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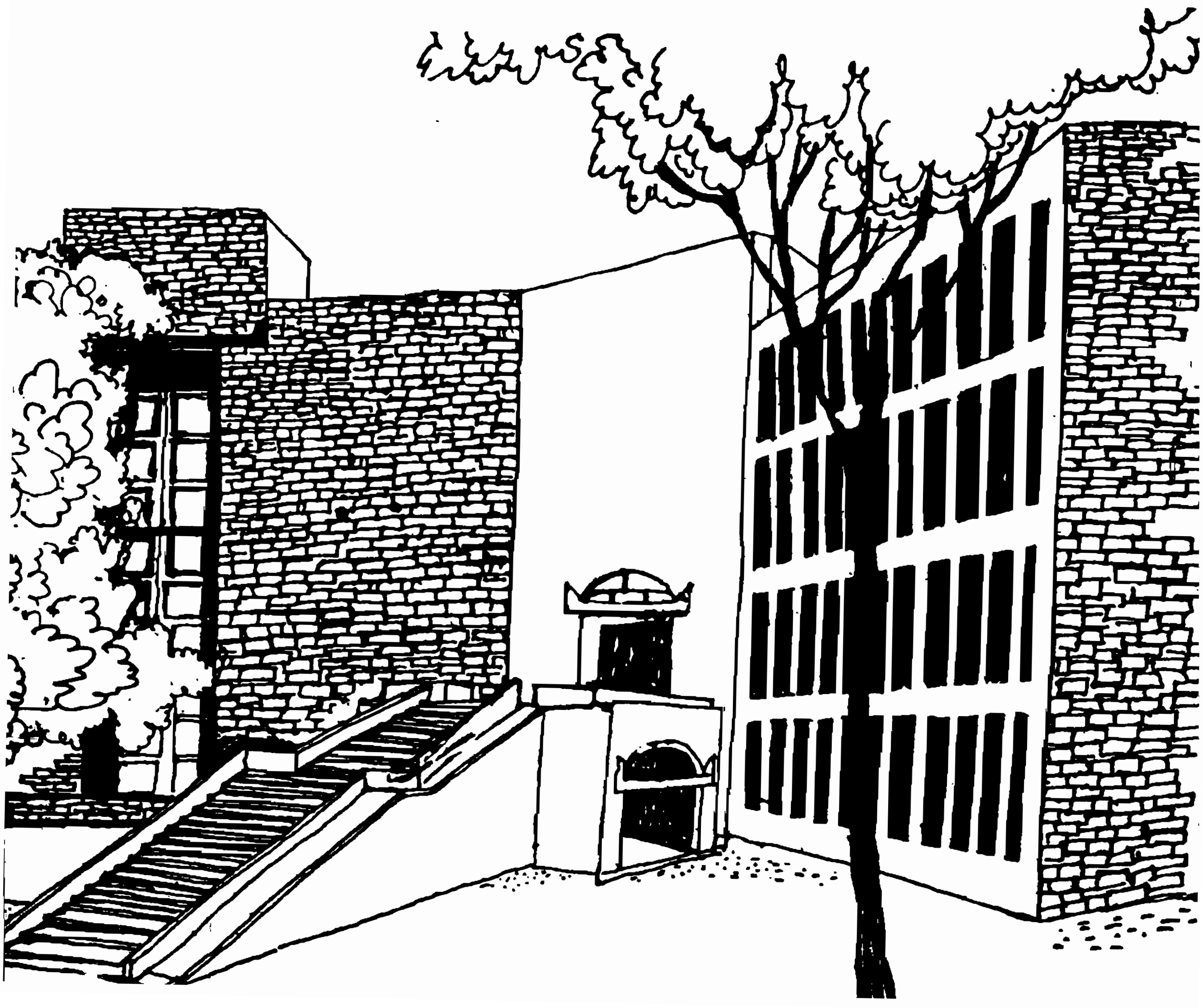

Biotechnology:
Promises, Concerns and Options

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Biotechnology: Promises, Concerns and Options

S.R.Asokan and S.N.Chokshi

Biotechnology is the application of scientific and engineering principles to the processing of materials by biological agents.

