BIOTECHNOLOGY AND AGROBIODIVERSITY

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Summary

Biotechnology and agrobiodiversity strongly interrelate. Mutual influences traditionally occurred and shaped our current agriculture. However, the influence of biotechnology on agrobiodiversity has recently strongly increased as a result of the enormous developments in modern biotechnology, whether in *in vitro* technology, molecular markers or genetic modification.

In a sense, these effects are not really novel but fit into the longer-term industrialization of agriculture which started in the developed countries a century ago. However, biotechnology has accelerated and strengthened such effects.

These effects have been both positive and negative and will probably continue to be so. The balance between the positive and negative effects to a large extent depends on strategic choices and decision making by private companies, governments and their research institutions, and community organisations.

Among the outstanding positive effects of biotechnology on agrobiodiversity may be regarded as,

• the contribution to more efficient *ex situ* management of genetic resources, through the use of *in vitro* tissue culture and cryopreservation techniques

- the use of molecular markers to analyse the genetic diversity present in *ex situ* collections and in on-farm and *in situ* populations of crops and domestic animals and their wild relatives
- the potential to protect the markets of traditional and regional genetic varieties by monitoring the integrity of market produce offered as such
- the use of molecular markers to improve the breeding of new varieties with the help of genetic resources, increasingly of markers which directly relate to specific traits
- the potential to improve the nutritional quality of our food and the sustainability of our agricultural production by exploiting genetic resources not available to traditional breeding because of sexual barriers.

Major negative effects include:

- a) the contribution of biotechnology to a further narrowing of global crop and animal improvement efforts on a small number of species and a limited intraspecific genetic diversity, due to the high investments needed for biotechnological applications and the consequent access of biotechnology to a small number of players
- b) the increasing reliance on *ex situ* genetic resources as opposed to the maintenance of agrobiodiversity *in situ*
- c) the growing privatisation of genetic resources through intellectual property rights and the exclusion of these genetic resources from the genetic pools available for further breeding

Agrobiodiversity has become an increasingly useful source for crop and animal improvement since biotechnology has widened and facilitated the potential use of genetic resources. Useful traits can be much more easily linked to specific genes and gene complexes, and such genes can be transferred across traditional genetic barriers. These options have raised awareness about the value of genetic resources, but not on the need to maintain our genetic diversity *in situ* as part of wider agrobiodiversity.

Awareness raising and public discussions will continue to be needed to correct for the current imbalance between biotechnology and agrobiodiversity.

1. Introduction

For centuries traditional biotechnological processes have been used to contribute to agricultural production (see also - *Traditional Plant Breeding for Yield Improvement and Pest Resistance*) and food processing (see also - *Food Fermentation and Processing*). However, as a result of the recent advances in molecular biology and genetics, existing biotechnological applications have been refined and many new biotechnological tools have been developed. Modern biotechnology on agricultural production and food processing has accordingly increased. Traditional and modern biotechnology can be regarded as a continuum, with modern biotechnology characterized as laboratory-based and resource-intensive. As a consequence of its biological basis, the use of traditional and modern biotechnology shows strong interactions with agricultural biodiversity: biotechnological applications are based on biodiversity, and in turn influence biodiversity (see also– *Biotechnology in the*

Environment: Potential Effects on Biodiversity).

Various definitions of biological diversity or biodiversity (see also- *Biodiversity: The* Impact of Biotechnology), agricultural biodiversity or agrobiodiversity, and biotechnology have been given. Now widely accepted are the definitions in the Convention on Biological Diversity, agreed in 1992, for biological diversity and biotechnology. Biotechnology is defined as 'any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use.' It is clear that this definition encompasses both traditional and modern biotechnological applications. Biological diversity is defined as 'the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.' Questions of diversity within species, i.e. genetic diversity, can be addressed at the species, population, and within-population levels. Thus, this definition distinguishes three levels of integration with increasing complexity. Agricultural biodiversity, also known as agrobiodiversity, forms a subset of total biodiversity. It refers to biodiversity related to agriculture and can be described as 'the variety and variability amongst living organisms (of animals, plants, and microorganisms) that are important to food and agriculture in the broad sense and associated with cultivating crops and rearing animals and the ecological complexes of which they form a part.' It includes the diversity found in farming systems as well as their surroundings to the extent that the latter influences agriculture. Food processing technologies - strictly speaking - are not covered by this definition, and will not be discussed, although the relationship between biotechnology and agrobiodiversity also largely holds for these technologies (see also-Biotechnological Applications for Food Production).

The interactions between biotechnology and agrobiodiversity are manifold. Traditional biotechnological applications in particular make use of microbial organisms. They include:

- composting, the accelerated microbial degradation of organic matter (see also -Composting agricultural and industrial wastes);
- nitrogen fixation, based on the ability of bacterial symbionts of leguminous plants to fix atmospheric nitrogen (see also - *Nitrogen fixation biotechnology*);
- fermentation, generating alcoholic beverages and dairy products and preserving a large variety of meat and plant products (see also *Industrial Biotechnology*);
- ethnoveterinary practices aimed at protection of domestic animals against infectious diseases (vaccine production).

For these applications, specific microbial strains have co-evolved and often been selected. In other words, biodiversity has been exploited to allow for these traditional biotechnological applications. Modern biotechnology has developed much more refined tools to select and generate optimal microbial organisms for a larger set of applications, and each of these involves the use of specific traits generated and expressed in the microbial domain.

These applications, as well as applications making use of plant and animal biodiversity,

have contributed to the shaping of agricultural production. Cereals and pulses have been intercropped in all Centers of Origin of agricultural crops, an essential combination to guarantee high yields. Other crops, such as soy bean and enset (Ethiopia), have gained importance because protocols were developed to ferment the harvested products and allow for prolonged food storage. Ruminants (cattle as well as sheep and goats) have been selected for milk production concomitantly with the development of milk fermentation technologies.

Modern biotechnology has already influenced the genetic diversity of crops (see also -Transgenic Plants and Crop Protection through Pest-resistant Genes) and animals cultivated and raised in the fields by allowing for the rapid and wide-spread introduction of desired starting material through in vitro technology. It is now on the brink of more profoundly changing our agriculture, in particular by the generation of novel crop varieties containing traits which could not be incorporated before and altering our farming practices. In this way, biotechnology has also changed and will further change our agricultural biodiversity. It can improve our production systems and the diversity of products we desire. The question to answer is whether agricultural biotechnology will be able to change the current, often negative image of modern agriculture into a new image which stands for a more sustainable way of dealing with resources, people and problems, or is going to intensify current problems in agriculture concerning sustainability and biodiversity. Modern biotechnology also has a potential or actual influence on natural ecosystems, either by allowing changes in agriculture which affect natural biodiversity or by directly influencing natural biodiversity itself. These developments are now often discussed in the framework of biosafety policies (see also Biosafety in biotechnology; Biotechnology in the environment: Potential effects on *biodiversity*).

