications (ISAAA). www.isaaa.org/kc/

Plant biotechnology teaching resources. Provided by Texas A & M University, United States. aggie-horticulture.tamu.edu/tisscult/biotech/biotechteach.html

Technical Cooperation Network on Plant Biotechnology in Latin America and the Caribbean (REDBIO/FAO). www.rlc.fao.org/redes/redbio/html/home.htm

10.3 Forestry sector conference

a) Documents

Burdon, R.D. 1994. The role of biotechnology in tree breeding. Forest Genetic Resources, 22. FAO, Rome.

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10.6 IPR conference

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10.7 Hunger and food security conference

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ABBREVIATIONS

AI = Artificial insemination
Bt = *Bacillus thuringiensis*
CBD = Convention on Biological Diversity
CGIAR = Consultative Group on International Agricultural Research
CGRFA = Commission on Genetic Resources for Food and Agriculture
COAG = FAO's Committee on Agriculture
ET = Embryo transfer
FAO = Food and Agriculture Organization of the United Nations
G x E = Genotype by environment
GM = Genetically modified
GMOs = Genetically modified organisms
IAEA = International Atomic Energy Agency
IARC = International Agricultural Research Centre
IDWGB = The FAO Inter-Departmental Working Group on Biotechnology
IPM = Integrated pest management
IPR = Intellectual property rights
IVM/IVF = In vitro maturation/in vitro fertilization
LAC = Latin America and the Caribbean
MAS = Marker-assisted selection
MNCs = Multi-national corporations
MOET = Multiple ovulation and embryo transfer
NGOs = Non-governmental organizations
OECD = Organisation for Economic Co-operation and Development
QTLs = Quantitative trait loci
PVP = Plant variety protection
SDRR = FAO's Research and Technology Development Service
The TRIPS Agreement = WTO's agreement on Trade-Related Aspects of Intellectual Property Rights
UNDP = United Nations Development Programme
UPOV = International Union for the Protection of New Varieties of Plants
VAD = Vitamin A deficiency
WIPO = World Intellectual Property Organization
WTO = World Trade Organization