The Office of Technology Assessment (OTA) of the U.S. Congress has defined biotechnology as "any technique that uses living organisms or substances from those organisms to make or modify a product to improve plants or animals or to develop micro organisms for specific uses." Biotechnology refers to " the manipulation of living organisms with a view to : altering their characteristics, using them as a component in the larger production process, producing a specific desired product" (Brenner 1991). Thus, the activities like brewing wine or beer, making cheese and yogurt since using yeast and bacteria, known to man for millenniums, is also biotechnological process. These are known as old or traditional biotechnology depending largely on natural selection to obtain desired traits. New biotechnology, however, is based on enhanced understanding of the genetic structure of organisms at the level of cells and molecules and offers powerful tools to modify them for a specific purpose. It is possible to wholly circumvent genetic incompatibility by moving genes containing the desired features between varieties and species.

Biotechnology can be applied to a wide range of production process in such diverse fields like agriculture, food, energy, forestry, chemicals, pharmaceuticals, mining, environment control etc. Biotechnology holds its immediate promise in the pharmaceutical industry. Recombinant DNA (deoxyribose nuclei acid) technology is expected to generate large scale manufacture of many drugs and vaccines at lower cost than conventional technology.

In this paper, we confine our discussion to agriculture biotechnology that too only to plant breeding.

The Tools

Tissue Culture

Cell or tissue culture is one of the commonly used techniques of biotechnology. It involves growing isolated cells from plants in an artificial medium. It provides more controlled means of selecting desirable plant characteristics and acceleration of propagation. Using tissue culture techniques, disease resistant plant varieties can be identified more rapidly. Millions of plant cells rather than the whole plants can be exposed to causative agents in vitro. The surviving cells are the resistant ones. If the species can be regenerated from a single cell, the resulting clones can be used for the production of resistant plants. Tissue culture represent a tremendous short cut over traditional plant breeding. Using this technique fields can be reduced to petri dishes and the time required for breeding can be reduced to weeks or even days (Lachkovics 1988).

The use of tissue culture technology to obtain plant derived products such as flavours, fragrances, colours, dyes, enzymes etc is called 'phytoproduction.' The basic technique used to produce natural substances via tissue culture involves the selection of cells from desired plant. The cells are then propagated in suspended cultures. Careful regulation of culture conditions, nutrients and metabolic regulations are used to induce production of the desired chemical compound.

Protoplast Fusion

Protoplast fusion creates new types of plants by combining cells from different types of plants and then regenerating a hybrid from the fused cell. A protoplast is simply a plant cell whose cell wall has been removed by treatment with digestive enzymes. Two protoplast can join on their own or they can be encouraged to do so by exposure to polyethylene glycol or a brief jolt of electricity. A single gram of plant tissue can yield as many as four million protoplasts each of which is a potential new plant either by itself or when fused with another protoplast. Protoplast has been successful when the parent cells have come from a closely related species.

Recombinant DNA

Much of the euphoria in the field of biotechnology is in gene splitting or recombinant DNA which makes it possible the transfer of genes between species. R DNA technique enables "plant breeders to introduce genes derived from any plant, animal or microorganisms into plant varieties." The removal of species barriers to reproduction will make accessible to plant breeders desirable genetic characteristics not found in the nature of gene pool thereby expanding the genetic base. It is thus possible to design novel plant varieties engineered to meet specific economic goals.

The genetic engineering is a group of techniques which allow pieces of DNA from a plant, animal or micro organism to be transferred to a host micro organism which incorporates them into its genome and thereby acquires new abilities for synthesis or other bio chemical transformations. The technical tools for transfer of genetic information from a donor organism into a host organism include vectors such as bacteriophages, a type of virus which infects bacteria and restriction enzymes which are made naturally by bacteria and which cut DNA molecules. Vectors are capable of moving from organism to organism and reproduce themselves as the cells divide. Restriction enzymes allow researchers to cut out a piece from the donor DNA into the host (Fairtlough 1986). Now companies have developed particle guns to bombard the plant with metal particles coated with DNA. The particles when shot with sufficient force on the plant could penetrate the cells and thus deliver the DNA. The particles are in the form of microns hence cause minimum damage to the plant which is quickly healed. This technique is widely used by many companies for different crops.