This introduction so far attempts to stress the continuum in the interactions between traditional and modern biotechnology and biodiversity. Also from another perspective, a continuum characterizes the influence of biotechnology on (agro) biodiversity in particular and agricultural practices in general. From ancient times onwards, farming practices, including animal and plant breeding, have profoundly influenced our agro-ecosystems and the biodiversity these contain, and thus this influence is not the prerogative of biotechnology but of technologies applied in agriculture in general. Impacts on biodiversity may not be different in nature, only in degree, from those of our traditional or conventional practices.

The term genetic resources refer to a resource-centered view on biodiversity. Accordingly, it is often stated that loss of biodiversity means loss of capital and potentially useful resources. The immediate relevance of agrobiodiversity concerns food production and the prime incentive to preserve agrobiodiversity is based on economics (see also *The Economics of Agrobiotechnology*). Although agriculture is both the predominant land-use system on earth and the largest global user of biodiversity, agrobiodiversity is a surprisingly minor topic in the global biodiversity debate.

The following text further elaborates the interactions between biodiversity and the applications of biotechnology. In particular, it focuses on the effects of the rapid developments in modern biotechnology on these interactions, both beneficial and

detrimental. It deals with the use of biodiversity in biotechnological applications, and with the subsequent effects of these applications on the biodiversity in farming systems and natural environments. Although a substantial part of research is currently devoted to the diversity of beneficial and noxious insects, microorganisms and other soil organisms, we have limited ourselves to the interface between agrobiotechnology and plant and animal biodiversity relevant to agro-ecosystems.

2. Technical aspects of agricultural biotechnology at the interface with agrobiodiversity

Modern biotechnology can be defined as all biotechnology that involves a laboratory phase in its development or application. The term stands for several different laboratory-based technologies that are used either independently or in combination with each other. These technologies are *in vitro* technology, marker technology and gene technology. More recent technological advances, commonly referred to as 'genomics', allow the application of former technologies in an (ultra)high-throughput context. As a consequence, genomics will further speed up the pace of (agro)biotechnological innovations. We will give a brief overview of the tools of modern agricultural biotechnology as applied to plants and animals. Although microbes are an integral part of agricultural systems, and microbial biotechnology is well developed, its application is predominantly in processing and food production. For an in-depth discussion of the tools briefly explained below, the reader is referred to related chapters in this theme (see *- Industrial Biotechnology*).

2.1 In vitro technologies

Modern plant biotechnology is based on hydroponics, the capacity to grow plants without a soil substrate in an aqueous solution of macro and micronutrients and light. Hydroponics has developed into a major technology for the mass propagation of highvalue vegetable crops. It also formed the basis for the development of plant cell and tissue culture techniques. Micropropagation allows the regeneration of complete new plants from leaves or shoot apexes; free from diseases, notably viruses, and thus a rapid clonal propagation of elite plant material. This is usually but not necessarily carried out in specialized laboratories. In particular the micropropagation of ornamentals and trees has become an important economic enterprise. The capacity of a single cell to regenerate into whole plants, is known as cell totipotency. It signifies the ultimate form of micropropagation. As an alternative application, in vitro somatic embryogenesis can be used for rapid propagation of plant material, and in various cases encapsulated embryos are replacing seeds. Also, the culturing of specialised plant cells in the form of mass cell suspensions has developed into a technology for the production of specialty chemicals. Finally, in vitro technology has been instrumental in the development of technologies as protoplast fusion, embryo rescue, mutagenesis and others that are part of modern plant breeding, as well as in the development of cryopreservation techniques, the storage of living cells at ultra-low temperatures (see also - Plant Cell Culture).

Storage of cells, tissues and organs of animal origin has also been achieved by cryopreservation (see also - *Mammalian Cell Culture*).

Micropropagation of plant material allows the production of millions of clonal progeny

that are essential identical. Nowadays, more than a thousand plant species are being propagated in tissue culture. The obvious advantage is that elite material can be quickly multiplied without changing the desirable genetic constitution of the material. Obtaining disease-free plants is another major advantage of the tissue culture approach. However, micropropagation in tissue culture also suffers from somaclonal variation, due to rearrangements and mutation of the DNA during the maintenance of cells in tissue culture. Tissue culture-induced somaclonal variation can also be exploited as a new source of genetic variation for crop improvement. This way, tissue culture, as well as mutagenic treatments, can contribute to a limited extent to an increase of diversity (see also - *Traditional Plant Breeding for Yield Improvement and Pest Resistance*).

In contrast to plant cells, animal cells are generally not totipotent. Although individual cells can be propagated in culture, regeneration of such cells into a new, fully developed animal is not known. What has been realized is the induction of directed differentiation (based on multipotentiality) of somatic mammalian and other animal cells (see also–*Transgenic Technologies for Animals as Bioreactors*).

In its effects, artificial insemination can be regarded as the animal equivalent of plant micropropagation. More recent and advanced developments have resulted *in vi*tro fertilisation combined with embryo transfer, widening the options for rapid propagation of desired genotypes.

2.2 Genetic modification and the sourcing of genes

In vitro technology formed a prerequisite for the development of genetic modification of plants. Genetic modification of plants combines techniques for plant tissue culture, techniques for cloning, *in vitro* amplification (PCR), and transfer of DNA, either by the use of the soil bacterium *Agrobacterium tumefaciens* as a vector, through electroporation or by the use of a particle gun. It is based on the ability to change the genetic constitution of a single cell and regenerate a new plant from that single cell (see also - *Genetic engineering of plant cells*) The aims of plant genetic modification are manifold. The technology can be used to transfer a gene from a wild relative simply to speed up breeding, but it can also be used for the transfer of genes into the plant gene pool that could not be introduced into plant genomes by other means.

In 1999 more than 70 transgenic crop varieties (see also - *Transgenic plants*) were registered for commercial cultivation. The crops involved include corn, soybean, rapeseed, tomato, tobacco, potato, chicory, papaya, pumpkin and clover. In 2005, biotech soybean continued to be the principal biotech crop, occupying 54.4 million hectares (60% of global biotech area), followed by maize (21.2 million hectares at 24%), cotton (9.8 million hectares at 11%) and canola (4.6 million hectares at 5% of global biotech crop area). During the first decade, 1996 to 2005, herbicide tolerance has consistently been the dominant trait followed by insect resistance and stacked genes for the two traits (James, 2005). In the future diversification may be expected not only from the private sector, but also from the (international) public sector. The CGIAR Challenge programme Generation focuses on drought tolerance in cereals, legumes and clonal crops. Genetic modification efforts of the M.S. Swaminathan Foundation regard combating drought and salinity in locally adapted rice and wheat varieties, whereas the

Indian Initiative on Crop Biofortification focuses on bio-availability and bio-efficacy with respect to iron, zinc and phosphor in rice, wheat and maize.

