BIODIVERSITY: THE IMPACT OF BIOTECHNOLOGY

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1. Introduction

The Convention on Biological Diversity requires that all Member States take measures to preserve both native and agricultural biodiversity. The intrinsic value of species and ecosystems, in addition to their value as starting material for finding new products, is the basis for these measures.

The biggest threat to biodiversity is habitat destruction. The ever increasing spread of cities and the accompanying expansion of agriculture must be held largely responsible.

Humid tropical forests are particularly valuable reservoirs of biodiversity and are currently being seriously threatened. As the human population expands, the need for food is expected to double in the next 30 years with the ensuing threat of massive habitat destruction particularly in the less developed countries. Increasing crop productivity on the land already under cultivation would prevent or at least reduce habitat destruction. One of several measures aimed at increasing yields is the use of better seeds, including those enhanced by modern biotechnology. Many other measures in the technical, socio-economic and political fields need to be taken at the same time in order to balance intensification and sustainability of modern agriculture.

Modern biotechnology offers new means of improving rather than threatening biodiversity. If properly tested for both risks and benefits to humans and the environment, transgenic crops are more likely to increase agricultural biodiversity and help maintain native biodiversity rather than to endanger it, in contrast to the claims of many environmental groups. Such applications need to be judged by the criteria of improved sustainability and compared to current as well as alternative farming practices.

2. The Essence of Biodiversity

Biodiversity is the multitude of different living beings in a particular ecosystem or on the whole earth. Biodiversity can be seen and studied at different organisational levels: genetic, organismal and ecological. It touches both upon native environments on land and sea as well as agricultural and other man made surroundings.

2.1 Native biodiversity

The biodiversity we observe today is the result of 3.5 billion years of evolution. Through the processes of mutation and selection all living organisms we know today, as well as those that ever lived before, developed from one single-cell micro-organism. How this first living being arose 3.5 billion years ago is still a matter for speculation. This unitary origin explains why all organisms share the same basic chemistry: DNA is always the storage molecule of genetic information and the complex process of protein biosynthesis is virtually the same in all organisms. Metabolic pathways too, are similar in all organisms, e.g. the reactions by which energy is generated or the way fatty acids, sugars and amino acids are made. Separate species arose, when mutations between relatives no longer allowed for interbreeding, for instance after geographic or reproductive separation.

Dinosaurs are by no means the only creatures of the past that became extinct: far more organisms lived at some time on our earth than are living here today. The vast majority, probably more than 99%, of species that arose on this globe, disappeared again. This shows that evolution is an ongoing process, with species coming and going. This dynamic situation is important when discussing the conservation of species living here today. In the long term view, there has never been any stability of life on earth - only change. However, these changes were very slow compared to the length of a human life, or even compared to the time humans have existed. Clearly, today, with the massive amount of human interference on the globe, changes are much faster than at any other time in the last 65 million years, the point at which the trilobites and later the dinosaurs and many other creatures vanished from the surface of the globe in a relatively short time period.

As suggested by Raven, the number of species of plants, animals and eukaryotic micro-organisms is probably around 10 million today, but only 1.4 million have been characterised and given a name by scientists. There is a large variation in what is known about the different groups. Virtually all of the 40’000 vertebrate animals are known and most of the 300’000 vascular plant species as well. On the other hand, there are likely to be over a million species each of fungi and nematodes, of which only 70’000 and 13’000 have been named. There are thought to be far more than a million different insect species as well. With prokaryotes the situation is even more extreme: about 5000 bacteria and viruses have been named individually, yet the total number in both of these two groups may well according to Bull be in excess of one million. Since many micro-organisms and viruses are associated with specific plants and animals, Staley considers their own biodiversity will depend on the biodiversity of their hosts, as well as the micro-organisms’ own host range.

