Biodiversity: the Impact of Biotechnology

- ***Biodiversity and population growth***
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- ***Economic and political considerations***

EUROPEAN
FEDERATION
of
BIOTECHNOLOGY

TASK GROUP ON
PUBLIC PERCEPTIONS
OF BIOTECHNOLOGY

Biodiversity is important for several very different reasons: the intrinsic value of species in the wild, the many varieties of plants, animals and micro-organisms used worldwide for farming and other human activities, as a genetic resource in healthcare, agriculture and food production, as well as for aesthetic and recreational purposes.

This briefing paper reviews the various aspects of biodiversity in relation to biotechnology. Biotechnology, while controversial particularly in agricultural applications, has the potential to improve sustainability in several ways and is expected, thereby, to help maintain natural as well as agricultural biodiversity. This paper results from the combined contributions of scientists, industrialists, and governmental and public interest organisations across Europe. It is intended to provide information and does not represent the views or policy of the European Federation of Biotechnology or any other body. The overall aim is to provide balanced information and advance public debate.

The essence of biodiversity

Biodiversity today is the result of 3.5 billions years of evolution. All the living organisms we know today, as well as those that ever lived before, have developed from one original micro-organism through the processes of mutation and selection. Separate species arose when mutations between relatives no longer allowed for interbreeding, for instance after geographic separation. The vast majority of species that arose, probably more than 99%, disappeared again. In the long-term view there has been no such thing as sustainability, only change. Clearly however today, with man's massive influence on the globe, change and the loss of biodiversity is much faster than at any time before, making concern with sustainability important.

Biodiversity can be distinguished at three different levels, ecosystems, species and genes. But there is no generally accepted definition of biodiversity and there is no general consensus on how to appreciate changes in biodiversity from scientific, political and/or normative perspectives. The number of species of animals, plants and micro-organisms today is probably 10 million or more, of which only 1.4 million have yet been named. Virtually all the 40,000 vertebrate animals and most of the 250,000 higher plant species are known. On the other hand there are likely to be over a million species each of fungi and nematodes (thread-like worms), and several million insects, of which only 70,000, 13,000 and 950,000 respectively have been identified. Only about 5,000 bacteria and viruses have been identified individually, yet their total number may also be well in excess of one million.

The various species of plants and animals do not live an independent existence but are associated in specific communities and ecosystems to form more or less stable associations. One such association, for instance, is the tropical rain forest which is generally thought to have the highest degree of biodiversity. Biodiversity needs to be considered both in terms of the number of species present and also of how many individuals there are of each of the species. Often the number of species in a given ecosystem is taken as a measure of the biodiversity of that system because other criteria are more difficult to apply. In addition, it is still not clear whether the total amount of living matter at a given location, the biomass, is generally dependent on biodiversity: some researchers claim that loss of species is not compensated by additional growth of other species and thereby leads to a reduction in total biomass.

In agriculture, some 7,000 species of plants are used by farmers throughout the world, but only 30 species provide 90% of our calorific intake, the top three crops being

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wheat, rice and maize (corn). Within the predominant crop species there are many hundreds of thousands of varieties (landraces) adapted to local climates and farming practices. Much of this large crop diversity is important for providing starting material for breeding. However, the genetic diversity in crops is much less broad than that of plants or animals living in the wild which indicates the importance of wild species for agricultural breeding programs.

Human population growth.

The world population has risen from 2.5 billions in 1950 to 6 billion today and is expected to reach some 9 billion in 2050. 800 million people are currently undernourished. Over 95% of the expected population increase will be in the less developed countries (LDCs) and most will occur in their cities, requiring more living space, water, energy, wood, food and services. For 1995 to 2020 the largest relative population increase (80%) is expected in sub-Saharan Africa rising from 500 to 900 million. Whether the HIV/AIDS epidemic in this region will substantially affect population dynamics is not clear as most of those currently infected are in the reproductive age range.

