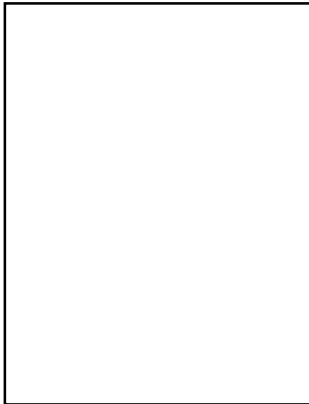


The role of biotechnology in food and environment security

Sheikh Riazuddin

The population growth of the twentieth century and the injudicious use of new technologies will place unprecedented burdens on food, energy and environmental needs in the new century. The new biotechnology appears to offer viable and technically feasible solutions to these problems, but the products and processes need to be monitored locally, regionally and internationally for hazards that may be as yet unknown. Although the new biotechnology offers food and environment security at the international level, like any new technology, it can be expected to affect international trade.



Dr. S. Riazuddin
*Professor and Director
Centre of Excellence in Molecular
Biology (CEMB)
University of the Punjab
Canal Bank Road, Thokar Niaz Baig
Lahore-53700, Pakistan
Tel: (+92-42) 5421235
Fax: (+92-42) 5421316
E-mail: riaz@lhr.comsats.net.pk*

Introduction

Biotechnology has been used since antiquity to increase food supply. Conventional biotechnology manipulated animals, plants and micro-organisms, and selection was the major force behind production of desired traits. The new biotechnology uses basic molecular biological research discoveries to direct and manipulate the products it makes. Directed alterations in cellular DNA can convert the simplest of creatures into living biochemical factories of rare biochemicals, foods, and renewable energy sources.

As a consequence, it seems to be within the reach of human endeavour to produce crops that exude toxins to drive off pests, grow under stressful conditions and live for weeks without water; devise mining and refining processes to eat away our industrial wastes and to relieve our anxieties about a future without sufficient raw materials; seek energy from the sun when we have squeezed our planet

for its oil and gas; produce edible vaccines in vegetables and novel pharmaceuticals in the milk of lactating animals.

Applications of biotechnological methodologies has made it possible to manipulate genes for almost any character, resulting in the production of desired traits in whatsoever host we desire. Although there are technical problems inherent to doing this, these problems are being solved slowly and gradually.

New needs and problems

Until the end of the nineteenth century, the human population had reached only one billion; the last century witnessed the addition of five billion human beings to raise the world population to over six billion. This population explosion (Figure 1) is the result of outrageous population growths in only twenty countries (Figure 2), among which Asian countries figure prominently. Although the rate of increase in population has slowed down, the

number of daily births still soars high and is not likely to come down even to the high levels of today until we move well into the second quarter of the present century.

The projected population growth will exert pressures of unimaginable magnitude on our food, energy and raw material reserves, and lead to gigantic problems of environmental pollution. To aggravate the situation, fertile farmland is being lost at a rapid rate due to erosion, water logging, salinity and urban development. Sweet water is in ever shorter supply. Raw materials and energy reserves are being depleted much faster than they can be replenished by newly discovered sources.

The world food situation is very precarious. About six countries provide the bulk of the world food needs in the form of about 16 crops and 7 farm animals. Obviously, therefore, sudden weather changes, plant epidemics, and animal diseases afflicting small geographic regions can upset global food supply. In order to increase agricultural production, a large number of countries are making major investments in bringing more land under irrigation. Good land resources, however, are in short supply, except in Latin America. This has led to indiscriminate deforestation, seriously threatening water regulation, soil holding, genetic diversity and provision of clean air.

In the past, high-yield technologies had been used to enhance production. Such technologies, however, depend on a liberal use of fertilizers, pesticides, insecticides, etc., which have placed a tremendous burden on the environment. Intensive cropping places an additional burden on energy and water reserves, which are already dwindling. Furthermore, demographic growth and industrialization steadily increase the competition for energy and water.

The question therefore arises as to how we can meet the challenges posed by the food, energy and environmental needs of the present century. The challenges are not only to produce enough for future generations but also to achieve that level of production without damaging the environment.