Research is on in some of the exotic combinations of genes from different species. Attempts are on to put a copy of a frost resistant gene from the arctic flounder (fish) into tomato so that it will be able to undergo refrigeration without harm. Trout genes have been placed in carp, firefly genes into tobacco and chicken genes into potatoes.

The Players

The versatility of the technique and its possible profitable use in such diverse fields as agriculture, pharmaceuticals, mining, environment, food processing etc have attracted lot of investment for research both from public sector and private sector companies. There are three basic categories of institutions involved in biotechnology research and development. The first category consists of the universities and other public and private non-profit institutions carrying on research both fundamental and applied.

The second category of institutions involved in biotechnology are research and development or venture capital firms. Most biotechnology companies start as privately held firms and with very low levels of capitalization. After they achieve a certain momentum they usually go public by offering equity investments through stocks. Cetus, Genentech, Genex and Biogen are examples of biotech companies that started as privately held firms but now have gone public (UNCTC 1988).

The third category of institutions active in biotechnology are the transnational corporations. These come from a number of sectors of the industry such as seed, pharmaceuticals, food processing, agro chemicals etc. TNCs are involved in biotechnology at two levels. First, their linkage with other two categories i.e. universities and other venture capital firms by sponsoring research or marketing their product under some agreement. Second, their own research and development, manufacturing and marketing. The nature of transnational corporation linkages to biotechnology company varies. Sometime it involves i) a joint venture ii) TNC may take an equity interest in a smaller company iii) Licensing of technology generated by a smaller biotech companies and iv) a TNC entering into a contract research with a smaller start up company.

The Promise

The World population is predicted to reach 6 billion by the year 2000 and 10.8 billion in 2050. Almost 90 percent of the global population increase is expected to take place in the developing countries. Just to maintain the current level of nutrition these countries would have to achieve an increase of more than 30 percent in food production and supplies. The increase in production in most of these countries would be possible by increasing the productivity rather than the expansion of area. The green revolution technologies which produced dramatic results in late sixties and seventies cannot sustain the required increases in food production. A yield plateau now appears to have been reached. Long term experiments conducted at many locations on IR 8 rice by IRRI supports the argument.[1]

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1 Agricultural and Industrial Survey 1990-91. Vadamalai Media.

Biotechnology promises to revolutionize agriculture both in terms of quantity as well as quality of the crop output. It is possible to produce hardier plants to grow in desert, alkaline and other extreme soil conditions. Growing seasons can be expanded, growth cycles can be reduced making it possible to have multiple harvests. Strains resistant to pests, diseases, heat, frost,drought and flooding can be developed. Further, biotechnology promises to improve the nutritional value and taste of products.

The green revolution technology depends on increased use of fertilizers and pesticide to boost production. The associated deterioration of soil and other environmental problems are well known. The chemical fertilizers and pesticides were considered necessary evils to increase crop output. However, biotechnology promises to change all that. Scientists predict man made "natural pesticides" fertilizers and drugs could replace present day agrochemicals to the benefit of the environment, livestock and humans.

It is possible to target genetically engineered organisms at specific pests or diseases. In U.K. for example, foreign genes were introduced in potatoes and cabbages which are fatal to caterpillars which affect the crops. Scientists are trying to transfer the genes that programme legumes to play host to the nitrogen fixing bacteria rhizobium which will lead to less dependence on fertilizers.

Increased production without use of fertilizers and pesticides, changing the tastes, nutrition content according to ones needs and preference etc are expected to usher in a new era in the evolution agriculture.

The Concerns

Though the application of biotechnology would result in higher productivity thereby opening up the possibility of eradicating hunger there are certain genuine concerns about the socio economic impact of the technology, risks involved especially to the environment due to the escaped engineered organism. Further the direction of the research especially in the West and the greater role of private sector indicates the priorities of the developing and developed countries are different.

"Biotechnology will have profound consequences on the food, agriculture and livestock sector in terms of the location of production, competition between crops or the substitution of one crop to another as well as on food processing and preservation and on the composition and quality of final food products" (Brenner 1991).