Loss of biodiversity

Loss of biodiversity can be measured by a loss of individual species, groups of species or by decreases in numbers of organisms. The major threats to global biodiversity are, firstly, habitat loss (mostly through expansion of cultivated land and of cities and roads) and, secondly, the introduction of exotic species. Habitats can also be damaged by flooding, lack of water, climate changes etc., natural or man-made.

Since tropical humid forests are particularly rich in biodiversity, their destruction is disproportionately damaging. It is estimated that only half of the original 16 million km^2 of these forests a century ago are left, with about one million km^2 being destroyed every 5 to 10 years. Biodiversity is not homogeneously distributed but rather there are areas with particularly plentiful biodiversity ("hotspots") of particular interest for conservation.

Imported plant and animal species threaten the native ones by being highly competitive and often by lacking local predators. One of the most extreme examples is seen in the pampas of Argentine, a flat grassland with a moderate climate, from which nearly all the native grasses have disappeared and have been replaced by European plants. This invasion was brought about by European farmers, bringing animals and crops, as well as accidentally spreading many different weeds and was already noted in 1833 by Charles Darwin. Islands are particularly threatened by invaders, as is well documented for Hawaii, New Zealand or the Galapagos Islands.

Biological control agents are often introduced into agricultural ecosystems intentionally to control pests or weeds without resorting to chemical controls. Whilst there have been many welcome successes, such systems may also go wrong. One example is the introduction of the seven-spot ladybird which was intended to control the Russian wheat aphid in the US. This proved to be a competitor of the native ladybird, which then disappeared. The mongoose, an Indian mammal, was introduced to several islands (Fiji, Mauritius, Hawaii) to keep rats and snakes under control: it lead to the extinction of several endemic birds, reptiles and amphibians. Introduced wasps have been seen to kill and possibly extinguish endemic butterflies.

Are transgenic plants as such prone to spread? In the longest term experiment so far, four different crops (oilseed rape, potato, maize and sugar beet) were grown in 12 different habitats and monitored over a period of 10 years. In no single case were the genetically modified plants found to be more invasive or more persistent than their conventional counterparts. However, one would not expect this to be the case unless the transgene increased its fitness in the wild. There is no plausible reason why crops that have for centuries depended for survival on human care should become weeds because of the addition of one or a small number of well-characterised genes, in addition to the many thousands of genes they already carry. Even so, monitoring of transgenic crops needs to continue for more than ten years. Large acreages of a single variety without rotation, should be avoided with any crop, since monocultures are more prone to disease and pest outbreaks.

Conservation strategies

Conservation may be *in situ* in a more or less natural or habitat or *ex situ* in some purpose-built environment depending on the particular case. *In situ* conservation involves the maintenance and protection of natural habitats while botanical gardens, seed banks and zoos are used for *ex situ* conservation.

Conserving a substantial fraction of the tropical rain forests would still allow half or so of their indigenous species to be preserved by selection of the most appropriate "hot spots". Protecting large tracts of land poses major socio-economic and political problems. How forests can be kept free from encroachment by hungry people in search of potential farmland is far from clear. A viable strategy may be to find sustainable livelihoods for rural populations compatible with conserving tropical rain forests and this is being attempted with mixed success. Policing alone will not be successful over vast territories, as seen in the combating of drugs.

Conservation also embraces agricultural biodiversity such as crop varieties, land races (local varieties), semi-domesticated varieties and crop relatives. The role of indigenous communities in maintaining agro-biodiversity is stressed by the Global Biodiversity Assessment and the Leipzig Plan of Action, two recently concluded international agreements.

The Convention on Biological Diversity (CBD)

The United Nations adopted the Convention in 1992 and it entered into force in 1993. This is the first time that a large majority of States, though not the USA, have agreed to a legally binding instrument for biodiversity conservation and the sustainable use of biological resources. A radical change brought about by the CBD is the recognition that States have a sovereign right over biodiversity within their own territory, while previously living organisms were considered the common heritage of mankind. Under the terms of the CBD, living organisms or their products may only be removed from a country under mutually agreed conditions. Action is delegated to the national level obliging States to assess biodiversity, enact legislation for its conservation *in situ* and *ex situ*, and to enforce legislation within national boundaries.