Beneficial applications of genetic modification in crop breeding and food production may include the following short-term options:

- Harnessing natural fungal resistance expressed in the seed phase for resistance in other phases of the plant growth cycle
- Developing non-toxin based insect resistance traits (e.g. hairiness)
- Changing seasonal conditions for plant growth, allowing the shift from winter crops to spring crops in moderate climates and allowing fallow land periods
- Developing crops with higher levels of insect tolerance

In order to improve or change a plant variety by genetic modification, a biotechnologist requires genes to code for the new character. As a consequence, biotechnology has a great need for well-characterized genes, preferably available as pieces of DNA or cDNA (= cloned RNA). Characteristic for genetic modification is that the origin of the gene of interest is not important. DNA is virtually independent of the organism from which it originates. The attitude of plant biotechnologists to plant improvement is often as straightforward as ambitious: for any trait desired, somewhere there will be an organism providing the genes that are able to do the job. The challenge is to find those organisms, to identify the gene or genes involved, and to transfer those genes into a suitable plant. Thus bioprospecting, the identification and evaluation of properties in organisms for potential exploitation, is currently becoming a major input in (plant) biotechnology. The suitable organism may be a plant, but may also be a bacterium or a whale: the concept of 'wild relatives' is of no relevance to biotechnology. The interest of biotechnology in genetic diversity is therefore unlimited and transcends the scope of gene bank collections or populations being conserved on-farm. Botanical gardens, national parks or pristine nature may be as useful, hence valuable, as the diversity in local farming communities. Any organism in any ecosystem may contain genes that are or may become of use for any application. All organisms should therefore be conserved. Biotechnologists are in a prime position to recognize the importance of genetic resources. Here the key issue is documentation. Which genes or properties or compounds are present in which organism; what is the function of these genes and compounds? And where is the organism and the relevant DNA or cDNA likely to be found?

Breeders and curators of plant genetic resources collections traditionally distinguish the primary, secondary and tertiary gene pools, based on the ease by which germplasm of different plants can be recombined. In line with this terminology, biotechnology relies on what could be considered the 'quaternary gene pool', encompassing all genetic material that occurs in nature but cannot be introduced into a plant by any sexual means. To fulfil a role in current plant biotechnology and plant genetic modification, genebanks might consider storing DNAs and cDNAs from a much wider range of species, forming part of this quaternary genepool. Furthermore, biotechnological tools might enable the much wider exploitation of indigenous knowledge on the properties of plants and microbial organisms which form part of the quaternary genepool, in food production and beyond. In the near future, biotechnology may also be able to create new diversity

that could be considered a 'fifth-level gene pool'. Examples of novel diversity created in the laboratory include the generation of new genes that encode proteins with improved functions by DNA shuffling, the random recombination of existing genes. Random shuffling of genes can be considered as the molecular equivalent of processes resulting in heterosis. However, this technique creates genetic diversity that does not necessarily have a counterpart in nature.

Genetic modification of animals is based on a combination of technologies (see also -*Genetic engineering of animal or mammalian cells*), as in the case of plants. It involves the genetic information and reproductive tissues that generate new organisms: nuclei, fertilized eggs, embryos, gonads or embryogenic stem cells, as well as the totipotent cells originating from the inner cell mass of the early blastula stage. Embryonic stem cells can be cultured *in vitro*, engineered and introduced in the inner cell mass of a suitable mammalian embryo. Gene transfer in animal genetic engineering is achieved either by microinjection, lipofection or electroporation.

In principle, new techniques involving inter-species somatic cell cloning and interspecies nuclear transfer technology allow for more efficient rescue of endangered animal species.

Discussions about the application of animal biotechnology run parallel to those on the application of plant biotechnology, but bio-ethical considerations are much more prominent in applications involving animals.

2.3 Molecular marker technology

A genetic marker can be defined as an observable trait at the morphological, cytological, chemical, protein or DNA level. Current molecular marker technology comprises protein-based and DNA-based techniques, whereas RNA-based marker techniques are under development. The more recently developed DNA-based markers are generally preferred, as they show no or little susceptibility to environmental or developmental influences, in contrast to the earlier protein-based markers, in particular isozymes. A DNA marker represents a short sequence of DNA, the presence of which is linked to a desired trait. In the last decade several marker techniques were subsequently developed, in particular RFLP (restriction fragment length polymorphism), RAPD (randomly amplified polymorphic DNA), AFLP (amplified fragment length polymorphism), and microsatellite (simple sequence repeat), SCAR (sequence characterized amplified region) techniques as well as the seemingly ultimate marker technique, scoring the SNP (single nucleotide polymorphism). In future, DNA sequencing may develop into the marker technology of choice (see also - *Methods in Genetic Engineering*).

The presence or absence of markers allows the genotyping of individuals and populations. In breeding, markers function as a flag. With these flags, complex or difficult-to-assay traits, such as quantitative traits based on a larger number of major and minor genes, can be evaluated and selected for more easily. An example where molecular markers may be used for crop improvement is improving resistance in rice against bacterial blight. Traditionally, single resistance genes are deployed in alternating

manner in modern rice cultivars to maintain appropriate resistance levels. A more sustainable strategy might be to combine several resistance genes (gene pyramiding). Evidence suggests that the deployment of four different resistance genes is more effective than their expected additive effect. Genetic markers are needed to allow for the intricate pyramiding of these genes.

Other types of markers, either DNA-based or protein-based, notably (monoclonal) antibodies, are used in diagnostics kits for a variety of applications, including the monitoring of plant and animal health.

2.4 Genomics and beyond

Since the 1990s molecular techniques to elucidate the DNA sequence of a given piece of DNA were gradually improved to such an extent that the goal of determining the full genome sequence of organisms became technically and economically feasible. This has resulted in a novel scientific discipline called 'genomics', basically the molecular characterization of whole genomes, both for its structure (structural genomics) and its function (functional genomics) (see also– *Bioinformatics on Post Genomic Era: from Genomes to System Biology*). Complete genome sequences of a variety of organisms are now available, including yeast, a nematode, the model plant *Arabidopsis thaliana*, and the major food crop plant rice, whereas current attention is focused on a series of genome sequences of agricultural interest, including sorghum, maize, Medicago, lotus, tomato and potato genomes.

Genomics has transformed molecular genetics from a one-gene approach to a more system-oriented science of pathways and interactions.

Large scale sequencing is also applied to DNA complementary to transcribed genes (cDNA) and this has resulted in large amounts of expressed sequence tag (EST) libraries. In addition, novel high-throughput technologies are available or are being developed for other molecules than DNA, such as mRNAs studied by genome-wide mRNA (transcript) expression profiling using microarrays (transcriptomics), proteins studied through profiling with two-dimensional gels and high-throughput mass spectrometry (proteomics), and a variety of metabolites and phenotypes.