Production Displacement

New biotechnologies have the potential to eliminate or displace food and beverages exports on a massive scale resulting in the loss of foreign exchange earnings, displacement of agricultural workers and economic instability in many third world countries (Dev Dialogue 1988). The uses of new technologies poses a particular challenge for poor countries and small scale improvised farmers. These are most likely to be affected by the social and trade changes that accompany modification in agricultural technology which frequently results in the displacement of small farmers by larger enterprises and the movement of centres of production to new area in response to changes in comparative advantage (World Bank 1991).

The case of vanilla illustrates the potential of biotechnology to displace or eliminate traditional exports and to transfer agricultural production from the South to the laboratories of the industrialized North. Natural vanilla is an expensive flavouring which comes from the bean of the vanilla orchid. Ninety eight percent of world production comes from just four countries Madagascar, Reunion, Comoros and Indonesia. These countries earn considerable foreign exchange by exporting the crop besides millions depend on it for employment and livelihood. US based companies are culturing vanilla cells to produce vanilla flavour, their products would be natural plant derived flavouring. This new technology has the potential to displace vanilla bean export on a massive scale. The need for traditional cultivation of the vanilla orchid would be eliminated putting the livelihood of millions in jeopardy and straining their countries' economy.

Cocoa is another case. It is the second most important crop traded in the international market from the tropical regions. Various biotechnologies are being applied to cocoa in the US, Europe and Japan. Efforts are on to produce cocoa butter from cheap oils. The impact of cocoa producing and exporting countries could well be imagined.

Biotechnology offers the potential to displace sugar as an industrial sweetener on a massive scale. New and natural sweeteners from plants such as thaumatin, stevia rehaudiana etc are being developed. The use of sugar substitutes has already affected significantly the export earnings of the sugar producing countries. These new developments would devastate them.

A great deal of biotech research is looking into the replacement or reduced use of flavour and fragrance with laboratory processes. There are companies working on a product called Nocardia which would eliminate the need for castor oil.

Environmental Impact

The assessment of any risk that new technologies may pose to public health or environment is a very vital issue. The introduction of new varieties of paddy in Punjab in 1966 brought about 40 new insects and 12 new diseases (Shiva. V). In agricultural biotechnology attempts are on to insert exotic genes into plants. The possibility of these engineered organisms escaping into environment and establish wild population cannot be discounted.

There are several ways in which an engineered organism can escape into the environment. Pollen can act as a vehicle for the export of engineered genes from crops to their wild relatives. The spread of these genes into natural population is said to be rapid if the engineered genes confer an advantage to this wild species. Biotechnologies are concentrating their efforts in imparting salinity tolerance, drought resistance, nitrogen fixation, herbicide resistance, disease resistance, herbivore resistance to crops. These traits can be transferred to weeds through an escaped organism as the difference between many crops and weeds are narrow (Levin and Harwell 1985). Needless to say it would cost enormously in terms of money and labour to eliminate such weeds to prevent damage.

The primary objective of the biotechnologists should therefore be to design organisms which have i) minimum probability of establishing outside than the intended area or species. ii) predictability to a fair degree of the behaviour of organisms with other species and organisms based on its nature of reproduction and spread and iii) ways and means of mitigating the organisms if they turn harmful after escape. Knowledge about these aspects of the organism prior to release would help to keep the risk low.

Intellectual Property Rights

There has been considerable debate and controversy in recent times regarding extending patent rights to living organisms like plants and animals. The producers and sellers of new technology are mostly based in developed countries and may not be interested in investing in developing countries either directly or through collaborative arrangements unless protection is extended to their intellectual property. Incidentally the industrialized North is poor in genetic resources. However, these countries argue for treating the genetic resources of the world as the common heritage of mankind thus trying to dominate the technologically poor but genetically rich third world countries through patent laws. Pressures are brought on these countries through the World Trade Agreement (WTO) to amend their patent laws.