Biotechnology is particularly affected by Articles 16 and 19 of the CBD since they require a fair and equitable sharing of benefits derived from the use of genetic resources. This includes providing facilities and financial means for technology transfer and open access to scientific and technical information.

The CBD has only been in operation for a few years and so it is too early to assess its long-term effects. As far as biotechnology and "bioprospecting" are concerned, it will take time to establish smooth administrative procedures to allow simple routine implementation of close collaborations. Only if national authorities from countries rich in biodiversity as well as pharmaceutical and other companies see the advantages to be gained from such collaboration will the system expand. One example of a joint effort in "bioprospecting" is the search for specific active ingredients of plants by the Merck Company in the tropical forests of Costa Rica which brought the country 2 million USA dollars over a five year period as well as the potential of royalties if profitable products emerge.

The Cartagena Protocol on Biosafety

The CBD provided a basis for developing an international agreement regulating the cross-boundary movement of living GMOs, called "living modified organisms" in the Protocol, which after a lengthy debate was agreed on in Montreal in early 2000. The main aim of the Protocol is to ensure that GMOs would not endanger biodiversity in the recipient countries; in addition it also covers potential threats to human health. In practice the Protocol will primarily affect the importation of transgenic seeds. It requires the exporting country to provide enough scientific information to allow the importing country to judge risks and then to issue, if the product is judged safe, an "Advance Informed Agreement".

A newly established Biosafety Clearing House collects and distributes relevant information, as defined by the Protocol. Based on the "Precautionary Principle" import licences can be refused, even when there is no clear-cut proof that the product is dangerous to human health or the environment, but such decisions need to be based on a risk assessment. The Protocol is construed to be as important as the World Trade Organisation (WTO) agreements which do not allow countries to prevent the import of products unless there are sound scientific reasons showing that the product may cause harm to human health. This apparent lack of priority between the CBD and WTO agreements may lead to some future difficulties. The Protocol will become operational when it is ratified by 50 nations, presumably in 2002.

Biotechnology for the acquisition of knowledge

Biotechnology can be used as a tool for acquiring scientific knowledge or to intervene directly in plant and animal breeding and, in particular, to transfer genetic information from any other organism to a crop or farm animal. Taxonomy, one of the sciences necessary to study biodiversity, uses molecular markers to identify individual strains of organisms or to identify species in much the same way as is done in forensic medicine to identify criminals. In seed banks genetic fingerprints are used to establish the origin of a seed or the relatedness of plant varieties.

Biotechnology is also useful for following genetic markers in plant and animal breeding done by conventional means. By analysing a few cells of the newly born calf or of the newly sprouted crop and looking for the presence or absence of certain genes it is possible to predict properties of the progeny which will show up only later in life such as the characteristics of a cow's milk or a crop's expected resistance to a plant disease. These applications of biotechnology to farm animals (not to humans) are hardly controversial.

Direct gene transfer to crops and farm animals

In 2000 there were about 44 million hectares world-wide planted with commercial transgenic crops mostly in the USA, Canada, Argentina, with smaller amounts in China, Australia, South Africa, Mexico and Spain. Soybean and corn ranked first and second with 25.8 and 10.3 million hectares. Cotton and canola accounted for about 5 and 3 million hectares, whilst only small areas of transgenic potato, squash and papaya were grown commercially. Herbicide tolerant varieties dominated with 74%, while insect resistant varieties made up 19%. Virus resistant crops were quite small. USA farmers adopted transgenic crops rapidly because of the economic benefits they offered.

The most noticeable difference to the farmers was the saving on herbicides. Many also found the new crops needed less frequent sprayings and allowed "no till" (no ploughing and no harrowing) management. These benefits may offset the initial higher costs of the new transgenic seeds. Clearly these considerations only hold for countries with agricultural and economic systems similar to those of the USA and not for developing countries. Whether in the near future there will be an expansion or a reduction in the area of transgenic crops grown will depend on market forces, the public perception of risks and benefits, as well as on the emerging national and international regulatory framework.