Of particular interest for animal and plant breeding is the field of comparative genomics. In this approach the similarity of genes and gene orders is studied, e.g. between *Arabidopsis thaliana* and its cruciferous crop relatives. Comparative genomics will facilitate the use of structural and functional genomic information in crop plants.

Continuing developments in techniques will further speed up the identification of novel genes and their function. Genomics and its underlying technologies are resulting in an avalanche of biological data that feeds new developments in computational molecular biology and bioinformatics as an essential supporting research area. It can be expected that genomics will dramatically increase our understanding of genomes and the processes they encode. The enhanced understanding of genomes and genome action will allow a more efficient use of breeding and biotechnology.

2.5 The context of agricultural biotechnology

The increasing role of plant and animal biotechnology and genomics in agriculture should be seen in its historical context. Since the earliest days of animal and plant domestication, the main purpose of agriculture has been to secure sufficient food and feed. Although agriculture shaped our landscapes in many areas in the world and has acquired an additional value as bio-cultural heritage, world-wide goals of agriculture have not changed very much. The aim of innovations in modern agriculture is to further improve total agricultural production and its economic efficiency. Increasingly, sustainability of our production is recognized as essential criteria. The application of various technologies in the framework of the industrialization of agriculture has contributed to this aim. Modern agrobiotechnology is only a next contribution to the development of agricultural production systems.

Crop improvement with inputs from biotechnology may regard agronomic characters, e.g. reduction of the environmental impact of agricultural practices by conferring pest resistance, or increasing post harvest quality or reduced allergenicity of produce. In addition to such improvements, agricultural plant biotechnology may generate a diversification of the use of plants (see also *- Biomass and organic waste conversion to food, feed, energy, fertiliser and commodity products*). By modifying metabolic pathways, common crops can be converted into small factories that produce virtually anything on demand, from commodity chemicals to pharmaceuticals and cosmetics. Furthermore, the detoxification of contaminated soils with the help of specially tailored plants allows plant-based bioremediation. Likewise, animal biotechnology aims both at increasing the efficiency of animal production, and at novel exploitation of livestock, in particular for the testing and production of pharmaceuticals.

3. Agro-biodiversity as a source for biotechnological applications

The recognized benefits of biological diversity for the biotechnology industry are at least twofold. On the one hand, biological diversity significantly lowers the research and development costs of biotechnology industries because it serves as a highly productive *in situ* stock of genetic materials. On the other hand, biological diversity represents insurance for agriculture because it diminishes the risks of productivity variations.

Total estimated economic benefits of biodiversity worldwide are estimated at 115 billion US dollars for conventional crop breeding and at 40 billion US dollars for animal breeding. This figure concerns the introduction of new genes and subsequent crop improvement through crossing with wild relatives. Since 1945, global crop yields have increased with a factor of two to four, depending on the crop, and it has been estimated that 20 - 40 percent of this increase was based on genetic improvements. Similarly, milk production per dairy cow in western agriculture has increased from 3600 kg per year in 1936 to 8600 kg per year in 1995 (see also - *Economics of agro-biotechnology*).

Benefits arising from the use of biodiversity in agrobiotechnological applications are much more modest, in line with the relatively short development period of most biotechnological applications. Biodiversity forms a source for biotechnological applications aimed at the production of specific proteins and peptides, lipids and fatty acids, carbohydrates and secondary metabolites. Many transgenic organisms producing specialty products have been obtained by the introduction of genes encoding existing pathways in other organisms.

The economic benefits from biotechnology are currently estimated at 10 billion US dollars per year, half of which relates to agricultural production. Due to company secrecy, it is often difficult to obtain a detailed insight in the acquired benefits. However, some facts can be mentioned.

Crop losses due to pests and diseases may account for 20 to 40 percent of global productivity. Approximately half of current research and development expenditures in plant breeding focus on the introduction of resistances (see also - Crop protection through pest resistance genes). Novel resistances are based on genes from unrelated species exploiting the enormous diversity of mechanisms which occur in living organisms. In general, the plant breeding industry, in its search for new varieties, spent 6.5 percent of its research on the utilization of germplasm of wild relatives and landraces, in a five-year period in the 1990s. Research and development requires a constant yearly influx of genetic information from natural sources amounting to 6.5 percent of the total germplasm currently used in breeding. Biodiversity is also valuable to industries outside the realm of agricultural biotechnology, in particular for pharmaceutical applications (see also - Pharmaceuticals from algae). The value of all plant genetic resources lies in their utilization in crop improvement programmes. Utilization will only take place if knowledge over the germplasm can be generated and be distributed. Information sciences, in particular bio-informatics (see also -*Bioinformatics*), are essential tools in the proper analysis, storage and retrieval of large data sets generated with the use of biotechnological applications such as marker-assisted breeding and genomics. So, bio-informatics is an essential tool in the biotechnological exploitation of biodiversity.

4. Biotechnological tools in genetic resources management

Genetic resources form part of the biological diversity at the lowest integration level, i.e. the genetic diversity within species. The term genetic resources refer to the utilization that is made or can be made of this diversity for any specific purpose. Major areas of utilization of biodiversity are agriculture and health (pharmaceutical agents).

Due to several developments, in particular an increasing population pressure and growing food demands, habitat destruction, the development of global markets and changing consumer habits, genetic resources in agriculture have become severely threatened. In the twentieth century, world food production has become dependent on an increasingly smaller number of species, and within these species on a decreasing number of varieties or races. This process has first been widely recognised by scientists and breeders in the 1960s and is since known as genetic erosion (Box 1). Genetic erosion is regarded as a highly undesirable process since genetic resources will remain needed since they form the basis for crop and animal development for future food security and sustainable agricultural production. To prevent the irrevocable loss of genetic diversity, two major complementary counterstrategies were developed, i. e. *ex situ* conservation and *in situ* conservation of genetic resources. These strategies relate to

the maintenance of genetic resources outside and inside their natural habitats respectively. The *ex situ* conservation of crop and domestic animal genetic resources is mainly realised through gene banks (see also– *The Importance of Microbial Culture Collections and Gene Banks in Biotechnology*). The management of genetic resources in genebanks nowadays makes extensive use of various biotechnological tools. In other words, biotechnology helps to maintain the very genetic diversity which is threatened by developments towards uniformity in modern agriculture which in turn are accelerated and intensified by the emergence of modern biotechnology. Here we discuss the role of biotechnology in the *ex situ* management of genetic resources. In the following chapter we shall explain how biotechnology also threatens the existence of genetic diversity (see also - *Biotechnology in the Environment - Potential effects on biodiversity*).

Although an estimated 7000 other plant species have been used as food by humans at sometime, approximately 60% of global food supplies are now provided by rice, wheat and corn, and 90% by a total of thirty crops only.

The Republic of Korea reports that 74% of varieties of 14 crops grown on particular farms in 1985 had been replaced in 1993.