The estimates on farm level impact of biotechnology by the year 2000 varies between 10 billion to 100 billion US dollars. Unlike the green revolution which was largely developed through public research institutions development in biotechnology is taking place mostly through private efforts. Although there is enormous market and returns are attractive there are considerable risks as well. A product developed after substantial expenditure may be promising at the lab stage but may not be good at the farmer's field. Further as competitors produce new and new products shelf life of a product may not be long. So there is lobbying to extend patent rights in order to sustain private investment in the field.

On the other hand, germ plasm is gathered from the third world at no cost on which many varieties were developed. There are number of cases where the germ plasm is taken from the third world which contributed millions of dollars to the economy of the developed countries but not a single dollar accrued to the country in which the gene originated. Prescott and Allen[2] estimated that between 1976 and 1980 genetic material from wild relatives contributed $ 340 million per year in yield and disease

2 op cit. in Shattering: Food, Politics and Genetic Diversity by Fowler and Mooney.

resistance to U.S. farmers. According to them wild germ plasm contributed $66 billion to the American economy. These valuable germ plasms are routinely collected from the Third world countries to the U.S. without any compensation (Fowler and Mooney 1990). Still worse the product made of the germ plasm may be sold to the country of origin with patent protection thus doubly benefitting the developed country.

Private/Public Sector

Research and Development related to new biotechnologies is being conducted in an institutional and economic environment which differs significantly from the earlier agricultural research establishment and notably from the development of the "green revolution" technologies in developing countries. The high yielding varieties of wheat and rice were developed at the International Agricultural Research Centres (IARC) and with in the National Agricultural Research Systems (NARs). Unlike the green revolution the 'gene revolution' is mostly taking place in the private sector labs. In US out of the total R and D investment in biotech private sector share is believed to be more than 70 percent.

The involvement of private sector could lead to greater concentration of efforts on potentially profitable crops thus many crops which may be vital for the future plant breeding would be neglected. Further, the need of the developing countries may not be the priority of their research. "Companies go where the money is, and there is more money to be made in cantaloupe for Americans than for cassava for Africans" (Mellon 1996). Most of the research in the West is concentrating on improving taste, flavour to meet the needs of the food processors, transporters and retailers not necessarily on improving productivity. Table 1 shows the biotechnology permits issued in the US for the private sector far outstrips the public sector.

The crops in which the permits were given is presented in Table 2.

As stated earlier the research on these crops is mostly directed to meet the needs of processors, transporters, wholesalers and not necessarily towards increasing productivity.

Apart from concentrating on potentially profitable crops the private companies may influence the research agenda of public sector such as universities by sponsoring research and in other ways. "The marriage between the university and business interests has taken another from. Hidden stock options, directorship in company boards and consulting contracts are currently cementing relationship between academia and business. More than 291 such ties exist in universities throughout the United States. For example, Calgene Inc., has 16 prominent university scientists as advisers and consultants.

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Table 1 : Biotechnology Permits and Notifications in the US between 1988-1993	
Private Commercial	489 (83.3%)
Universities	71 (12.1%)
US Agricultural Dept	27 (4.6%)
The details of the Biotechnology Permits to Companies:	
Monsanto	146
Calgene	61
Upjohn	50
Pioneer	43
Du Pont	24
Frito Lay	18
Northrup King	15
De Kalb	14
Ciba-Geigy	12
DNA Plant Tech	10
Holdens	9
Hoechst-Rousell	7
Crop Genetics	7
Cargill	7
Campbell	5
Others	61
Total	**489**
Source: U.S.Department of Agriculture.	

Table 2: Biotechnology Permits for Crops	
Crop	No.Permits
Corn	125
Tomato	92
Soybean	87
Potato	76
Cotton	54
Tobacco	46
Melon and Squash	27
Rapeseed	19
Alfalfa	13
Clavibacter	6
Rice	6
Cucumber	5
Others	31
Total	**587**
Source: U.S Deaprtment of Agriculture	

Similarly two thirds of scientists with industry ties reviewed grant proposals for the National Science Foundation, a prestigious institution which helps determine the direction of basic research in the United States. In addition, nearly one quarter of biotechnology related sections at National Academy of Science were occupied by academic scientists with ties to the industry" (Perlas, N. 1994).