A large number of transgenic crops are in the development stage, including many tropical crop plants; most of them will only come on the market in a few years, if at all. They are likely to show benefits for the consumers and some may be of particular interest to farmers in tropical countries. Two rice varieties currently being developed should lead to important health benefits. "Golden Rice" contains increased levels of vitamin A and another variety has more iron in the grains than usual, a clear benefit to anaemic women and their children.

Several lines of transgenic farm animals have been produced but none have been commercialised. Some lines are made for the pharmaceutical industry to produce drugs in their milk.

Others may show improved resistances towards certain infections or produce novel enzymes. Transgenic salmon that grow faster than normal have been developed and have roused considerable concern amongst ecologists, particularly regarding their potential to compete with native salmon in the wild. Here many environmental issues still need clarification.

Native biodiversity and biotechnology

Biodiversity in the wild has been massively reduced in the industrialised countries over many centuries and about half the tropical rain forests have already been destroyed. How then can the rest be preserved, given that the world population is increasing rapidly and more food has to be produced regionally?

Yields of cereals in LDCs have gone up very considerably in the last forty years primarily as the result of the Green Revolution. However, the annual growth increases in cereal yields in LDCs have slowed down from about 3% during 1967-82 to about 1% per year from 1993 onwards. This lowering of the rate at which yields have increased means that productivity will probably not keep up with the demands of increased populations. The consequences for biodiversity are devastating as more land will be required for farming which will primarily come from areas with high native biodiversity, and in particular tropical rain forests.

The single most promising way to avoid habitat destruction is to increase farm yields in a process that has been called the "Second Green Revolution". Several components will be required including training and education of farmers (in particular of women who do most of the farm work in LDCs), more favourable economic and political climates, availability of farm credit schemes, etc. In addition, technical contributions will be necessary and, in particular, improved seed produced either by traditional crop breeding or by modern biotechnology. Reliance will have to be more on the latter since traditional breeding appears to have reached a plateau in yield and is slower, less precise and only feasible when interbreeding is possible. So agricultural biotechnology, which is viewed frequently in the public debate as harmful to biodiversity, is, paradoxically, likely to contribute to conserving it.

A more limited concern that largely affects Northern Europe is the conservation of native plants and animals, in particular birds, in farmed areas. Their habitats are fields, hedges, roadsides and fallow land where they depend for food on insects and seeds produced by weeds in or near crops. Computer models suggest that more intense weed control measures may lead to smaller amounts of seeds being available to birds. This depends far more on weed management regimes rather than on transgenic plants. Herbicide tolerant beets allow farmers to control weeds later by treating after the seedlings have emerged. The more efficient methods may allow setting aside of more land. Setting aside more farmland requires financial incentives.

Agricultural biodiversity and biotechnology

Could newly introduced transgenic crops transfer genes to native wild plants and thereby change important characteristics of the wild plants? Gene transfer between cultivated and wild plants has always occurred within the limits of species if the two types of plants were in close proximity and flowered at the same time.

No new problems can be expected from transgenic plants except if the gene transferred from the GMO to the wild plant significantly increased the biological fitness of the recipient. This generally seems unlikely *a priori* and can, and should, be checked experimentally by risk assessment. Some people feel there is a crucial difference between transfer of genes from conventionally bred plants to their wild relatives and transfer of man-made transgene constructs from a GM plant into a gene pool. Whether ecological risks may result from the introduction of a man-made gene construct into the gene pool of a species is a different question.

Farmers all over the world use a remarkable number of landraces and varieties of many different crops. These are usually closely adapted to the local climate and topography, and are also used to produce foods for different purposes. Will the traditional varieties and landraces disappear when, and if, transgenic crops are introduced? Will only one or very few varieties dominate in the field? To judge by what has happened on the US soybean market, this will not be the case.