China reported that nearly 10000 wheat varieties were used in 1949, but only 1000 in the 1970s. 15 million hectares of hybrid rice in China share a common cytoplasmic male sterility source. Till 1970, about 5000 varieties of rice were grown in India, but currently about 500 varieties are grown of which 10 - 20 may be covering a large part of the country.

Only 20% of local maize varieties in Mexico reported in 1930 are still known today. It should be noted that loss of varieties does not necessarily mean loss of diversity, since this can be conserved in new varieties.

In a FAO monitoring programme on 6500 races in 170 countries the development of animal genetic resources diversity is followed. It appears that globally one third of these races is threatened with extinction, whereas in Europe even half of the remaining races is in danger. In particular, races of domestic birds disappear at a high rate, 63% now being threatened by extinction.

Almost 2 billion people depend at least partly on domestic animals for their livelihood and 12 percent of these people depend on them almost completely. In India, 50 percent of the indigenous goats face the threat of extinction, and an estimated 80 percent of all poultry produced are now from exotic breeds. China is home to the vast majority of the world's pig breeds; however, these are now very rapidly being replaced by exotic breeds, which have very different feed requirements, reproduction rates and meat qualities.

Box 1: Some facts on genetic erosion

4.1 Conservation

Crop genetic resources can often be maintained in the form of seed. However, for a substantial number of crops this simple method cannot be employed, either because of lack of storability of the seeds (e.g. tropical fruit trees), the clonal nature of valuable varieties (e.g. many root and tuber crops), or sterility (banana). In those cases alternative methods are used, including the establishment of field genebanks or the storage of plant material of genetic resources *in vitro*. The term *in vitro* culture covers a wide range of techniques under sterile conditions including seed germination, micropropagation, meristem culture and callus culture. *In vitro* culture has been widely used for propagation of agricultural and horticultural crops and for conservation of crop genetic resources, particularly with those crops which are vegetatively propagated or which have recalcitrant seeds which cannot be stored under conventional seed bank conditions. Over 1000 species are being propagated *in vitro*, with representatives from many different families.

In vitro techniques include the storage of plant material at lower temperatures to retard the growth of the plant material and so to diminish labour costs and risks of contamination; as well as cryopreservation of plant meristems at extremely low temperatures (in liquid nitrogen at -196 C). The latter alternative is resource-intensive and protocols have yet been developed for a limited number of species only.

Cryopreservation is the method of choice for the *ex situ* conservation of animal genetic diversity. For most domestic species, only the conservation of sperm forms a viable and cost-effective technology, but conservation of embryos and egg cells, e.g. in the case of poultry, will be increasingly employed.

In conclusion, *in vitro* storage technology is a major biotechnological contribution to the *ex situ* management of crop and animal genetic resources.

Molecular markers represent another biotechnological tool which is of growing importance in the effective ex situ management of crop and animal genetic resources and the in situ management of crop and animal populations. The last few decades have witnessed an ever increasing size of plant genetic resources collections concomitant with growing financial constraints and logistic collection management problems. Although genetic erosion in crop species is taking place at a rapid pace, there are still a virtually unlimited number of genetically different populations in many species. As the facilities available for storage and regeneration begin filling up, there is an increasing need for quantitative and qualitative assessment of the diversity present and its relationship to the total diversity available. Due to financial constraints, setting priorities for the inclusion of genetic resources in long-term storage collections has become a major issue. In the process of improving collection management efficiency, molecular markers may also be used to identify duplications within or between plant genetic resources collections. Duplications can then be removed from the collections. Given a pre-determined size of the collections, molecular markers may help in taking management decisions: marker profiles exhibit genetic relationships between the accessions in a crop collection and form an indication which genetic diversity is rare or over-represented. It thus helps in identifying genetic diversity for long-term conservation. Finally, markers can help to determine the origin of the material. More in general, molecular markers may help in understanding the genetic make-up of the species and its relatives.

Whereas most animal genetic resources collections are still being established, similar issues are at stake in the management of those collections. It will be obvious that maintaining animal genetic diversity collections in the field, *ex situ* or *in situ*, are at least as costly as in the case of crops. Therefore, *ex situ* cryopreservation forms a major contribution of biotechnology to the conservation of domestic animal genetic diversity. Again, the identification of those animals contributing most to the conservation of the species, is crucial given the limited financial resources available, and molecular markers form an essential tool to reach that objective.

Current economic systems hold no incentives for the conservation of genetic resources. This is reflected in the current debates on intellectual property rights in plant and animal breeding and the debate over the ownership of genetic resources.

4.2 Utilization

Probably more important, molecular markers can assist in the selection of specific breeding materials for utilization. It is expected that molecular markers will increasingly be related to functional diversity, rather than structural diversity: with the advance of genomics, markers will be linked to genes responsible for specific traits rather than to locations in the genome or even to random DNA sequences only. And genes encoding desired traits can be selected and followed in breeding programmes, or isolated and used for genetic modification of unrelated crops. Developments in genomics will result in a shift in paradigm. The potential use of a sample will no longer be dependent on the phenotypic scoring of a particular trait, but on the identification of specific genes known to contribute to specific traits, whether these are expressed in the sample material or not. The first plant genome which has been sequenced in that of the weed Arabidopsis thaliana, a popular laboratory species because of its small genome, its small plant size and short regeneration cycle, properties which all facilitate genetic research. Detailed knowledge of the genome structure and genetic composition of this model species will allow extrapolation to gene functions of related crops, e.g. cabbage, rapeseed, mustard and radish. Similar model species are rice for the cereals, and tomato for the solanaceous crops. Likewise, knowledge on the cattle genome can be used to understand the genetics of the small ruminant species sheep and goat.

The utilization of genetic resources collections is hampered by the high costs and long time frames necessary to transfer desired genes from the germplasm in these collections to elite breeding lines. The genetic information stemming from genomics will facilitate such utilisation through fine-tuned targeting of the desired information in the donor materials and the subsequent breeding steps.

To utilize the wealth of structural information obtained from the genome through plant genomics an understanding of the functions encoded by DNA sequences is essential. To

understand these functions we need to study phenotypic variation and for this biological resources are a prerequisite.

Biotechnology has the capability of moving genes from one organism to any other. In other words, any non-cultivated organism can be regarded a potential provider of genetic information, potentially of prime commercial value. Biotechnology has transgressed the traditional boundaries of breeding to limited germplasm pools.

5. Impact of biotechnology on agrobiodiversity

Biotechnology has provided tools to more effectively maintain and utilize genetic resources ex situ as well as on-farm, and has thus contributed positively to the conservation of genetic resources. A limited contribution of biotechnology to the development of novel genetic resources in agro-ecosystems may also emerge in the near future, as a result of introgression of novel traits by means of genetic modification. However, the increasing role of biotechnology also forms a potential threat to the survival of agrobiodiversity in the environment, whether this is in the farmer's field (onfarm), or in natural ecosystems (in situ). The impact of biotechnology on agrobiodiversity retains several components, which are very different in nature but do closely interrelate. While new technological developments take place at a rapid pace, their environmental and social implications are not well understood, let alone under control. Biological, socio-economic and cultural effects can be distinguished, and the various biotechnological applications differ strongly in the degree and direction of their effect. Similarly, technological risks can be distinguished into two types: technology inherent risks concern the risks to human health, ecology, and the environment, and technology derived risks which are the result of the specific use of the technology, either reducing or enhancing the poverty gap, reducing or protecting biodiversity, and centralising or decentralising the control over and access to technology and its products.