The changing patterns of food consumption will also influence the direction of biotechnology research. Quantitatively demand for food has virtually reached a saturation point in industrialized countries and with the continued low population predicted it would remain so in the future. This is not the case with regard to third world countries where quantity of food produced would continue to remain a priority in order to meet the needs of the burgeoning population. So, the kind of research pursued in the industrialized countries would have little relevance for these countries.

There has been a large number of take over of seed companies by the food processing and agricultural inputs industries especially chemical industry. The reasoning behind this is that whatever be the wizardry of the technology it has to be packaged in the form of seed and delivered to the farmers. The backward linkage allows these companies to manipulate the crop at the seed level to their advantage.

As of mid 1991 the US department of agriculture had approved approximately 120 applications for small field trials of transgenic plants of which 40 percent were for herbicide tolerant plants. The farmers who buy the seed will naturally have to buy the herbicide of the company. Instead of developing an agriculture system less depended on chemicals research efforts are on to increase the chemical consumption.

Narrow Genetic Base

The Irish Potato famine of 1840s the corn blight in U.S in 1970 and the loss of wheat in Ukraine in 1972 are dramatic and powerful pointers to the vulnerability of agriculture based on narrow genetic base. An unexpected pest or disease could wipe out the entire crop thereby putting the population under great risk. Narrow genetic base is a threat to food security. Biotechnology helps to expand genetic base by breaking sexual barriers of species. However, the technology is used to develop crops with uniformity in growth, maturity or ripening which would facilitate harvesting and marketing, naturally they are going to be based on narrow genetic base. The reproduction of thousands of genetically identical plants through cloning results in an extremely narrow genetic base. The oil palm plantation developed through cloning by Unilever in Malaysia was completely affected after a few years of growth and had to be uprooted.

Options

The first step in assessing the usefulness of a new agricultural technology is to identify the problems that have been intractable by conventional means but may be solved through the application of biotechnologies. The focus must be on the problems to be solved and not on the new technology itself.

The major concerns arising out of the application of biotechnology for the developed countries are i) the environment risk and public safety due to the engineered organism and ii) the influence of private sector over university research resulting in neglect of minor crops which may not be of immediate commercial use but would be of use in the future plant breeding. In case of developing countries apart from environmental risks, the concerns are on displacement of foreign exchange earning crops, barrier to access of technology developed through IPRs, socio economic impact on the populace due to the application of the technology, neglect of research on crops which are important to them in order to fight hunger and malnutrition etc. Therefore, the developing countries should devise appropriate strategies as far as possible to prevent, if not, to mitigate the adverse impact resulting from application of biotechnology.

The development of the technology and its application in the industrialised countries should be constantly monitored. Early warning systems should be developed whereby the potential negative substitution effects could be monitored and strategic adjustments recommended where economically damaging substitution effects are identified. The government should step in through appropriate fiscal measures in order to alleviate the misery caused by joblessness and lose of income arising out of the situation. The World Bank and International Monetary Fund should assist countries which are affected in their effort to adjust to new production relations.

The green revolution has exacerbated the divide among the rural population by conferring prosperity on certain sections of the population. The gene revolution is also capable of doing the same. Volumes of knowledge were generated and valuable lessons learnt on the impact of green revolution. This would be of immense help to the policy makers in avoiding the same mistakes while introducing gene revolution technology.

The National Agricultural Research Systems (NARS) should be strengthened by the national governments as well as through the international aid agencies. These public sector institutions should aim their research programme in order to meet their national priorities. "New initiatives rather than new institutions are required and these must build on the traditional strengths in agriculture research, not displace them" (Persley G.J 1990).

The International Agricultural Research Centres(IARCs) should initiate "orphan commodities" programme that is on those crops overlooked by private sector through strengthening public sector research and involving private sector as well in collaborative research.

National governments should evolve appropriate guidelines on the release of novel products for experiments and eventual commercial use to ensure public health and environmental safety. In many countries existing legislation is believed to be sufficient to regulate the use of most agricultural products using biotechnology. Apart from preparing guidelines effective monitoring should be done developing appropriate institutions and mechanisms.