Although virtually all herbicide resistant soybeans derive from a single transformation event in Monsanto's Roundup Ready soya, hundreds of different varieties have been derived from it by different seed companies using traditional breeding to develop soya varieties that suit different climatic and soil regions. This shows that at least with this dominant transgenic crop biotechnology has not led to a loss of agricultural biodiversity. On the other hand, judging from the last 100 years in Europe, the diversity of varieties of farm animals and crops has, in fact, diminished considerably, but not because of any biological hazard emanating from some of the breeds, but because farmers need to produce economically. Many old varieties of apples have disappeared, for example, because of the preference of food retailers and consumers.

The rapid consolidation in the global seed market may be a concern in this respect and anti-trust legislation may be needed to prevent the dominance of oligopolies with limited competition between few producers. It can be argued that only wealthy farmers will be able to afford transgenic seeds. However, the technology is well suited to small farmers, since it is packaged in a small seed grain, which can be reproduced locally. However, if the seeds are to reach small farmers, there need to be many seed outlets (public cooperatives or private companies) and adequate agricultural extension programmes.

Economic and political considerations

Under what economic and political conditions will biotechnology benefit agricultural productivity and thereby help biodiversity? The original green revolution which improved wheat and rice production in Asia was initiated by research carried out in the public sector. Today's innovative research in biotechnology is mainly done by a few large companies with modest contributions from public sector and small companies. Companies strive for intellectual property rights (IPR) through patenting for return on their research investment. This is largely unavoidable with the present IPR systems. Provisions need to be made so that the agricultural research institutions of LDCs obtain access to information as well as patented materials and procedures needed for regional farmers. Unfortunately financial support to the agricultural research systems of LDCs has been substantially cut in the last ten years: this trend endangers world food security and needs to be reversed.

A limited number of transfers of specific patents to LDCs has already occurred from companies such as Monsanto and Syngenta for producing virus-resistant sweet potatoes and Vitamin A enriched golden rice. This approach, including the possibility of enforced licensing, is probably more practicable than changing the world's patenting system which does, however, need to be adapted in order to deal with living organisms. A new issue arising in the field of IPR is the attempt to protect traditional, indigenous knowledge through novel international legislation.

Lack of food appears to be, and is largely, a problem of distribution; there is not sufficient food available to those who need it. The poor simply do not have the money to buy enough. Since in LDCs most of the poor still live on the land, it is here that production has to be increased so that there is not only enough for survival but a surplus which can be sold to buy other goods and services. Increasing local agricultural productivity is the most effective way to do this and should, according to many economists of the public sector including those of the UNDP, embrace modern biotechnology as an important component.

Conclusions

The issues involved in the interaction between biodiversity and biotechnology have far-reaching consequences and need to be subject to an open and well informed dialogue in society. The discussion needs to include all the different stakeholders, including farmers of LDCs, scientists, industrialists, public interest organisations, policy makers and the media. Cultural values involved in farming and food production need to be taken into consideration, just as much as the emotive aspects of eating and drinking.

Agricultural biotechnology may have quite different impacts on biodiversity, depending on what particular application is considered and how it is applied. The results will depend both on the agricultural as well as societal context. If in the LDCs, new transgenic seeds are only available to a small group of large farmers, this may lead to large monocultures and a modest improvement in sustainability with little alleviation of poverty. Biotechnology has the clear potential to save native untouched land, particularly in tropical rain forests, by reducing or eliminating the pressure to bring more land into cultivation. The UK Nuffield Council on Bioethics concluded that because of this potential of agricultural biotechnology "The moral imperative for making GM crops readily and economically available ... is compelling.". Similar conclusions were reached in a joint report by the Science Academies of India, China, Mexico, the United Kingdom, Brazil and the USA as well as the UNDP stressing that there is a clear need for this technology. These and other sources from the public sector maintain that agricultural biotechnology has the potential, when judiciously applied, to increase farm productivity amongst the poor in the LDCs. As a consequence some native biodiversity can be expected to be saved.

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