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Results of an electronic forum

FAO RESEARCH AND TECHNOLOGY PAPER

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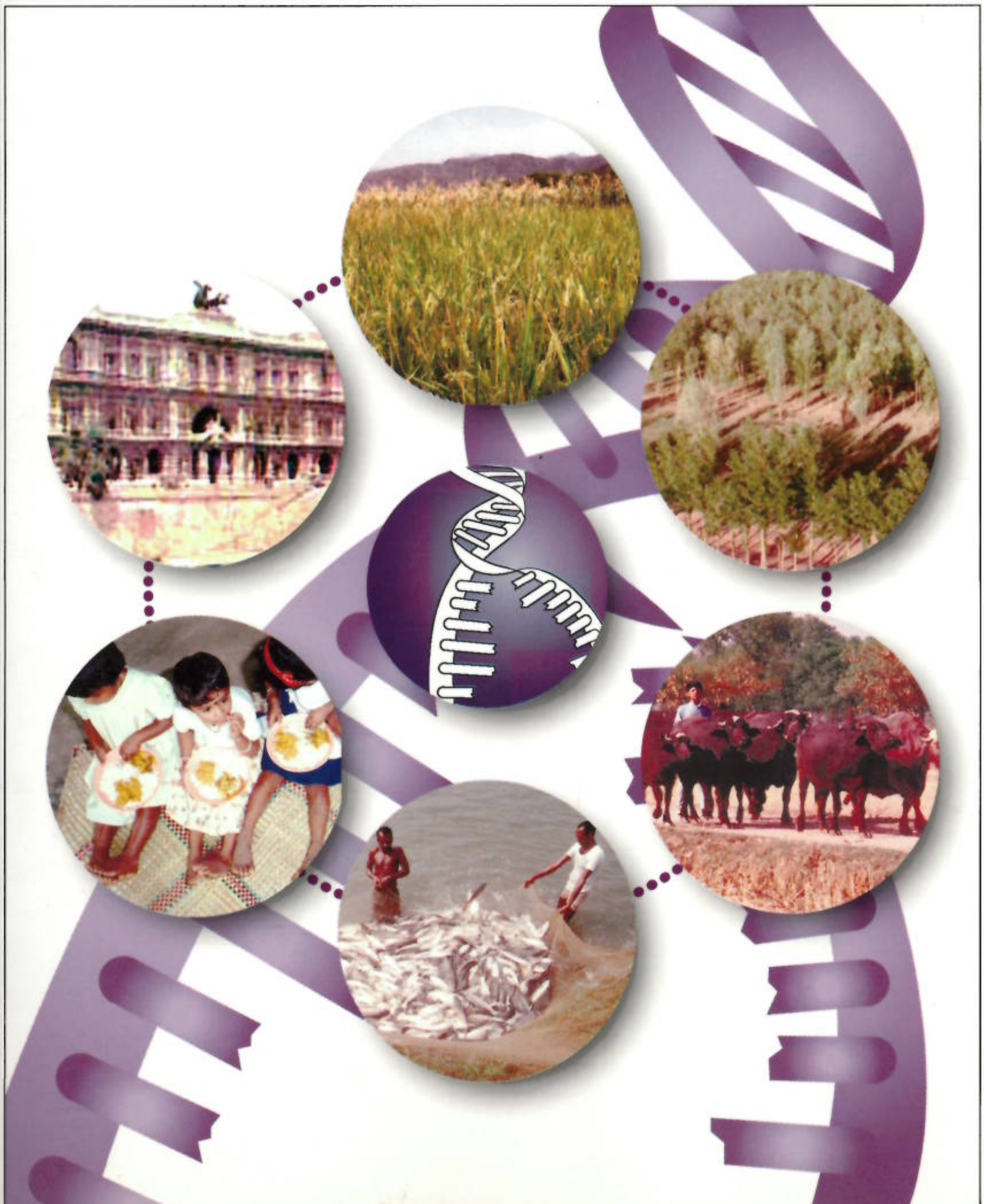

Food and Agriculture Organization of the United Nations

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John Ruane
and
Maria Zimmermann
Forum Coordinators

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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 (-196°C). 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