In general, the effects of biotechnology resemble the effects of the industrialization of agriculture. The 'container term' industrialization of agriculture refers to several developments in the global organisation of agriculture which have profoundly changed food production over the last century. Biotechnology can be regarded as the latest factor contributing to this industrialization and changing our food production and, in parallel, our agrobiodiversity. Earlier developments in the framework of industrialization of agriculture include:

- 1. a gradual specialisation in breeding from expert farmers to small specialised familyowned breeding companies which have gradually merged into a small number of large international breeding companies;
- 2. the creation of global markets in which a few crops dominate and are the main target of modern breeding efforts;
- 3. the growing importance of food processing, in which a limited number of raw product materials are used to generate a large array of consumer products (e.g. the dairy industry), and in which different crops can be used to generate the same consumer goods (e.g. vegetable fats);

4. uniformization standards applied to new crop varieties to allow for mechanical treatment and harvesting of crops, and to animal races to rear them under standardised conditions.

All these effects already contributed to an increasing uniformity in agriculture, and this is a potential effect of biotechnology as well. The selection of agronomically important traits in breeding and the use of a small set of resulting improved varieties in crop production results in a reduced genetic diversity in the field.

A recent development is the shift from material-based to knowledge-based economies, which has caused an increased search for novel forms of information. An example is the accelerated search for biological resources that provide useful natural products and genetic sequences, especially for pharmaceuticals and crop breeding. As new compounds and genetic sequences are discovered, they are incorporated not only into the economies of industrial societies but also into their intellectual property regimes (see also - *Social, educational and political aspects of biotechnology*).

Some of the effects are discussed in more detail below.

5.1 Biological effects

In vitro technology allows for the rapid propagation of plant material. In tissue culture, plant parts or plantlets are grown under sterile conditions and split in several subsamples at regular intervals. This material can then be regenerated and reintroduced to *in vivo* conditions, resulting in a fast multiplication of the plant material. The effect on agro-biodiversity depends on the use of this technology, or in other words on the material that is rapidly propagated and multiplied. If rapid micropropagation is used to distribute a small number of novel varieties into agro-ecosystems which traditionally exhibit a large array of varieties, the net effect of this biotechnological application on agro-biodiversity is clearly negative. However, if the technology is used to maintain or revive traditional races, which have been totally or largely lost in the field because of natural factors (drought, diseases) or human factors (civil unrest, market changes), then the net effect is positive. A net positive effect is also reached if tissue culture propagation is used to clean traditional varieties from diseases occurring in the field followed by rapid propagation of healthy plant material. Such tissue culture approaches are in particular and successfully used for root and tuber crops, such as potato, sweet potato, cassava, as well as banana.

Artificial insemination (AI) of domestic animals is generally used to promote the spread of genetic properties of a very small number of animals. Sperm of a recent Dutch top bull belonging to the dominant Friesian-Holstein race has been used in over a million inseminations worldwide. *In vitro* fertilisation (IVF) is another capital intensive technology in animal breeding only used for a narrow, highly valued set of breeding materials. In theory, AI and IVF can also be used to enlarge the genetic diversity in our domestic animal populations, but in practice such applications have occurred only rarely, except to avoid the negative effects of inbreeding.

Molecular markers represent a biotechnological application with arguably the most

profound effect on current breeding. They are used for many divergent purposes. The technology helps in identifying diversity and understanding pedigrees, and in breeding efforts, and applications are diverse.

On the one hand, molecular markers have allowed to determine the genetic differences and distances between traditional varieties of major and minor crops, and to understand how small-scale farmers generate new farmers' varieties containing germplasm from traditional and modern backgrounds. This utilization of the technology has helped in acknowledging the value of farmers' varieties, in other words of on-farm managed biodiversity.

On the other hand, since public breeding efforts have strongly declined over the last two decades and commercial breeding is carried out by a decreasing number of players, the genetic diversity of germplasm used as a source to produce new varieties has also decreased. Because molecular marker technology is still a capital-intensive application, this has probably accelerated the global merging of breeding companies, and the narrowing of genetic diversity actually utilized in breeding.

It can be concluded that as such the direct biological effects of molecular marker technology on agrobiodiversity can be regarded as small, since they only represent a tool for analysis, which speeds up breeding processes and facilitates the study of diversity, but does not really influence diversity directly. Its socio-economic effects are much more profound.

Genetic modification could give us a future where perennial crops have in-built resistance to pests and diseases, fix their own nitrogen, and give higher yields. We may eventually be able to produce entirely new plants designed specifically to produce foods, medicines, industrial chemicals and fuel. At the same time, genetic modification forms a technology with a potential direct influence on the environment (see also -Environmental Biotechnology) and consequently on agrobiodiversity. Governments, scientists, environmentalists and industry disagree strongly about the ecological effects of transgenic crops. Although ample evidence shows that the industrialisation of agriculture has resulted in a strong reduction of biodiversity worldwide, it is yet unclear whether the widespread cultivation of transgenic crops will make things better or worse. Concerns in society on these effects have been raised since the early development of this technology, in fact by the scientists who developed the technology in microorganisms in the early hours. In the late 1970s, a plea for a moratorium on the application of genetic modification and the introduction of genetically modified organisms in the environment was aired by a group of leading scientists headed by the Nobel Laureate Paul Berg, and this plea was largely respected until appropriate legislation had been introduced. Since then, utilization of the technology has been defended and promoted by many proponents, scientists, industrialists and government alike. A major argument to promote the development and use of transgenic crops and domestic animals has been the notion that new transgenic varieties and races could enhance food production, improve food quality and allow for more sustainable agricultural practices. Parties opposing the release of transgenic organisms in the environment, the field trials and the commercialisation of new transgenic crops and animals, stress the risks and lack of sufficient knowledge concerning the spread of the

'transgenes' and their 'carriers' in the environment (see also - *Why genetic engineering causes concern - social, cultural and political impacts*). Also, the production of plant and animals to suit specific environments could lead to the transformation of yet more land, presently occupied by natural ecosystems, into agricultural land, in particular in the case of marginal ecosystems in the tropics.