All the different species of plants and animals are not living an independent existence, but are associated in specific communities and ecosystems to form more or less stable associations. One such association is, for instance, the humid (and dry) tropical forest which is generally thought to have the highest degree of biodiversity, with more tree species per km^2 than there are tree species in North America or in Europe, as discussed by Burslem. Another example is specific types of alpine meadows or specific sorts of rivers or ponds. Biodiversity needs not only to be considered in qualitative terms of the species present, but also in quantitative terms considering how many individuals of certain species of plants and animals are present. With large mammals this is quite easy to determine, but impossible with micro-organisms. Often the number of species found in a given ecosystem is taken as a measure of the biodiversity of that system: other criteria are more difficult to apply.

In this paper we will concentrate on terrestrial biodiversity, although it is clear that streams, lakes and oceans are the habitats of a vast biodiversity of animals, plants and micro-organisms. In addition, as calculated by Naylor, they are an important source of protein as food for humans and feed for farm animals, with about 120 millions tons of catches per year in aquatic systems.

2.2 Agricultural biodiversity

In addition to biodiversity in the wild, there is the biodiversity of organisms used for farming and other human activities. In agriculture, 7000 species of plants are used by farmers somewhere in the world, but only 30 species provide 90% of our caloric intake as observed by Heywood. Within these preponderant crop species there are many hundred thousand varieties (landraces, cultivars) adapted to local climates, farming practices, cultural predilections like taste, colour, structure, ability to store the products etc.. Much of this large crop diversity is important for providing starting material for breeding [see also– *Conventional Plant Breeding for Higher Yields and Pest Resistance*]. However, it must be recalled that the genetic diversity found in crops is much less broad than the genetic diversity observed in plants or animals living in the wild, which points to the importance of wild species for agricultural breeding programs. The top three crops worldwide are wheat, rice and maize (corn) with around 500 million tons annual production each. Traditional breeding brought us in the trap of narrowing down the genomes, and wisely used biotechnology could bring back at least that part of genetic diversity which enhances pest resistance and perhaps yield.

There are many indications that mixtures of varieties of a crop or of different crops may give higher yields and be more resistant to pests and diseases than monocultures, as reported recently by Zhu for rice in China [see also– *Biotechnology in Rural Area*] . However, even in mixed cultures high quality, well defined varieties and pure seeds are required and the sustainability of mixed cropping related to pest management has still to be proven. In addition, it is still not clear, whether in natural, non-agricultural habitats yield is basically dependent on biodiversity. On the basis of the same experiments, some researchers claim that loss of species leads to a reduction in biomass, while others disagree, as demonstrated by Hector and by Kaiser. There may not be generally valid correlations between biodiversity and biomass yield, neither in agricultural nor non-agricultural settings.

2.3 Human population expansion

The one species that is still globally expanding in numbers are humans. The world population has gone up from 2.5 billions in 1950 to 6 billion today; it is expected by the UN to reach 8 billion in 2015 and 9 – 10 billion in 2050. Over 95% of the expected population increase will be in the less developed countries (LDCs). In those countries, most of the population growth will occur in the cities. The additional population will require more space to live in, more water, more energy [see also– *Bioenergy-a sustainable solution for developing countries*], more food and more services.

For the years 1995 – 2020 the largest relative population increase (80%) is expected in Sub-Saharan Africa: in absolute numbers it is expected to go from 500 to 900 million, as indicated by the Population Reference Bureau. The HIV/AIDS epidemic with an estimated 65 million infected today worldwide and 25 million infected in Sub-Saharan Africa, is likely in the next 25 years to affect population dynamics at least for the countries with the highest infection rates. In these areas economic growth is dropping by around 1% per year because of HIV/AIDS as estimated by Bread for the World. In the context of this paper it is important to realise that the FAO estimates that there are globally over 800 million people who do not have enough to eat today and it is imperative that more food be produced and made available to them, also through poverty alleviation as emphasized by Sachs & Reid [see also– *Bio-Refinery – concept for sustainability and human development*].

3. International agreements

In view of the importance of biodiversity for the future of mankind, several international agreements have been reached. Since this has only occurred in the last few years, the long term impact of these agreements can not yet be estimated.