The access to technology is sought to be restricted by the developed countries through IPRs mechanism. First, the developing countries should assess the appropriateness of the technology developed and if they are found suitable efforts should be made to obtain them. Developing countries often ignore public domain technology which are knowledge "spillovers" and innovations which are not protected. Screening and using such public domain technology is a viable option for NARS. Developing countries should ensure constant monitoring of such technology and incorporate them in their research efforts (Wijk.J. et.al 1993).

The U.N. Biodiversity Convention of 1992 made some provision with regard to exploitation of the germ plasm of the third world. According to the convention the exploitation of the genetic material and the preferential treatment in transferring the technology for countries of origin the access to the germ plasm to the private sector seed companies should be made contingent upon sharing the variety developed. For example, if a variety is developed out of the germ plasm collected in India, India should get preferential treatment in getting the material developed in terms of lower cost or shorter period of protection say 3-4 years rather than 15 years. The variety developed may be provided under license with preferential terms to the public sector organizations in India. Access to material developed may result in larger social benefits than providing monetary compensation to the country or community for which the genetic material originated.

There should be increased South South Cooperation in sharing genetic materials and sharing the fruits of research.

Annexure I

Chronology in Development of Biotechnology

--	7000 BC	Sumerians brew beer
--	4000 BC	Egyptians leaven bread with yeast
--	1866	Mendel postulates a set of rules to explain the inheritance of biological characteristics in living organisms.
--	1878	First pure bacterial culture.
--	1900	Hugh De Vries 'Rediscovers' Mendel's theories.
--	1903	Sutton postulates that genes are located in chromosomes.
--	1910	Morgan's experiments proved genes are located in chromosomes.
--	1911	Johnson devises the term "gene" and distinguishes genotypes (determined by genetic composition) and phenotypes (influenced by environment).
--	1922	Morgan and colleagues develop gene mapping techniques and prepare gene map of fruit fly chromosomes.
--	1944	Avery, Mclead and Mccarthy demonstrated that genes are composed of deoxyribo nuclei acid (DNA) rather than protein.
--	1952	Hershey and Chase confirm role of DNA as the basic genetic material.
--	1953	Watson and Crick discover the double helix structure of DNA.
--	1960	Genetic code deciphered.
--	1971	Cohen and Boyer develop initial techniques for recombinant DNA technology to allow transfer of genetic material from one organism to another.
--	1973	First gene (for insulin production) cloned using r DNA technology.
--	1974	First expression in bacteria of a gene cloned from a different species.
--	1976	First New Technology firm established to exploit recombinant DNA technology (genentech in U.S.A).
--	1980	USA Supreme Court rules that micro organisms can be patented under existing laws (Diamond vs Chakrobarthy). Cohen/Boyer patent issued on technique for the construction of r DNA.
--	1982	First successful transfer of a gene from one animal species to another (a transgenic mouse carrying gene for rat growth hormone). First transgenic plant produced, using an agribacterium transformation system.
--	1983	First successful transfer of a plant gene from one species to another.
--	1985	US patent office extends patent protection to genetically engineered plants.
--	1986	Transgenic pigs produced carrying the gene for human growth hormone.

--	1987	First field trials in USA of transgenic plants. First field trials in USA of genetically engineered microorganisms.
--	1988	US patent office extends patent protection to genetically engineered animals. First genetically modified micro organism approved for commercial sale.
--	1989	PGs announces the cloning of a male sterility gene to develop commercial hybrids of all crops.
--	1990	Several companies announce success with "gene gun" to engineer any crop genetically.
--	1994	Genetically engineered tomato of calgene commercially marketed for consumption.

Source: Hobbelink.H (1991); Wijk (op cit in World Bank 1991).

Annexure II

Status of Biotechnology in India[3]

With the establishment of the National Biotechnology Board in 1982 India became one of the first developing countries to have an institutional set up to promote research and training in this new area. The Board's initial objective was to create an awareness among related ministries and departments of the possibilities offered by biotechnology. In 1986, the board was upgraded into a department of biotechnology within the ministry of science and technology.

The mandate of the department is to

i) Evolve integrated plans and programmes in biotechnology;

ii) Identify and finance specific R and D programmes in biotechnology related manufacturing having a clear end use.

iii) Establish infrastructural support at the national level.

iv) Act on behalf of the government in the import of r DNA based products, processes and technology.

v) Prepare safety guidelines for research into and application of biotechnology.

vi) Initiate scientific and technical efforts relating to biotechnology.

vii) Promote manpower development in biotechnology.