The biological effects on agrobiodiversity are related with the intended use of transgenic organisms and the perceived risks of such use. The risks include the following:

- the transgenic plant itself becomes a weed; this is less likely for more domesticated plants which are less competitive to other plants (e.g. maize, banana) and also depends on the introduced trait; whereas herbicide resistance may have an advantage for farm weeds, it will be of no benefit in natural ecosystems; however, increased drought tolerance may change the competitiveness of the transgenic plant under drought conditions in both environments;
- the introduced DNA is sexually transmitted into wild relatives; transferred genes will spread more rapidly if these encode an added advantage; many foreign genes when transferred from crops to wild relatives will in fact decrease the fitness of the wild relative, resulting in a strong selection pressure against survival of that gene and trait; foreign genes encoding resistance against pests and diseases may increase the fitness of hybrids between crops and wild relatives and result in novel aggressive weeds or plants that swamp not so much the farm land but wild populations; weeds having multiple resistances obtained from traditionally bred crops have already been reported
- the introduced DNA is transmitted horizontally to unrelated species, including species of other kingdoms; the effects of such transmission will be highly dependent on the genes transferred and the acceptor organism.; it can be argued that all transferred genes already exist in some niches and thus only the frequency of such event involving a specific gene is influenced through the introduction of that gene into a domesticated species by molecular means
- the impact of broad-spectrum herbicides in combination with herbicide-resistant crops may be far more damaging to agro-ecosystems than traditional narrow-spectrum herbicides; it is not the volume of herbicides but their impact on non-cultivated species in the agro-ecosystem which counts (Box 2).

Substantial evidence for spreading of resistance traits introduced by traditional breeding from cultivars to wild and weedy relatives in lacking. However, long term monitoring of commercially grown transgenic crop varieties will be needed to evaluate the risks for spreading of traits introduced through molecular technology. This is exemplified by the following scarce date. The transfer of 12 marker genes from cultivated to wild sunflowers occurred at high rates, 28% of the marker genes being detected in wild sunflowers close to fields where sunflowers had been grown for 10 years. In a population of wild strawberries growing within 50 meters of strawberry field more than 50% of the wild plants contained marker genes typical for the cultivated strawberries.

Insect resistance crops (maize, cotton, potato, canola) based on the bio-insecticide producing genes from Bacillus thuringiensis (Bt) have been released since 1996. Insecticide products containing Bt have been widely used in agriculture and forestry

with an excellent safety record. The issue at stake is not the inherent toxicological risk of Bt but the environmental impact of crops producing Bt insecticidal toxins. The impact involves the management of non-target pest species, the persistence of the Bt toxins in plant debris in the soil, the consequences of outcrossing to wild and weedy relatives, and the development of Bt toxin resistance in pest populations. The development of resistance against Bt toxins in pest insects and the consequent loss of an effective insecticide would not be an novel phenomenon; however it could make the contribution of biotechnology to an increasing food production a short-lived one. Risk should be balanced against benefits, in particular a reduced use of chemical insecticides. Whereas the introduction of Bt crops has resulted in a substantial reduction of the use of chemical insecticides in Western agriculture and in an enhanced functioning of naturally occurring biological control (predator fitness), this effect may be different in tropical agro-ecosystems, e.g. in rice production, where the use of chemical insecticides has remained much less intensive.

Most currently introduced and widely grown transgenic crops confer tolerance to herbicides or insects. Herbicide tolerance concerns the wide-spectre compounds glyphosate and glufosinate, whereas insect resistance in based on a toxin derived from the soil bacterium Bacillus thuringiensis. The potential long-term negative impact – either direct or indirect – of insects-resistant plants on non-target insects, birds and mammals, the potential transfer of introduced genes to other species in agro-ecosystems and natural ecosystems, and the effects this would have on organic production feature high in the research list of governments.

Box 2: Some consideration on biotechnological risks

In general, most Centres of Diversity of crops are situated in tropical countries, and thus in those countries the probability of the second type of events, the transfer to wild relatives, is higher. Also, remaining agrobiodiversity is largest in tropical countries and thus the impact of any effect on agrobiodiversity is likely to be larger as well. Genetic transfer to native ecosystems not only undermines native ecosystems as such but also their function as a reservoir for genetic resources *in situ*. Moreover, agro-ecosystems provide food chain links between native species and crops. Environmental risk assessments of the introduction of genetically modified crops, obligatory in developed countries, have only limited relevance for agro-ecosystems in developing countries, where fewer resources are likely to be available for proper risk assessments.

Probably the most likely effect concerns the fact that transgenes will spread from one crop variety to another. Although this event would occur more easily in outcrossing species, such events will take place eventually even in inbreeding species. These events will pose problems to those production systems and their environments which are meant to remain GMO-free, such as organic production systems. Various reports have suggested the likelihood of geneflow for canola and maize. Such findings have been reported from Mexico and Brazil, although these findings have remained heavily contested.

As control on the propagation of animals is easier to achieve than control of plant propagation, negative ecological effects which can not be contained are regarded less

likely.

5.2 Socio-economic effects

The socio-economic effects of biotechnology on agrobiodiversity may be considerable. These effects all relate to the relatively high investments and human expertise which are needed to employ biotechnological applications. Generally, sufficient resources can only be generated by a small number of stakeholders in the private and public sector. Very few exceptions yet exist, for example the M.S. Swaminathan Foundation in India, an NGO that performs its own biotechnology programmes. Stakeholders mainly invest in a small number of major food crops, and within those crops only a limited diversity is readily accessible to these companies and institutions. Finally, returns on investments can only be realised if the projected markets for the generated products are sufficiently large. Thus, few players use a limited part of available genetic diversity to improve a small number of crops which can then be grown over extended areas for large markets. These developments characterize not only the efforts of the private sector, which accounts for more than 80 percent of international biotechnology research, but also of the public sector, in which the role of the national agricultural research systems (NARS) in many tropical countries has decreased due to declining funding in comparison to the role of the private sector. It can be argued that this is not a direct effect of the increasing role of biotechnology, but of changes in investments in agricultural research in general. The high investments needed for biotechnological applications have only diverted more funds to the improvement of a more limited set of genetic materials. Here, four consequences of this development are highlighted.

In the first place, public and private breeding programmes in many traditional regional crops have been reduced considerably, and improvements in sustainable production, yield and qualities of these crops have been very modest in comparison to a limited set of varieties of global food crops. A growing number of farmers are therefore attracted to the use of uniform varieties of few staple crops, and much of traditional genetic diversity is banned to the farm gardens or completely lost. Only in those agroecosystems which are not suitable for the production of the uniform varieties of professional breeding, for instance because of large fluctuations in weather conditions or adverse soil conditions, traditional genetic resources adapted to local circumstances and traditional cropping practices remain. This phenomenon has often been mentioned as an effect of the Green Revolution, which took place in the 1970s and 1980s.

In the second place, since the production of commercial high-yielding varieties requires high investments, market prices for the seed of such varieties is comparatively high and only wealthier farmers can afford the purchase of commercially produced seed. Transnational companies are building monopolies over transgenic seed production, and thus may eventually disadvantage poor farmers in developing countries (see also-*GMO-Technology and malnutrition*). Farmers in developing countries might be forced through the use of biotechnology in crop breeding to yearly buy patented seeds or at the best pay yearly license fees for its continued use. Such improved varieties often need fertilisers and pesticides for optimal yields, which add to farmer's costs and risks.