3.1 The Convention on Biological Diversity (CBD)

Recognising that biodiversity of organisms in the wild should be maintained both for their own intrinsic value, but also on practical grounds, the United Nations prepared this Convention and succeeded in having it adopted in 1992. 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 organisms were considered the common heritage of mankind. Living organisms or their products may, under the terms of the CBD, only be removed from a country under mutually agreed conditions. The CBD is a comprehensive approach to biodiversity conservation of both wild and domesticated species. It aims at conservation at the genetic, species and ecosystem levels. As reviewed by Buhenne-Guilmin 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.

The field of biotechnology is particularly touched 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 sovereignty over biological resources means that no-one can remove specimens of plants, animals or micro-organisms from a country without the prior consent of that country. One example of a joint effort in "bioprospecting" is a search for specific active ingredients of plants by the Merck Company in the tropical forests of Costa Rica. This brought the country 2 million dollars over a five year period, as well as the potential of royalties, if profitable products emerge, as reported by Manteo. A small number of similar agreements have been concluded elsewhere in the world.

The regulations of the CBD have only been in operation for a few years. It is too early to assess their long term effects. As far as biotechnology and "bioprospecting" is concerned, it will take more 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 or other companies see the mutual advantages to be gained from such collaboration, will this system spread. One of the real obstacles in developing new drugs are the exorbitantly high costs of drug testing needed to be done to meet strict and justified regulation before marketing. The expectations of some LDCs to make rapid earnings may have been too optimistic. The search for natural, highly active pharmaceuticals in wild plants may often be more cumbersome than laboratory searches using genomics, proteomics, rational drug design and combinatorial chemistry.

3.2 The Cartagena Protocol on Biosafety

The CBD provided a basis for developing and formulating a further international agreement, namely one regulating primarily the trans-boundary movement of living GMOs. After much debate in 1999, the new protocol was agreed on in early 2000 under the name of the "Cartagena Protocol on Biosafety". The "Intergovernmental Committee for the Cartagena Protocol on Biosafety" had its first meeting in Montpellier in December 2000. It paved the way for launching a pilot phase of the "Biosafety Clearing House", a centre for information exchange as explained on the web. The latest meeting (COP-MOP3) took place in Curitiba, Brazil in March 2006 as seen on the web site of the Convention on Biological Diversity.

The Protocol is a world-wide regulation for the transfer, handling and use of living GMOs, particularly crop plants that may have an adverse effect on biodiversity, also taking into account risks to human health and focusing on transboundary movements. It makes explicit reference to the precautionary approach. It establishes an Advance Informed Agreement (AIA) procedure for imports of GMOs intended for introduction into the environment and an alternative procedure for mass movements of GMOs intended for food, feed and for processing (commodities). The permit for transboundary movement will or will not be issued on the basis of a risk assessment procedure by the national competent authority. The Protocol does not pertain to pharmaceuticals or other non-living products made by genetic modification.

In practice, the Protocol will be most important for the import of transgenic seeds. It requires a risk assessment by the national authorities and allows countries to reject GMOs. The protocol specifies that "lack of scientific certainty due to insufficient scientific information and knowledge regarding the extent of the potential adverse effects …. shall not prevent the party from taking a decision:" This may or may not be in agreement with the WTO rules, but will need to be tested in the courts. If there are disputes between the interpretation of the Protocol and the WTO regulations, which allow for trade barriers virtually only if there are scientific reasons to do so, the outcome of such disputes will depend to a considerable degree on the quality of scientific data assessing benefits and risks of GMOs.

The Protocol has become operational in 2003, after ratification by 50 nations and has now been signed by over 100 (excluding, importantly, for instance the US). The Protocol will, as pointed out by Mahoney, be a challenge to the scientific community to provide solid scientific data to convince national authorities of the benefits of transgenic crops and their relatively low and manageable risks. It is far too early to make any assessment of the Protocol's effect. Hopefully it will allow (and not prevent) planting GM crops that may have real advantages for LDCs, while at the same time minimising their risks to humans and their environment. Some scientists have become altogether sceptical of the usefulness of the Cartagena Protocol pointing out that decisions on the introduction of new technologies need to balance risks and benefits and not be based only on risks. The Protocol is by them considered as overburdened by administrative activities and abused as a platform by those opposing green biotechnology and therefore no longer necessary, as expressed by Ventura, a scientist from Jamaica.