Currently available production technologies, which have done wonders in the past, are not moving fast enough to cope with our future needs. Evidently,

Figure 1: Human population projections 1950-2025

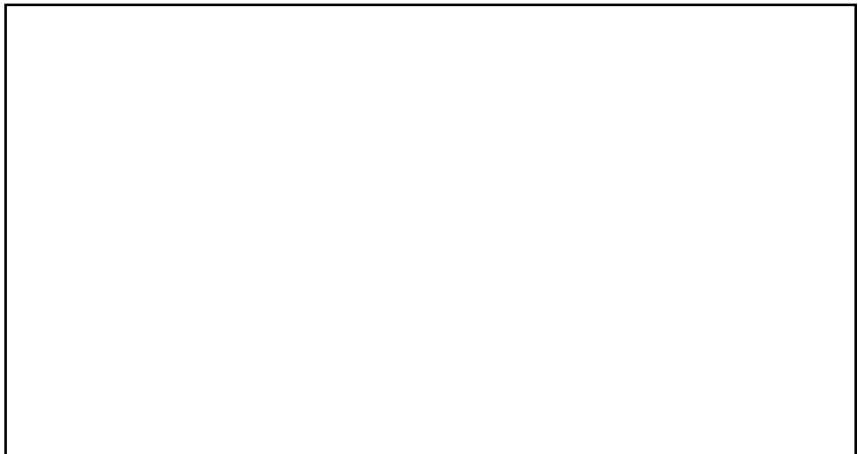


Figure 2: Projected populations of 20 most populous developing countries



therefore, considerable attention has to be paid to, and expectations based on, new technological breakthroughs. The new biotechnology may be just such a breakthrough, which can provide food and environment security by gradually increasing food production in a manner that does not seriously disturb the environment and the ecosystem.

Application of biotechnology

Food and agriculture

Plants

Traditional plant breeding techniques are limited by sexual incompatibility barriers. In addition, many valuable traits such as tolerance to specific herbicides and insects do not exist in plants. The new DNA manipulation techniques provide practicable means to overcome the limitations

of plant breeders. Genes can be isolated from bacteria, viruses, fungi or animals, and made to express in plants. Four categories of innovations seem of particular importance to future agricultural needs:

- Those that breed resistance against specific diseases and common pests and insects;
- Those that reduce the environmental burden of fertilizers;
- Those that reduce the demand for irrigation water; and
- Those that continue to improve crop production per hectare.

The field of plant biotechnology is expanding exponentially and can be expected to do so for the next few decades. It was only a few years ago that the first expression of a bacterial gene in a plant, using the Agrobacterium vector system, was reported. Today, over 70 different commercially important species of plants have been modified to incorporate sev

Table 1: Genetic transfer of traits in transgenic plants by recombinant DNA technology

<ul style="list-style-type: none"> ● Herbicide tolerance ● Insect resistance ● Viral disease tolerance ● Fungal disease tolerance ● Product quality improvements 	<ul style="list-style-type: none"> ● Male sterility traits ● Others (production of metabolites/chemicals, improvement of nutritional traits, stress resistance properties, etc.)
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en main transgenic traits (Table 1). The important crops include maize, soybean, cotton, tomato, potato, alfalfa, petunia, rape/mustard, rice, wheat, beet, barley, chickpea (gram), cabbage and tobacco.

Animals

As a result of traditional breeding programmes, animal reproduction has increased a little over twofold since 1920. However, in the same time span, human population has increased nearly fourfold. Nature has gone to great lengths to ensure that animals do reproduce; however, the natural process is both slow and extravagant. For example, each male of most forms of animal species produces trillions of sperms each year, yet under natural conditions sires only a few dozen offspring per year. Fertilization of each ovum requires only one sperm. Female farm animals usually produce a few offspring in their lifetime, yet their ovaries contain hundreds of thousands of oocytes. The unused oocytes degenerate within the ovaries at a rate of several dozen every day.