During 1988 an agreement was signed between India and UNIDO for the establishment of the New Delhi Component of the International Centre for Genetic Engineering and Biotechnology.

The Biotech Consortium India Limited (BCIL) conceptualized as science-industry consortium for the promotion of biotechnology was established in 1991. The role of BCIL is to facilitate interaction among scientists, industry, financial institutions and government to promote the commercial activities. The BCIL is jointly funded by the financial institutions, industry, research and development laboratories and government.

The private sector began to show keen interest in the biotech research in the late ·80s. Some of the prominent players in agriculture are " A.V.Thomas Group Companies (AVT), Indo American Hybrids,

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3 Based on Agricultural and Industry Survey 1990-91, Vadamalai Media

Hindustan Lever, Tata Tea, Unicorn biotech, Nath Seeds, RPG enterprises, Indian Tobacco Company, Maharahstra Hybrid Seeds, Hindustan Agri Genetics etc"[4] As is evident the private sector is concentrating on diverse range of crops such as tea, coffee, rubber, spices besides vegetables, fruits and flowers.

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4 Prakash.J "Biotechnolgy: Applications and Achievements in Agriculture" Agriculture and Industry Survey 1990-91. Vadamalai Media.

References

1. Brenner, C. *Biotechnology and Developing Country Agriculture: The Case of Maize.* OECD. Paris, 1991.

2. Da Silva, E.J. et.al. *Biotechnology Economic and Social Issues for Developing Countries*, Cambridge University Press, Cambridge, 1986.

3. Fairtlough G.H. Genetic Engineering- Problems and Opportunities, in *The Challenges of Biotechnology* (ed) By Jacobsson. S. et.al. Cambridge University Press, Cambridge, 1986.

4. Fowler, C. and P. Mooney, *Shattering: Food, Politics and the Loss of Genetic Diversity*, University of Arizona Press, Tucson 1990.

5. Fowler, C. et al *The Laws of Life: Another Development and the New Biotechnologies*, Development Dialogue 1:2 1988.

6. Gurdev Singh and S.R.Asokan, Agricultural Biotechnology: Ready for Harvest, *Economic Times* Jan, 1993.

7. Juma, C. *The Gene Hunters*, Zed Books Limited, London 1989.

8. Hobbelink, H. *Biotechnolgy and the Future of World Agriculture*, Zed Books Ltd, London. 1991.

9. Kenney, M., *Biotechnology: The University and Industrial Complex*, Yale University Press, New Haven 1986.

10. Lachkovics, E. Journey to the Centre of Life, *Development Dialogue* 1:2 1988.

11. Levin, S. and M.A. Harwell, Environmental Risks and Genetically Engineered Organism, Paper presented at the *Conference on Biotechnological implications for public policy* Jan 15-16 1985. The Brookings Institution Washington D.C.

12. Lyon, J. Building a better tomato, *Chicago Tribune* Feb, 20 1994.

13. Mellon, M. Ripen-On-Command: In a society with ample food, why bother, *Nature biotechnolgy* Vol.14 No. 7 July 1996.

14. Perlas, N. *Overcoming Biotechnology*, Third World Network, Penang, Malaysia 1994.

15. Persley, G.J. *Beyond Mendel's Garden : Biodiversity in the Service of World Agriculture*, ISNAR, The Hague. 1990.

16. Shiva, V. India's Human Guinea Pigs, *Science and Culture* Vol.2 Part.I No. 10.

17. Trevan, M.D., and others, *Biotechnology : The Biological Principles*, Tata McGraw Hill, New Delhi, 1991.

18. United Nations, *Transnational Corporations in Biotechnology*, United Nations Centre on Transnational Corporation. 1988.

19. Wijk, J. et.al. *Agricultural Biotechnology: Options for Developing Countries*, ISNAR Report No.3 1993.

20. World Bank, *Agricultural Biotechnology : The next "Green Revolution"* World Bank, Technical Paper Number 133. 1991.

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