In the third place, the proliferating use of biotechnology in the food industry has already led to declines in markets for crops like sugar, cocoa butter and food oils because substitutes can now be manufactured. New biotechnologies potentially reduce the close relationship of specific crops and their natural environment with particular products. Agricultural production will become much more flexible from a biological and geographic point of view.

In the fourth place, the role of intellectual property rights will change as a consequence of the marketing of genetically modified crops (see also - Inventions, patents and morality). Commercial varieties are traditionally not protected or only protected by plant breeders' rights. A growing number of countries has now implemented legislation which prohibits the marketing of protected seeds, but allows the use for breeding and as seed within the farm (known as breeder's exemption and farmers' privilege respectively). Genetically modified crops will be protected by patents on the introduced transgenes and the patent legislation does not allow for breeding and free regrowth of the seed. This means that genetically modified crops may no longer be used for smallscale breeding efforts by small breeding companies or farmers, and that farmers who grow crops in which these transgenes occur, consciously or unwillingly introduced, trespass legal provisions. The net effect of the introduction of patent rights in breeding will be that breeding with any genetic material is no longer a universal right (also regarded as part of farmers' rights) and this may negatively influence further crop improvement, small-scale and large-scale alike. In particular, the development of local genetic diversity may be hampered.

5.3 Nutritional and cultural effects

As a general feature, since biotechnology contributes to a growing uniformity in food production, it will also result in a growing uniformity in food consumption. Novel varieties in staple crops improved with the use of molecular markers or containing transgenes will outcompete and largely replace traditional varieties because of a greater abundance and lower prices. Traditional varieties will only survive where these have distinct added value, in particular in processing and taste or in their use in cultural practices. Long-duration rice varieties with specific taste, treasured in many Asian countries, are an example of the latter category.

Molecular markers may help protect traditional varieties and regional products as these act as an instrument to monitor and control whether a product which is marketed for its specific quality does indeed adhere to the agreed standards or not, and to prevent misappropriation of traditional or modern farmers' varieties by third parties. For instance, molecular markers have been selected and developed to guarantee the origin and quality of Basmati rice, cultivated in the Himalayan foothills and exported to Western consumer markets. In other words, here biotechnology supports protection of traditional genetic diversity.

Vitamin A deficiency affects 14 million children under five years of age, and iron deficiency forms a problem for one billion men and women in the developing countries. Recently, the development of a new transgenic rice variety was reported, containing elevated levels of vitamin A and iron, correcting for food deficiencies in the poor parts of the Asian populations. Whereas this new rice variety, termed Golden Rice, may indeed improve the nutritional status of many people, such improvement may also be

reached by more attention for and higher investments in the improvement and promotion of traditional vegetables in Asia, which may also form a major source of vitamin A and iron. Choices between investments in the biotechnological improvement of rice and the improvement and promotion of traditional vegetables thus may result in different food habits and therefore exert divergent cultural effects.

Glossary

Biosafety: issues regarding the safe transfer, handling and use of living modified organisms resulting from modern biotechnology **Centre of Diversity:** the geographic region exhibiting a major degree of genetic diversity for a certain crop or domesticated animal species, including regions where the species was first domesticated Consultative Group on International Agricultural Research **CGIAR:** the conservation of components of biological diversity outside Ex situ their natural habitats conservation: cultivated ecosystem and accompanying cultural practices for **Farming system:** food production process altering the genome of an organism by the use of Genetic modern biotechnology in such a way that a novel combination modification: of genetic material is obtained; use of recombinant DNA methods to alter or improve living organisms facility where genetic resources are maintained ex situ Gene bank: In situ the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in conservation: their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties genetic diversity within a species Intraspecific diversity: techniques and practices used in a laboratory setting under In vitro techniques: sterile conditions multiple, physically distinct forms of enzyme, each encoded by **Isozymes:** one of a family of highly similar genes an identifiable physical location on a chromosome using Molecular molecular techniques whose inheritance can be monitored markers: in situ conservation of domesticated or cultivated species **On-farm** conservation:

Bibliography

Almekinders C and De Boef W. Encouraging diversity. The conservation and development of plant genetic resources. 2000. Intermediate Technology Publications, London, UK [Around 80 briefly described cases which illuminate the accumulated experience in utilizing and managing crop genetic diversity in farmers' fields]

Anon. 1996. Report on the State of the World's Plant Genetic Resources for Food and Agriculture. FAO, Rome, Italy [Formal report describing an assessment of the state of plant genetic resources and current effectiveness of and capacity for their conservation, development and use]

Anon. 1999. The Global Strategy for the Management of Farm Animal Genetic Resources: an executive

brief. FAO, Rome, Italy [Document aiming to increase awareness of the many roles and values of animal genetic resources, and providing a framework for efforts to make better use of, develop and conserve these resources]

Bunders J, Haverkort B and Hiemstra W. 1996. Biotechnology; Building on Farmers' Knowledge. Macmillan Education Ltd, London, UK. [This book looks at the application of biotechnology to agricultural development, including farmer-based and science-based biotechnology in its socio-political context]

Callow JA, Ford-Lloyd BV, and Newbury HJ. 1997. CAB International, Oxon, UK (This book illustrates the application of biotechnologies in the various areas of plant genetic resources work]

Heywood VH. 1995. Global Biodiversity Assessment. United Nations Environment Programme, University of Cambridge, Cambridge, UK (An exhaustive standard work for decision-makers, officials, and scientists, providing a scientific analysis of issues, theories and views regarding global aspects of biodiversity]

Persley GJ and Lantin MM. 2000. Agricultural biotechnology and the poor: proceedings of an international conference, Washington, D.C., 21- 22 October 1999. CGIAR, Washington, USA(Proceedings of a conference promoting the safe use of biotechnology to reduce poverty and improve food security]

Pistorius RJ and Van Wijk JCAC. The exploitation of Plant Genetic Information: Political Strategies in Crop Development. 1998. CAB International, Wallingford, UK [A historical-political analysis of strategies to manage plant genetic resources world-wide]

Wood D and Lenné JM. Agrobiodiversity: characterization, utilization and management. 1999. CABI Publishing, Oxon, UK [This book relates the evolution of agrobiodiversity and its successful management to the broader environment]

Biographical Sketches

Bert Visser is a molecular biologist by training. He is the director of the Centre for Genetic Resources, The Netherlands, which holds the mandate for the implementation of the Dutch plant genetic resources programme, and maintains a gene bank of 20 different crops. He is involved in policy development of PGR and in genetic resources management aspects, and participates in various international programs on this issue. He is particularly interested in complementarities between ex situ and in situ conservation approaches.

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