Animal biotechnology provides the means to take advantage of the huge numbers of sperms and oocytes from genetically superior animals that ordinarily are wasted by degeneration of oocytes and loss of sperm. Successes have been achieved through newly discovered techniques of embryo transfer and embryo splitting. As methods for genetic transfer of material in livestock are further developed, it will be possible not only to continue and accelerate the process of improving the reproductive performance of individual animals, but also to improve the quality of animal products produced. For instance, future generations of meat animals will be produced with inherently leaner carcasses while maintaining tenderness and flavour as desired by the consumer. It seems technically feasible to introduce novel traits such as the production of high value proteins in lactating mammary glands and their secretion into the milk.

The ultimate solution to animal disease will be to genetically engineer disease-resistant animals. Through the application of recombinant DNA technology, specific genes controlling disease resistance are being identified. The identification, mapping and cloning of these genes coupled with techniques in embryo manipulation offer dramatic potential for generating disease-resistant animals through gene transfer.

Poultry is another area in which successes have already been demonstrated through the production of new and improved vaccines, and more effective gender control. Manipulating the composition of eggs from cholesterol-rich to cholesterol-free is an area of current interest.

Industry and environment

Annual world production of organic chemicals is approximately 100 million metric tonnes, about 90 per cent of which are oxy-chemicals, and their current value is over US\$ 15 billion. It has been estimated that 60-80 per cent of oxychemicals and 20 per cent of all other chemicals used by man can be produced by microbial fermentation.

Further, several microbes such as *alkaligenes spp.* and *pseudomonas spp.* synthesize polysaccharide biopolymers which can be used to replace synthetic plastic. Other soil microbes of *pseudomonas* species produce oxygenases which can open up the ring structure of halogenated derivatives of polycyclic aromatic hydrocarbons to allow initiation of their degradation in the natural environment.

Bacterial oxygenase genes have been identified and cloned in plants possessing elaborate root systems, as a convenient means of amelioration of environmental pollutants. These oxygenase genes have been cloned in bacteria in order to increase the efficiency of catabolic functioning, resulting in efficient and economical biological treatment of industrial effluents. Synthetic chemical insecticides are a serious risk to the hu-

man population as well as to microbial flora and fauna. Environment-friendly microbial and fungal pesticides are expected to greatly reduce the environmental burden of such synthetic chemicals.

Energy

In the long term, we shall need renewable sources of energy, and the sun will remain the ultimate source of energy. Photosynthesis is the solution to the need for a renewable energy source that has been perfecting itself for more than 3 billion years. Genetically engineered bacteria and fungi can provide hydrogen energy as an alternative to green energy.

It is evident from the above that biotechnology offers technically viable solutions to our most urgent problems in the agricultural and environmental sectors. However, there are social, legal and economic problems arising from injudicious and uncontrolled uses and applications of biotechnology.

Social and legal implications

New technologies have been developed and deployed, often with little or no consideration of the basic needs of end-users. The climate of opinion has changed. The prospective impacts of new technologies are matters of strong public concern. Gene transfers are considered exotic because genes from unrelated organisms are made to express in organisms which do not normally host them. Such mixing of genes from unrelated organisms might create a natural imbalance by the transfer of genetic traits into organisms, which nature has not so far ordained. The consequence of flow of genes into unrelated organisms is not yet adequately known. There are some theoretical considerations that certain transgenic organisms may become harmful to economic plants, animals and human beings if manipulated genes are allowed to move around freely in nature. It is important, therefore, that all GMO's and their products should be monitored to assess not only technical merits but also environmental and socio-economic impacts.

Nearly all the advanced countries and some developing countries already have, or are in the process of developing, laws pertaining to the introduction of bio-engineered organisms and products into the environment, though many regulations are rapidly changing. Most biosafety regulations still reflect caution be

cause of the lack of scientific data on environmental and health risks.

There are, as yet, no internationally agreed standards for the field-testing of genetically engineered plants. Recently, however, a Protocol on bio-safety to the Convention on Biological Diversity has been adopted in Cartagena. This Protocol proposes different mechanisms, including the establishment of a Bio-safety Clearing House. This clearing house, in turn, aims at building national capabilities to assess the risks, if any, associated with the products of the new biotechnology; and to ensure that trans-boundary movements of modified organisms and their products is according to internationally agreed principles that will ensure the safety of all users.

