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Biotechnology: Tools for conserving Biodiversity and Sustainable Agriculture

Abstract

The loss of India's forests and bioresources is occurring at an alarming rate, a consequence of increasing population pressure, agricultural land degradation, urbanization, deforestation and negligence. Plant genetic resources are the major biological basis of the world food security. Biodiversity is the store house and acts as a cushion against potentially dangerous environmental changes and economic reforms. Such a buffer is facing threat due to manmade and ecological disasters. Hence, there is a growing recognition worldwide that conservation and sustainable management of bioresources are pressing priorities in the world today. Traditional means of germplasm storage and conservation of plant genetic resources has been immensely useful and are not without drawbacks. The choice of conservation methods and techniques depend on the objectives of the particular conservation effort, the breeding system and behaviour of the species in question as well as the available resources including funds, trained personnel, infrastructure and technologies. Thus utilizing the biotechnological approaches towards the improvement of in situ and ex situ conservation programmes are becoming vital. Integrating biotechnology in conservation programmes is a prerequisite to achieve success in sustainability and to complement the existing technologies.

Keyword: Bioresources, Genetic Conservation, Biotechnology, Biodiversity loss, Sustainability

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Introduction

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 Biodiversity can be distinguished at three different levels, ecosystems, species and genes. 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. The distribution of biodiversity is uneven on the earth because of the different environmental conditions. Warm humid tropical areas are rich in biodiversity compared to temperate and polar areas. The countries like Brazil, Columbia, Mexico, Indonesia, Peru, Malaysia, Ecuador, India, Zaire, Madagascar and Australia are known as **Megadiversity countries** because of their rich biodiversity. In India, over 1, 15,000 species of plants and animals have already been identified and described. Vast majority of species that arose, probably more than 99%, disappeared again. 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. Rapid biodiversity loss worldwide could be attributed to the deforestation, forest fragmentation, invasion by invasive species, Overexploitation due to increasing population, environmental pollution, global warming, climate change and commercialization of agriculture and forestry.

Biotechnology for the acquisition of knowledge

The Convention on Biological Diversity (CBD) defined biotechnology as "any technology application that uses biological systems, living organisms, or derivatives there of, to make or modify products or processes for specific use." In a broad sense, the definition covers many of the tools and techniques, which have been commonly used in agriculture and food production, processing, and utilization. In a narrow sense, however, it encompasses DNA techniques, molecular biology, and reproductive technological applications dealing primarily with gene splicing and recombination, and genomics. 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.

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.

Role of Biotechnology for Conservation

Biotechnology is invaluable in research on conservation of bioresources. Although modern biotechnology is a newly introduced science (less than 50 years old) its impact has greatly excited the imagination and provoked the concern of almost every part of the society worldwide (Eneobong, 2003). The richness of plant and animal diversity in developing countries is a major asset in agricultural development and, therefore, the conservation of such resources is fundamental to the progress and usefulness of biotechnology. The tools of modern biotechnology are being increasingly applied for plant diversity characterization and undoubtedly they have a major role in assisting plant conservation programmes.

1. Plant Genetic Resources

The Efficient conservation of plant genetic resources can best be achieved through an appropriate combination of *in situ* (in natural or original areas) and *ex situ* (in artificial habitat or habitat different from the original one) methods (IPGRI, 2001). Generally plants with orthodox seeds (high tolerance of low temperature storage conditions) are best preserved *ex situ,* under medium or long term conditions as comparatively dry seeds stored at low temperatures (Ng, 1991). Plants that produce recalcitrant seeds (intolerant of desiccation and low temperatures) could be preserved as *ex situ* live-gene banks (or gene libraries) or by *in vitro* conservation methods of enforced reduced growth storage. Plant resources are also routinely preserved *in situ* in parks, reserve areas and rangelands.

This section of the paper will discuss *in vitro* methods for storage as well as the cryopreservation of embryos, seeds, protoplasts and other materials in long-term liquid nitrogen base-storage systems. Many plants, especially forest plants, are extremely difficult to propagate through conventional means since they are frequently polyploids and aneuploids or produce seeds with little or defective endosperms. Also the risk of losing some of these plants due to industrialization and urbanization, characterized by rapid deforestation, uncontrolled logging, burning and uncontrolled search for food and other non-timber forest products. Plant tissue culture provides a method for the mass clonal propagation of such materials, as well as serving as a tool for their germplasm conservation.

Micropropagation:

This refers to *in vitro* mass production of plant propagules from any plant part or cell. Such propagules are used to raise whole plants.

a. In vitro conservation

Germplasm conservation of vegetatively propagated crops (e.g. banana, cassava) forest species especially those with recalcitrant seeds (e.g. mango, coconut) is live genebanks, in fields poses tremendous problems in terms of required land space and labour input during annual or perennial replanting, testing and documentation. Such collections are also exposed to threats by biotic and abiotic stress agents. Consequently, *in vitro* conservation is recommended, at least as a supplement to field collections, as long as an adequate protocol for micropropagation has been worked out for the species. The advantage of *in vitro* include little space necessary in growth rooms for maintaining thousands of genotypes and the absence of diseases and pest attack in culture vessels. Furthermore, *in vitro* storage eliminates the need for long and frustrating quarantine procedures during movement and exchange of germplasm.

b. Cryopreservation:

The collections of base seed must be maintained under very cold conditions in high tech ultra low temperature freezers. Cryopreservation is an attractive alternative for the storage of base collections and involves the freezing of plant material, usually to the temperature of liquid nitrogen (-196oC), at which point cell division and consequently growth and all other biological activities are completely arrested. This must be done in a manner that viability of the stored material is retained and biological functions and growth can be reactivated after thawing (Towill, 1991; De, 1995). Liquid nitrogen storage is useful for the preservation of various types of plant material including whole seeds, embryos, suspension cells, callus, protoplast cultures, gametes and meristems.