4. Loss of biodiversity and conservation

Losses of biodiversity are undoubtedly occurring in many parts of the globe, often at a rapid pace. These losses require countermeasures such as an increased effort towards conservation by many different means.

4.1 Reduction of biodiversity

The loss of biodiversity can be measured by a loss of individual species, groups of species or decreases in numbers of individual organisms. In a given location the loss will often reflect a degradation or a destruction of a whole ecosystem. Recently the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) of the CBD ranked the priority of threats to global biodiversity in the following manner: first comes habitat loss (most of it through the expansion of cultivated land), second comes the introduction of exotic species. Habitat loss comes not only from taking more land under the plough, but also from expanding cities and road building. In addition, habitats can be damaged by flooding, lack of water, climate changes, salination etc., all phenomena, which may be both natural and man-made.

Since tropical humid forests are particularly rich in biodiversity, their destruction is disproportionately damaging to biodiversity. It is estimated by Pimm and Raven that of the original 16 million km^2 of these forests known a century ago, only half are left, with about one million km^2 being destroyed every 5 to 10 years. Burning and selective logging may damage an even greater area. Biodiversity is not homogeneously distributed over the humid tropical forests, rather there are hotspots with a particularly high level of biodiversity. The hotspots are according to Myers of particular interest for the implementation of conservation measures.

The second most important reason for loss of biodiversity is invasion by exotic plants and animals. Knowingly, or unknowingly, imported plant species threaten the native ones by being highly competitive and often by lacking local predators, such as insects or birds. One of the most extreme examples is seen in the pampas of Argentine, 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, importing animals and crops, as well as accidentally spreading many different weeds. This phenomenon was already noted in 1833 by Charles Darwin, as recorded by Crosby. Still today, droves of gardeners transport seeds all over the globe and never think of the possible threat to biodiversity, as suggested by Ammann in 1997. It is estimated by Sukopp & Sukopp that one in ten imported plants may spread in a modest way and that one in a hundred may turn into a nuisance weed. Even in today's Europe invasion by exotics may threaten ecosystems. In the Ticino region of Southern Switzerland *Robinia pseudoacacia,* a native of North America, is displacing chestnut and oak trees, whilst in the Northern regions of the country *Solidago canadensis* is replacing native Irises in swampy areas. Islands are particularly threatened by invaders, as is well documented for Hawaii, New Zealand or the Galapagos Islands. For North America it has been estimated that damage caused by exotics amount to137 billion dollars a year, as calculated by Pimentel. Although such calculations are fraught with uncertainties, there is no doubt that the costs of exotics are tremendous.

Exotic biological control agents are often introduced into agricultural ecosystems on purpose, in order to control pests or weeds without resorting to chemical controls agents. Whilst there are some success stories, Strong pointed out that such systems may also go wrong. One example is the introduction of the seven-spot ladybird which was intended to fight the Russian wheat aphid. The consequence, however, was the disappearance of the native ladybirds, for which the seven-spot import was a competitor and an actual predator. Another example is the decimation of the large American moths, which are killed by European Compsilura flies, introduced nearly a century ago to control the gypsy moth. Field experiments recently done by Jensen showed that caterpillars of the American moth Cecropia were killed by massive infestations with Compsilura maggots.

Whether transgenic plants are specifically prone to spread in the long term, cannot be said today on the basis of experimental evidence. However, one would not expect this to be the case unless the transgenic plant had an increased fitness. There is no good argument why crops that have for centuries depended for survival on human care should become weeds just because of the addition of one or a few well characterised genes, in addition to the many thousands of genes they already carry. However, this issue needs to be studied in a case by case manner, keeping in mind that the absence of a negative effect can never be proven with absolute certainty under all circumstances. The results of a fairly long-term study of the performance of transgenic crops in natural habitats were recently presented by Crawley. 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 case were transgenic plants found to be more invasive or more persistent than their conventional counterparts, in agreement with the general hypothesis put forward above.

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