The possibility that the new biotechnology, or its products, might become subject to intellectual property protection rights, such as the patenting of genes and living organisms, will obviously have serious implications for the free exchange of genetic resources.

Economic implications

Biotechnology will affect international trade with varying impacts in different areas of application. Though more biotechnology research takes place in the health sector than in all other sectors, the impact on trade flows will be much larger in agriculture, for two reasons:

- Trade in agricultural products has more than ten times the value of trade in pharmaceuticals; therefore, shifts in agriculture trade would have more important implications.
- Social repercussions of shifts in international trade would be more important in the case of agriculture than in the case of health products.

A decline in agricultural exports could have serious consequences for those countries that rely almost exclusively on them for foreign exchange. We should naturally be concerned about these developments, which will obviously have grave consequences on the economies of least developed or developing countries. The impacts are nearly all of a trade-substituting character, as a result of:

- Production of new traits in existing products or creation of entirely new substitutes for previous products; and
- Introduction of new production processes or improvement in the existing

production processes leading to reduced consumption of raw materials (dematerialization).

There are at least four major types of substitution processes; the first three apply mainly to north-south trade relations while the fourth relates to south-south trade.

- *Introduction of additional characteristics into existing products.* Recent successes to develop vegetables and fruits that can grow actively in cold weather would lead to shifts of specific agricultural production from the south to the north, and simultaneously undermine the diversification of certain developing countries into vegetable production for the world market.

- *Trade shifts as a result of changes in food processes.* This kind of substitution is best exemplified by the commercial production of Higher Fructose Corn Syrup (HFCS) through immobilized enzyme technology. As a direct consequence, sugar export from Latin American countries dropped from over 5 million tonnes in the 1970s to less than 2.0 million tonnes in the 1980s and 1990s. Enzymatic conversions will have similar effects on other commodities. For example, production of structured lipids or tailored fats would eventually push coconut oils and other seed oils out of the market. Other important examples of such substitution processes are the development of improved food substitutes, such as cocoa butter substitutes.

- *Industrial production of plant components or substitutes.* A number of low-volume, high value compounds which are traded internationally, and which could not be produced (or could only be produced at exorbitant costs) by chemical synthesis can now be obtained from microbial fermentation or plant/animal cell suspension cultures. For example, cane and beet sugar have lost ground to industrially produced low caloric sweeteners such as saccharin, cyclamates and aspartame. As a result, a relatively small plant can produce an enormous sweetening power compared with a similar volume of sugar. Other suitable candidates for industrial production are compounds of pharmaceutical value, unsaturated fatty acids, fragrances, flavours, pigments and bio-insecticides.

- *Unequal capabilities in biotechnology processes.* The capability to exploit

the biotechnological advances differ from country to country, and from crop to crop. Some crops such as rice and maize have received a lot more attention in international biotechnological research than wheat. Some crops have received major attention from private DNA companies, making it difficult for scientists in developing countries to exploit the economic potential of biotechnologies due to restrictions under international Patent Laws. The best example is cotton. Other crops like mango and jute, which are exclusively developing country crops, have received no attention in international biotechnological research.

Impact on trade of Asian countries

The introduction of new technologies has always led to shifts in international trade. New production processes make the production of specific goods cheaper in one region than in another and accordingly lead to shifts in world supply. Replacement of commodities as a result of the introduction of new technologies is not a recent phenomenon. It has occurred again and again in history. Cases in point are the replacement of indigo and other pigments by colours produced on a petrochemical basis, the replacement of natural fibres like jute and silk by synthetic fibres and the competition between natural rubber and synthetic rubber. Nevertheless the present situation may differ significantly in that:

- Switching on to any new raw material base may actually be effected much quicker than in the past;
- A large number of commodities will undergo major changes in supply and demand at the same time; and
- Alternative sources for foreign exchange earnings may be more limited than at other historical junctures.

For the densely populated countries of Asia, biotechnology will inevitably help to increase food self-sufficiency. India, the Philippines, Malaysia, Singapore and Korea have built up the capacity to introduce technological advances quickly into production.

They will probably be able to increase their share in agricultural exports much more rapidly. A case in point is Malaysia, which has not only increased palm oil production but also expanded the large-scale production of cocoa. □