2. Animals Genetic Resources

Animal genetic resources, like plant genetic resources need to be conserved for future generations. The use of artificial reproduction is a very useful tool in conservation of endangered species. It should, however, be made to complement the conventional methods of breeding. Some of the biotechnological methods used for production and conservation of animal genetic resources are summarized below:

a. Cryopreservation:

Materials such as cells, tissues, gametes, oocytes, DNA samples are also used for cryopreservation and stored in a genetic databank for future use.

***b. In vitro* production embryos:**

Methods used in the production of embryos *in vitro* include splitting and cloning of embryos, marker-assisted selection, sexing of embryos and transfer of new genes into an embryo (First, 1992).

Cloning in animals is enhanced by nuclear transplantation, a method used to produce a large number of viable identical embryos and offspring of desirable genotype in cattle, sheep, rabbits and swine. The procedure involves the separation and transfer of nuclei of a valuable embryo at a multicellular stage into enucleated oocytes at metaphase II followed by serial cloning.

c.Embryo Culture and Transfer:

This technique is used to introduce fertilized embryos into surrogate mothers. Sometimes closely related species can be used to produce the offspring of an endangered species. The great majority of commercial embryo transfer is done with cattle for strictly economic reasons since the economic value of production per head is much higher for cattle (and buffaloes) than for other farm animal species.

d. Artificial insemination:

This technique is useful in livestock farming. Cryopreserved sperm from selected males are thawed and introduced into ovulating females.

e. Intracytoplasmic sperm injection:

This technique is used to introduce sperm from selected males are microinjected directly into the oocyte.

Biotechnological methods vs. conventional captive breeding procedures

These biotechnological methods offer many advantages to conventional captive breeding procedures.

- less stress is experienced since the animals do not have to be moved around.
- the problem of space for keeping the animals is also solved since samples can be taken in the wild.
- storage of genetic resources will help to preserve biodiversity and counter the effect of genetic drift on small populations.
- even if an animal dies, its genes will still be available for future breeding work.
- gametes can be extracted from animals that have been dead for upto 24 hours and cryopreserved for future use.

The main disadvantage is that sometimes preserving only the DNA samples may not be enough to conserve the entire animals as many animals need to learn behaviour (which may not be in the genes) in order to survive. Moreover, the use of biotechnological tools for endangered species is still at a very early stage and is very expensive.

Biotechnology and Sustainable Agriculture

Biotechnology contributes to sustainable agriculture by reducing the dependence on agro-chemicals, particularly pesticides, through the deployment of genes conferring tolerance or resistance to biotic and abiotic stresses. Carefully selected genes from related or unrelated genetic resources are integrated in otherwise desirable genotypes. Systematic pyramiding of genes allows integration of desirable genes in one genotype for different traits, such as tolerance to stresses, productivity, and nutritional quality. It is also contributing in bioremediation of polluted soils and biodetectors for monitoring pollution.

Technology, including new varieties and breeds, is an essential element of sustainable agriculture. However, it is not the only element of sustainable agriculture. Some examples of transgenic crops are given in **Table 1** along with genetic modification and advantages.

Crops	Genetic Modification	Purpose
Tomatoes, peas, peppers, Tropical fruits, broccoli, Raspberries, melons	Controlled ripening	Allows shipping of vine ripened tomatoesimproves shelf life, quality
Tomatoes, potatoes, corn, rice, lettuce, coffee, cabbage family, apples	Insect resistance	Reduces insecticide use and crop loss
Peppers, tomatoes, cucumbers	Fungal resistance	Reduces fungicide use and crop loss
Potatoes, tomatoes, cantaloupe, squash, cucumbers, corn, oilseed rape (canola), soybeans, grapes	Viral resistance	Reduces diseases caused by plant viruses and, since insects carry viruses, reduces use of insecticides and crop loss
Soybeans, tomatoes, corn, cotton, oilseed rape (canola), wheat	Herbicide tolerance	Improves weed control
Corn, sunflower, soybeans, rice	Improved nutrition	Increases amount of essential amino acids, vitamins or other nutrients in the host plants
Oilseed rape (canola), peanuts	Heat stability	Improves processing quality; permits new food uses for healthier oils

Conclusions

Biodiversity is vital for our existence. Its depletion at a faster rate is a cause of concern for everyone. It is thus very important to conserve it at the local, regional, national and even at the international levels. 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, farmers, scientists, industrialists, public interest organisations, policy makers and the media. Technical contributions will be necessary 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 biotechnology has the potential, when judiciously applied, to increase farm productivity and conserve biodiversity.

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